Dense Communication and R&D in Knowledge-based Industrial Clusters: Comparative Study of Small & Medium-sized Firms in Korea and China

Nobuaki Hamaguchi
Research Institute for Economics&Business Administration, Kobe University
and
Yoshihiro Kameyama
The International Centre for the Study of East Asian Development

Working Paper Series Vol. 2007-21
October 2007

The International Centre for the Study of East Asian Development, Kitakyushu

Dense Communication and R&D in Knowledge-based Industrial Clusters: Comparative Study of Small & Medium-sized Firms in Korea and China

Nobuaki Hamaguchi[†] **and Yoshihiro Kameyama**[††]

[†]*Research Institute for Economics & Business Administration, Kobe University*
[††]*The International Centre for the Study of East Asian Development (ICSEAD)*

Abstract

This paper presents an analysis of the effects of dense communication of industry-university-government cooperation on enhancing in-house (a company's own) R&D activities in Korean and Chinese knowledge-based industrial clusters: the Seoul Digital Industrial Complex, Daedeok Valley, and the Zhongguancun Science Park. Our unique survey data enable us to examine firms' communication behaviors, i.e., communication frequency, participants, and purposes, related to the choice of communication mode. Results of this study demonstrate that agglomeration might impart least two influences on an individual firm: agglomeration stimulates more in-house R&D through exchange of ideas; and it reduces in-house R&D by promoting its outsourcing.

JEL classification: O32, R11, O40

Keywords: agglomeration, communication externalities, industrial cluster, Seoul Digital Industrial Complex, Daedeok Valley, Zhongguancun Science Park

† 2-1 Rokkodai Nada-ku, Kobe, 657-8501, Japan. E-mail: hamaguchi@rieb.kobe-u.ac.jp
†† Comments are welcome. Send your comments to kameyama@icsead.or.jp . Address: 11-4 Otemachi, Kokurakita-ku, Kitakyushu, 803-0814, Japan. TEL: +81-93-583-6202; FAX: +81-93-583-4602.

1. Introduction

This paper analyzes the effects of communication among local business partners on the innovation efforts of small and medium-sized firms in scientific-knowledge-based industrial clusters in Korea and China. These two countries are known for their strong performance in manufactured goods exports. Despite the increasingly high technological intensity of their exported products, their innovative capability has only rarely been studied empirically. Studies of knowledge-based industrial cluster have mainly examined cases of developed countries; the related literature on developing countries is thin.

Aiming at filling such gaps, we conducted an empirical study of three high-tech industrial clusters: the Seoul Digital Industrial Complex (SDIC), Daedeok Valley (DDV), and the Zhongguancun Science Park (ZSP). These industrial clusters are located within densely populated metropolitan areas of Korea and China. Our prime questions are how much and in what way innovation of small and medium-sized firms in these clusters can benefit from local interaction. The selection of these three clusters is justified by the following observation. Scientific-knowledge-based industries usually start in developed countries, but they have become partly dispersed to developing countries to achieve cost savings. However, unlike assembly-type activities, because knowledge is strongly concentrated globally, the spread of such industries is constrained by the availability of qualified human resources. Within this scenario, the three clusters of our study represent a small group of newly emerging clusters of knowledge-based industries.

Observing the location pattern of knowledge-based firms, they are apparently created mainly in large metropolitan areas. Locational advantages of urban centers include the existence of larger markets for new technology products both for selling products and for purchasing inputs, availability of a highly educated workforce, and access to the scientific knowledge created at universities. Information related to such advantages of markets, talent, and knowledge is frequently exchanged within metropolitan areas often through informal and unplanned meetings. Accessibility of such information is important for innovation. Therefore, it is natural for firms to seek metropolitan locations which enable face-to-face communications with key persons. For example, a telecommunications equipment sector executive in Beijing replied to our interview: “It’s only in Beijing that we can meet informally with high-rank officials and university scientists who are involved in the decision of the technological standard of the next generation. By using them, we try to take any information which might help us to determine the strategy of our company.” Certain types of tacit knowledge of this sort would lead many firms to gather in specific regions[1].

For the discussion in this paper, an industrial cluster is defined as an agglomeration of numerous technologically related firms. It can be sustained when more firms enter (by starting up or by relocating from elsewhere) than exit (by closing down or by relocating elsewhere). To some extent, we can attribute the growth of a cluster to government policies such as construction of science parks and provision of tax incentives to foreign direct investment. However, the provision of such incentives is not generally sufficient to sustain the cluster. Other factors affecting the behavior of individual firm's action of entry and exit must be addressed to explain the existence of clusters.

For the specific case of knowledge-based industries, knowledge is an essential input. Each firm seeks differentiation by its unique ideas resulting from efforts in research and development (R&D). The environment in a cluster can offer both opportunities and risks for new start-ups to be established as sustainable businesses. Although opportunities might stem from knowledge spillover through dense communication with other agents, there are also risks of imitation and harsh competition that will rapidly render its technology obsolete. Our viewpoint on the theoretical rationale of the formation of knowledge-based industrial clusters is described in the next section.

2. Theoretical Background

It is widely accepted among economists that firms benefit from knowledge spillover, which gives rise to aggregate increasing returns to scale because of non-excludability and non-rivalry of knowledge. Saxenian (1994) described how people and firms are closely interrelated within thriving clusters such as those of Silicon Valley.

Provided that the benefit from knowledge spillover is sensitive to distance, especially when the knowledge is tacit, it is apparent as a source of agglomeration economies. Notwithstanding, the stylized models of new economic geography (Fujita, Krugman and Venables, 1999) have avoided incorporation of knowledge spillover because knowledge flows "are invisible; they leave no paper trail by which they might be measured and tracked, and there is nothing to prevent a theorist from assuming anything about them that she likes (Krugman, 1991, p.53)." As Fujita and Thisse (2001) observed, precedent studies of knowledge spillover include the weakness of vague definitions of the sources of external economies, simply assuming that the increased number of locally participating agents might increase interaction. They do not clearly define the underlying mechanism of the local interaction. Therefore, theoretical analysis should open such a black box and explicitly incorporate interaction of agents who engage in innovation. Consideration of the interaction over the geographic space naturally leads us to the question of communication cost. Thus, anybody seeking a relevant spatial economic model of knowledge spillover must confront the challenge of addressing: "not only that knowledge spills over but also why those spillovers decay as they move across geographic space (Audretsch and Feldman, 2004)."

In this regard, the empirical literature provides some clues to understanding the localization phenomenon of innovation. A pioneer study by Jaffe, Trajtenberg, and Henderson (1993) considered patent citations as a visible paper trail of knowledge flows and found that patent citations is 5–10 times more likely to occur within the same city, suggesting the effects of proximity. Audretsch and Feldman (1996) and Varga (1998) investigated the geography of innovation, specifically addressing the role of university and R&D institutions. Audretsch and Feldman (1996) found evidence that, even after controlling the degree of geographical concentration of production, knowledge created by university research engenders greater innovation of nearby firms. Results of their study also suggest that the propensity of innovative activities to cluster is more attributable to knowledge spillovers than mere locational advantage in production. According to Varga (1998), university knowledge is transferred through R&D cooperation between academia and industry, university seminars, scholarly publications, faculty consulting, industrial associates programs, industrial parks, spin-offs (faculty and students), technology licensing, the local labor market of scientists and engineers, and local professional associations of scientists. Then Egeln, Gottschalk, and Rammer (2004) found that firms established as spin-offs from public research institutions decide their location as an optimization problem subject to the benefits of being closer to their parent institutions against some reasons to leave them. The former include continuing collaboration in research, obtaining commercial contracts with universities, and dependence on university's research infrastructure, and existing social relationships. The latter involve proximity of customers, opportunities for cooperation with other institutions, and lower factor prices.

Empirical studies of this type should confront the difficulty of lack of data and ambiguous concepts of measuring "innovation", "knowledge," and "proximity." Jaffe, Trajtenberg, and Henderson (1993) have considered that the output of innovation is represented by patents, which is also convenient because patent data are easily accessible. Nevertheless, patents might not be a perfectly good measure of innovation because all innovative outputs are not necessarily filed as patents. Alternatively, Charlot, and Duranton (2004) prefer to measure the higher productivity resulting from externalities by earned wages, whereas Anselin, Varga, and Acs (2000) measure innovation by the number of new product announcements in trade and technical journals. In turn, knowledge is treated as a sort of firm capital stock to produce innovation. Its measurement is also a subject of debate. Continuing efforts are being made to construct a meaningful index synthesizing R&D investment, employment of knowledgeable talent, and stock valuations reflecting depreciation of past accumulations. Regarding proximity, the concepts of distance, traveling time, and the use of telecommunications must be considered (because face-to-face communication and telecommunications are sometimes mutually complementary, rather than substitutive).

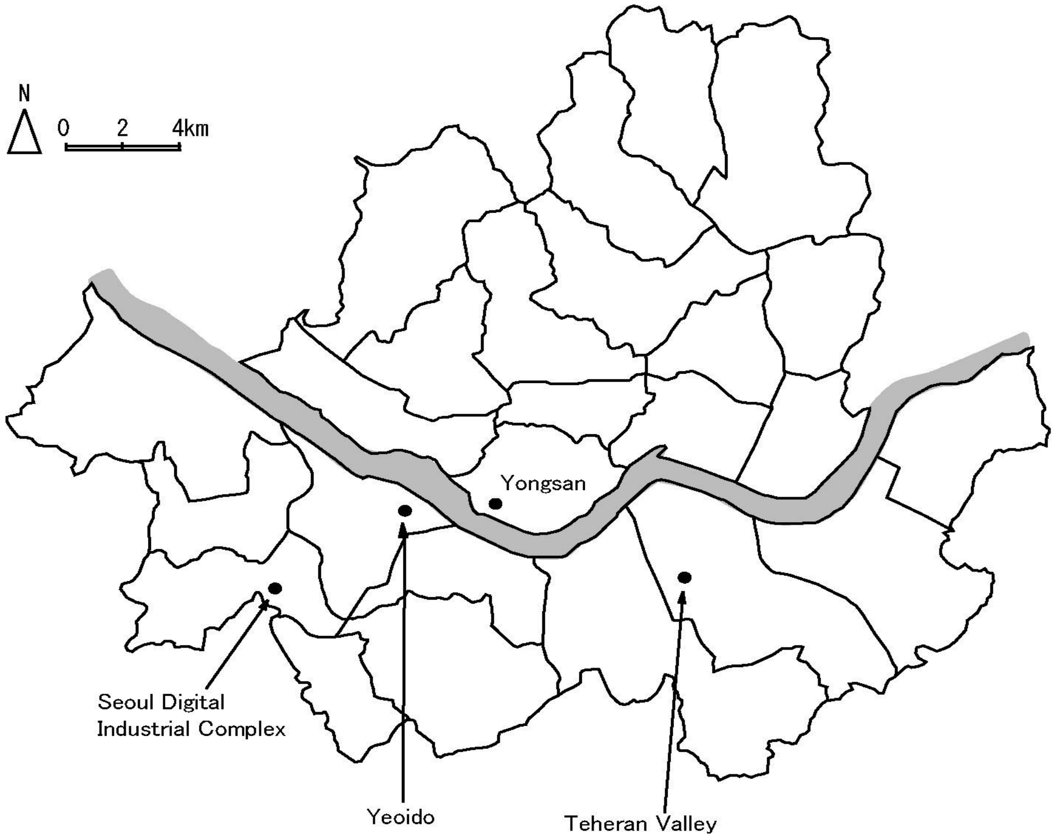
Regarding the data, we little expected that any readily available dataset would meet our necessity to specify the trail of actual interaction influencing productivity and innovation. Many researchers rely on small-sample survey data, e.g., Adams (2002), Charlot and Duanton (2004, 2006), and Arita, Fujita, and Kameyama (2006). The data analyzed in this paper were also obtained from a questionnaire survey administered to firm managers, which was conducted in the three clusters in March–April 2005 as a part of the research project of the International Center for the Study of East Asian Development (hereinafter ICSEAD Survey). Before describing detailed information of the survey data in Section 4, in the next section, we provide a brief profile of each industrial cluster from which the data were collected.

3. Development of industry clusters in metropolitan areas: Seoul, Daejeon and Beijing

3.1. Seoul Digital Industrial Complex

The Seoul Digital Industrial Complex (SDIC) is located in a southwest area of Seoul (*Figure 1*). The location was previously known as the Guro Industrial Complex. As Korea's first industrial complex, it led exports of traditional manufactured products such as textiles and garments during the 1970s and 1980s. However, structural changes of Korean industry paved the way to closure of labor-intensive factories in this area. In the late 1990s, the Korea Industrial Complex Corporation (KICOX) transformed the rusty factory district into a high-rise intelligent office complex designed for venture companies related to information and communication technology (ICT). As of December 2006, the total office space is almost two million square meters, accommodating six thousand firms and more than 80 thousand workers[2].

Figure 1: Seoul: Establishment of IT industry locations



Perhaps the so-called Teheran Valley is better known as the ICT-related industrial cluster of Seoul. Development of the Teheran Valley started at Teheran Street in the busy business center of Gangnam District (*Figure 1*). That development was prompted by the 1997 financial crisis, which prompted massive layoffs of engineers from large business groups (Chaebol) and drastically lessened job opportunities for students, some of whom resorted to establishment of venture companies. Since then, the Teheran Valley grew very rapidly, supported by the boom of the venture capital stocks listed on the KOSDAQ in 2000. However, because of the office rent hike and ICT bubble collapse and, more importantly, because of the lack of competitive technological sophistication, numerous ICT-related venture companies in the Teheran Valley had either failed or relocated (Sohn and Kenney, 2007). Some moved to SDIC and Daedeok Valley, attracted by the benefit of government support measures. The Teheran Valley is increasingly occupied by digital content firms, which require frequent interaction with their customers concentrated in the Gangnam District.

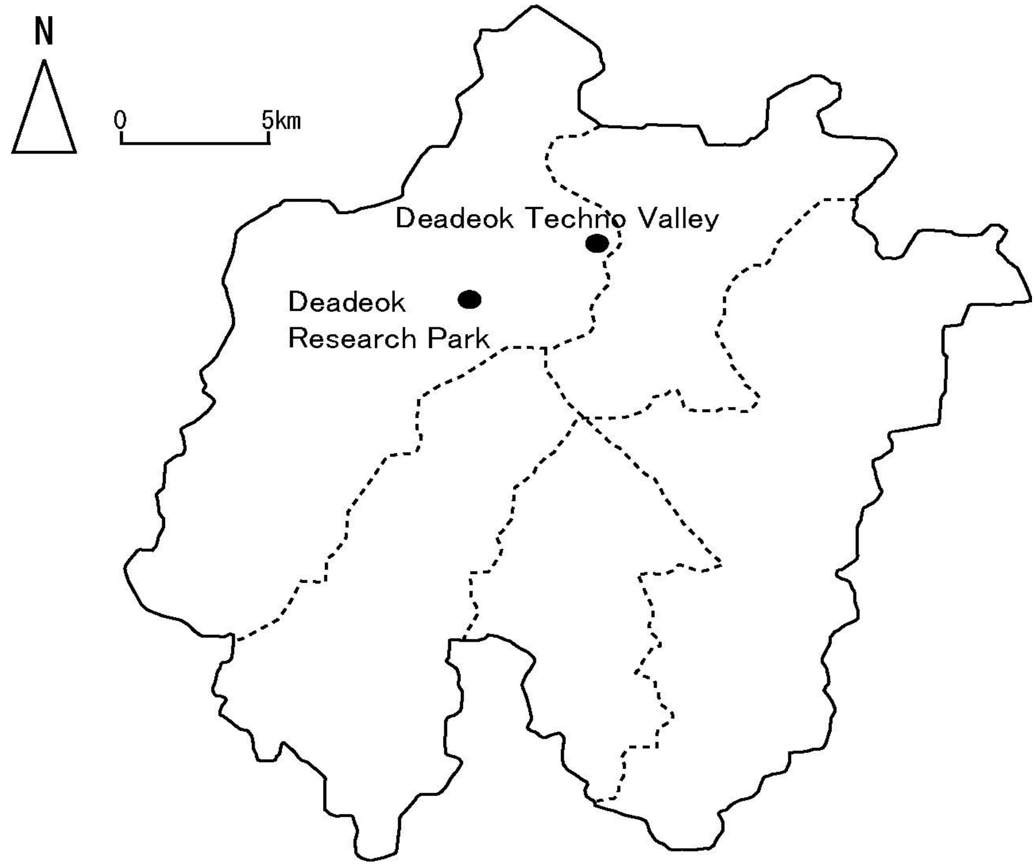
3.2. Daedeok Valley

The Daedeok Valley (DDV) is an industrial complex of the central region of Korea. It is located in the Yuson District of Daejeon Metropolitan Area, which is 150 km south of Seoul (*Figure 2*). Daejeon is the fifth largest urbanized area of Korea, positioned at the junction of two super express railways (KTX) departing from the southern cities of Busan and Mokpo. Following the establishment of the Daedeok Research Complex[3] in 1973, the transfer of national scientific research institutions such as the Electronics and Telecommunication Research Institute (ETRI) and the Korea Advanced Institute of Science and Technology (KAIST) has strengthened DDV's function as a basic research hub. Later, research institutes of Korean private business groups were established, especially after the Daejeon Expo in 1993.

Establishment of venture companies has mushroomed since the 1997 financial crisis, when numerous researchers were dismissed from local laboratories. The Korean government launched the DDV development plan in 2000 to support high-tech venture companies in the 56 million square meters of the developed area. As of 2006, the area's six universities, along with 824 high-tech companies and 63 research institutes, employ approximately 12 thousand researchers with master's and doctoral degrees: they number about 10% of all research workers in Korea[4]. Throughout that expansion, along with the availability of such rich scientific human resources and sophisticated physical infrastructure, widely various support instruments for venture startups provided by the local public agencies have also served an important role.

In an earlier evaluation, Shin (2001) presented the criticism that the research park with DDV has created few networks among research institutes. Yusuf (2003) found that DDV has not developed into a full-fledged innovative cluster because of the lack of the following aspects: cultural and social amenity, easy access to financial and commercial center, start-up culture and diversified producer services to support it, and market realities which stimulate applied and development research. More recently, Sung, Gibson, and Kang (2003) presented their conclusion that although the venture entrepreneurs of DDV think "they did it all," through provision of low-cost space and information sharing; science parks and incubators might have contributed to their success to a greater degree than the entrepreneurs appreciate.

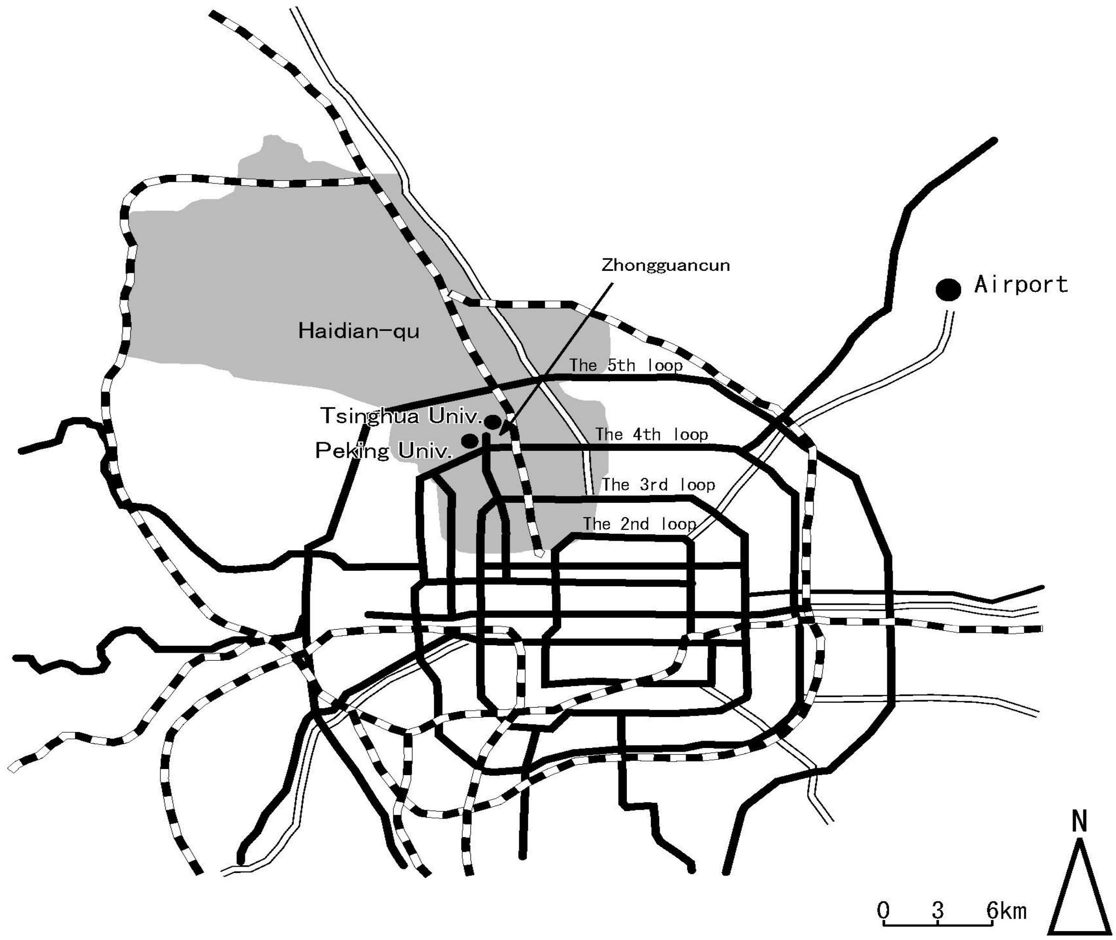
Figure 2: Map of Daedeok Valley



3.3. Zhongguancun Science Park

The core of the Zhongguancun Science Park (ZSP) is in Haidian District in the northeastern corner of Beijing, where more than a dozen highly recognized academic institutions, including Tsinghua University, Peking University, and the Chinese Academy of Sciences (CAS) are located (*Figure 3*). In the early 1980s, computer related private businesses (retail, parts and components, maintenance) emerged around universities to form the Electronics Street. In 1988, the Beijing municipal government announced the creation of the High-Technology Industry Development Experimental Zone, which became the first science park of China. The current structure of ZSP was established in 1999 as a result of the unification of five science parks in Beijing under the centralized management of the Zhongguancun Science Park Management Committee.

Figure 3: Map of Beijing



According to Tan (2006), the restructuring of research institutions and universities in response to state budget cuts and the implementation of new government programs to encourage commercial application of scientific results, such as the Torch Program, have formed a favorable environment for Chinese high-tech development and have encouraged state-owned institutes to set up venture companies. Some spin-off companies have received investment from universities. Among such companies are today's start-up high-tech conglomerates of China such as Unisplendor and Dongfang from Tsinghua University, Founder from Peking University, and Lenovo and Stone, which originated from CAS. Many of these companies retain majority capital participation of the original universities and research institutes.

High-tech venture companies have also grown in number. They have arisen not only from the local community of Zhongguancun, but have been formed by former students who studied or worked abroad and were subsequently encouraged to return and establish their own businesses. Firms registered in ZSP have been supported by a series of benefits such as simplification of the firm establishment procedure, access to the venture capital fund, tax reduction, and civil registration with permanent resident status. The scene of the Zhongguancun area has changed dramatically from a suburban rural appearance to crowded skyscrapers in a decade or so.

Although Chinese universities, especially those elite schools in ZSP, have achieved extensive commercialization, Chen and Kenney (2007) express concerns that “some professors are so engrossed in their commercial activities” and “students are being used as cheap labor with little attention to research quality or pedagogy.” Consequently, the involvement of university administrators in the daily operation of commercial enterprises “might skew university decision-making regarding research funding, faculty hiring and promotion.”

4. ICSEAD Survey in SDIC, DDV and ZSP

4.1. Data Description

In administering the ICSEAD Survey to firms of the three industrial clusters, we restricted the respondents to those of firms related to ICT and asked identical questions to facilitate comparative study of the responses. Main activities of our sample ICT-related firms are “machinery and equipment (hardware),” “electronic parts and devices” and “package software (including information processing)” in SDIC and DDV, and “electronic parts and devices,” “package software” and “information processing” in ZSP.

The questionnaire was designed to elicit responses describing the manner, purpose, frequency of firms’ contact with business partners such as “suppliers,” “customers,” “research institutes (as science research functions of universities),” “higher education (as educational functions of universities which refer to job search assistance offices of educational institutions),” “business support agencies,” and “financial institutions (including investors and banks),” and how geographical distance affects such interactions. We selected firms registered by local business support agencies, namely, the Korea Industrial Complex Corporation (KICOX), the Daedeok Valley Venture Association (DVVA), and the Zhongguancun Science Park Management Committee. In addition, the survey was conducted either by telephone or on direct visits[5]. The effective replies were 50 each in SDIC and DDV, and 207 in ZSP.

Table 1 shows summary statistics. The average age of firms in the three industry clusters is matched at about six years. It seems that these firms have arisen from the boom of venture business in Korea and China during the late 1990s and early 2000s.

The average number of employees is 23 in SDIC, 30 in DDV, and 46 in ZSP. These firms are categorized as small and medium-sized according to the definitions used in each country. They appear to be highly oriented to R&D, such that about 40% of all employees are research staff engaging in R&D, with a high ratio of R&D expenditures against the total sales revenue in each cluster: 20% in SDIC, 22% in DDV, and 26% in ZSP. Patent rights field were 8 in SDIC, 11 in DDV, and 4 in ZSP. The low incidence of patents filed in ZSP is attributable to the fact that patenting has come to be widely used only recently in China in reaction to increased competition with foreign firms and amendments of the legal system (Hu and Jefferson, 2006). The number of product items, serving as a proxy for the level of product differentiation and responsiveness to the market, is 23 in SDIC, 11 in DDV, and 12 in ZSP. Greater product variety in SDIC compared to DDV is an indication of its strong orientation to the market taking locational advantage of its location in Seoul, whereas DDV is characterized by greater production of patents based on the proximity of scientific research centers.

Table 1: Summary statistics for sample firms in three clusters

(a) SDIC						(*N* = 50)
	Measure	Mean	Standard deviation	Coefficient of variation	Maximum	Minimum
Firm Age 1 (from the year of establishment)	Year	6.80	5.58	0.82	32.00	1.00
Firm Age 2 (from the year located in this cluster)	Year	3.58	4.91	1.37	32.00	1.00
Number of Employees	Person	22.98	29.42	1.28	180.00	2.00
Number of Researchers	Person	6.60	6.08	0.92	24.00	0.00
Researchers' share of Employment	%	37.57	28.65	0.76	100.00	0.00
Sales Revenues in 2004	10,000$	418.03	747.73	1.79	4284.19	17.49
R&D Expenditure in 2004	10,000$	37.86	34.24	0.90	136.39	0.00
R&D Expenditure share of Sales in 2004	%	19.77	19.31	0.98	80.00	0.00
Average Growth Rate (Sales Amount, 2001-04)	%	2.07	5.71	2.76	9.02	-21.36
Average Growth Rate (R&D Expenditure, 2001-04)	%	-1.50	11.87	-7.92	4.15	-59.08
Number of Patents		8.68	10.91	1.26	44.00	1.00
Number of Production Items		22.73	104.99	4.62	700.00	0.00
(b) DDV						(*N* = 50)
	Measure	Mean	Standard deviation	Coefficient of variation	Maximum	Minimum
Firm Age 1 (from the year of establishment)	Year	6.72	3.02	0.45	15.00	0.00
Firm Age 2 (from the year located in this cluster)	Year	6.02	3.13	0.52	15.00	0.00
Number of Employees	Person	30.36	27.21	0.90	126.00	2.00
Number of Researchers	Person	10.18	8.15	0.80	35.00	0.00
Researchers' share of Employment	%	41.68	24.50	0.59	100.00	0.00
Sales Revenues in 2004	10,000$	318.60	491.90	1.54	3156.31	0.00
R&D Expenditure in 2004	10,000$	49.17	60.90	1.24	331.94	0.00
R&D Expenditure share of Sales in 2004	%	22.78	17.97	0.79	80.00	0.00
Average Growth Rate (Sales Amount, 2001-04)	%	2.83	3.82	1.35	12.82	-6.87
Average Growth Rate (R&D Expenditure, 2001-04)	%	0.97	2.32	2.39	5.92	-3.97
Number of Patents		11.10	11.14	1.00	60.00	0.00
Number of Production Items		11.21	41.33	3.69	290.00	0.00
(c) ZSP						(*N* = 193)
	Measure	Mean	Standard deviation	Coefficient of variation	Maximum	Minimum
Firm Age 1 (from the year of establishment)	Year	6.54	8.67	1.33	53.00	0.00
Firm Age 2 (from the year located in this cluster)	Year	5.64	7.26	1.29	51.00	0.00
Number of Employees	Person	43.75	58.24	1.33	300.00	2.00
Number of Researchers	Person	16.13	29.56	1.83	260.00	0.00
Researchers' share of Employment	%	39.22	31.88	0.81	100.00	0.00
Sales Revenues in 2004	10,000$	140.73	342.47	2.43	2415.46	0.00
R&D Expenditure in 2004	10,000$	32.55	111.06	3.41	966.18	0.00
R&D Expenditure share of Sales in 2004	%	26.41	28.73	1.09	160.00	0.00
Average Growth Rate (Sales Amount, 2001-04)	%	1.81	2.13	1.18	11.19	-3.89
Average Growth Rate (R&D Expenditure, 2001-04)	%	0.47	1.67	3.51	7.98	-2.76
Number of Patents		3.38	5.75	1.70	50.00	0.00
Number of Production Items		11.74	71.81	6.11	1000.00	0.00

Note: Some firms in the ZSP answered these figures not by single-unit establishment level but at the all business establishment level. Those figures of sample firms were not included in this table.

4.2. Characteristics of communication behavior

Table 2 presents the distribution of answers to the question related to the frequency of contacts with major business counterparts at the R&D stage[6]. Not surprisingly, it is common among the three clusters that most firms contact their "suppliers" and "customers" with higher frequency shown as "1–3 times a month" and "once a week or more." Especially, more than half of the firms in SDIC gave the latter response[7]. Similarly, contact with "financial institutions" is frequent in the three clusters. Regarding contact with "research institutes," firms in the ZSP maintain more frequent contact than their Korean counterparts. Still, firms that reported contact of at least once per month with "research institutes" were more numerous in DDV than in SDIC. This difference suggests that firms in SDIC are more market-oriented and those in DDV are more research-oriented. Contacts with the source of "higher education" and "business support agency" are scarce in Korea and more frequent in ZSP.

Table 2: Frequency of business partner contact (%)

(a) SDIC						(N = 50)
	Supplier	Customer	Research institute	Higher education	Business support agency	Financial institution
Several times a year	12.2	6.5	48.0	80.0	55.2	34.2
1 to 3 times a month	36.6	34.8	44.0	20.0	37.9	26.3
Once a week or more	51.2	58.7	8.0	0.0	6.9	39.5
(b) DDV						(N = 50)
	Supplier	Customer	Research institute	Higher education	Business support agency	Financial institution
Several times a year	10.6	6.1	31.0	84.2	68.2	40.0
1 to 3 times a month	48.9	38.8	57.1	15.8	31.8	37.8
Once a week or more	40.4	55.1	11.9	0.0	0.0	22.2
(c) ZSP						(N =207)
	Supplier	Customer	Research institute	Higher education	Business support agency	Financial institution
Several times a year	13.9	7.8	16.4	39.8	27.7	36.7
1 to 3 times a month	46.5	49.5	46.1	37.8	51.8	34.2
Once a week or more	39.6	42.7	37.5	22.5	20.5	29.1

Next, Table 3 reports which of face-to-face contact or telecommunications (such as telephone, fax and e-mail) is preferred as the mode of communication with business counterparts in each cluster. In general, we consider that by preferring the use of face-to-face communication, firms are exchanging more tacit, intangible, and complicated information with their counterparts. In the three clusters, such relationships are more relevant in their contact with "business support agency" and "financial institution," perhaps because their communications are expected to involve subsidies and credit. The firms in the two Korean clusters value face-to-face contacts with "customers" as well. It is also noteworthy that firms in DDV engage in more face-to-face contact with "research institutes." Although Table 2 shows that firms in the three regions maintain frequent contacts with "customers" and "suppliers" equally, Table 3 shows that the relation with "suppliers" relies less on face-to-face communication than in the case with "customers." That fact might suggest that the relationship with "suppliers" is fundamentally at arms length, guided by price, but human relationships are more important in sales. Taking the information that firms in ZSP have a higher incidence of contact with "business support agencies" suggests a strong influence of incentives offered by public policies in the region.

Table 3: Means of communication with business partners (%)

(a) SDIC						(*N* = 50)
	Supplier	Customer	Research institute	Higher education	Business support agency	Financial institution
Face to face communication	36.59	48.89	24.00	20.00	60.71	92.31
Telecommunication	63.41	51.11	76.00	80.00	39.29	7.69
(b) DDV						(*N* = 50)
	Supplier	Customer	Research institute	Higher education	Business support agency	Financial institution
Face to face communication	29.79	51.02	54.76	27.03	52.38	77.27
Telecommunication	70.21	48.98	45.24	72.97	47.62	22.73
(c) ZSP						(*N* =207)
	Supplier	Customer	Research institute	Higher education	Business support agency	Financial institution
Face to face communication	27.84	37.00	34.17	37.36	57.14	57.53
Telecommunication	72.16	63.00	65.83	62.64	42.86	42.47

We can characterize some aspects of the communication behavior of ICT-related small and medium-sized firms in the three clusters. In terms of the frequency of contact, we found high intensity with "customers," "suppliers," and "financial institutions" in all three regions. Contact with "research institutes" is most frequently done in ZSP, and also in DDV. The firms in ZSP contact "business support agencies" more frequently. Contact with "suppliers" does not generally involve face-to-face meetings, but meeting face-to-face is considered more effective for communications with "customers" in the two Korean clusters. With "business support agencies" and "financial institutions," face-to-face communication is more valued in all three clusters. Communication with "research institutes" is mostly undertaken in face-to-face meetings in DDV, but firms in ZSP use telecommunications more because of the higher frequency. Communications are done mostly within the same region, but ZSP firms are more likely to find their "suppliers" and "customers" outside the cluster when direct contact is necessary.

5. Dense Communication and R&D Activities

5.1. Estimations with Two Hypotheses

In this section, we explain the methodology of our empirical analysis. Our research strategy relies on the following two competing hypotheses.

Hypothesis 1 (H_1): Firms that use industry-university-government cooperation report higher in-house R&D activities (e.g. the number of researchers).

Hypothesis 2 (H_2): Firms that use industry-university-government cooperation report lower in-house R&D activities.

We can infer that interaction within the cluster enhances R&D activity of each firm if the data support H_1. The hypothesis is related to the insight of Jacobs (1969) related to the role of the cities in economic development where innovation of one firm becomes an input for the others, leading to mutually self-reinforcing creation of new opportunities among interacting firms. In other words, H_1 states that external knowledge is a complement rather than a substitute for in-house R&D.

In contrast, we can paint a different picture of an industrial cluster if the data support H_2. In this case, the benefit of locating in the cluster is the possibility of outsourcing. To our knowledge, the relationship between the outsourcing of innovation process and urbanization has not received much attention. A notable exception is a study by Love and Roper (2001), which found evidence of a substitutive relationship between in-house R&D and outsourcing activity.

To investigate these hypotheses, we consider the following reduced form model.

$$\begin{aligned}\ln RES_i = {} & \alpha_0 + \alpha_1 \ln Emp_i + \alpha_2 \ln Age1_i + \alpha_3 \ln R\&D_{ii} \\ & + \beta_1 DM_{1i} + \beta_2 DM_{2i} + \beta_3 DM_{3i} \\ & + \beta_4 DM_{4i} + \beta_5 DM_{5i} + \beta_6 DM_{6i} + \mu_i \qquad (1)\end{aligned}$$

Therein, RES_i stands for the number of research staff employed by the company, $R\&D_i$ represents the firm's R&D expenditure, Emp_i and $Age1_i$ respectively express firm characteristics of the employment size and the years in operation from establishment, and μ_i is the disturbance term. The first two terms are for control according to the size and experience of firms, which tends to increase R&D activities. Because R&D can be done either in-house or by outsourcing, the sign condition of the correlation between RES_i and $R\&D_i$ is not obvious: firms might increase R&D expenditures to contract outside services while not increasing (or reducing) their own R&D staff. We introduce dummy variables denoted as DM_1 through DM_6, where subscripts respectively correspond to counterparts: 1= "suppliers"; 2= "customers"; 3=

"research institutes"; 4= "higher education"; 5= "business support agencies"; and 6="financial institutions". We assign 1 to each dummy variable if the answer is such that the firm would have face-to-face contact with each counterpart more than once per month and 0 otherwise[8]. These dummy variables represent firms' dense communication with respective counterparts. Universities generally have multiple functions as institutions of scientific research and higher education. In the case of ZSP, universities play an enhanced role as a sort of business support agency by organizing scientific parks and as "financial institutions" by investing in spin-off firms (Chen and Kenney, 2007). We assume that firms' counterparts in universities are different for each purpose. In eq. (2), we expect a positive sign for βs if H_1 is supported. Alternatively, the sign should be negative if H_2 holds.

Taking eq. (1) as a benchmark case, we extend the model by incorporating the interaction terms of the R&D expenditure and dense communication dummies. This enables us to examine H_1 and H_2 more directly by examining the correlation between the R&D expenditure and the in-house R&D effort about firms which maintain dense communication with any business counterpart described above. This model is given as

$$\begin{aligned} \ln RES_i = \alpha_0 &+ \alpha_1 \ln Emp_i + \alpha_2 \ln Age1_i \\ &+ \beta_1(DM_{1i} \times \ln R\&D_i) + \beta_2(DM_{2i} \times \ln R\&D_i) \\ &+ \beta_3(DM_{3i} \times \ln R\&D_i) + \beta_4(DM_{4i} \times \ln R\&D_i) \\ &+ \beta_5(DM_{5i} \times \ln R\&D_i) + \beta_6(DM_{6i} \times \ln R\&D_i) + \mu_i \end{aligned} \tag{2}$$

Further extension is made by stipulating that longer experience of a firm might not affect in-house R&D efforts directly, but it indirectly influences them: firms with longer experience have effective human relationships through which firms can draw more advantage of external knowledge from communication activities. Letting a dummy variable YD_1 represent a "more experienced firm," we assign 1 if $Age1_i$ of a firm i is above the average firm-age of the sample group of each cluster; we assign 0 if it is below the average. Consequently, the model will be the following.

$$\begin{aligned} \ln RES_i = \alpha_0 &+ \alpha_1 \ln Emp_i + \alpha_2 \ln Age1_i \\ &+ \beta_1(YD_{1i} \times DM_{1i} \times \ln R\&D_i) + \beta_2(YD_{1i} \times DM_{2i} \times \ln R\&D_i) \\ &+ \beta_3(YD_{1i} \times DM_{3i} \times \ln R\&D_i) + \beta_4(YD_{1i} \times DM_{4i} \times \ln R\&D_i) \\ &+ \beta_5(YD_{1i} \times DM_{5i} \times \ln R\&D_i) + \beta_6(YD_{1i} \times DM_{6i} \times \ln R\&D_i) + \mu_i \end{aligned} \tag{3}$$

A dummy variable YD_2 represents a "less experienced firm," which we assign 1 if $Age1_i$ of a firm i is below the average firm-age of the sample group of each cluster and otherwise 0. We substitute YD_2 for YD_1 to examine the effect of communication for younger firms.

5.2. Estimated results

We estimate the three specifications for the three-cluster sample group using the OLS estimations with robust standard errors.

Estimation results of eqs. (1) and (2) are reported in Tables 4(a)–4(c). Using eq. (1), it is common to the three clusters that in-house R&D effort (RES) is positively correlated with R&D expenditure ($R\&D$) and firm size measured by employment (Emp). The effects of the firm age ($Age1$) are positive and statistically significant only for DDV firms. In other words, in SDIC and ZSP, firm age from their established year might not directly contribute to in-house R&D efforts. Regarding the communication dummies, panel (a) shows that SDIC firms exhibit an H_2-type effect (low in-house R&D effort) in their relationship with "financial institutions" such as banks. In other words, if firms have dense communication with local financial institutions, it is likely that they can obtain information related to the opportunities for outsourcing a part of the R&D process. Similarly, the panel (b) shows that the DDV firms have an H_2-effect channel through "customers" and "business support agencies," although communication with "higher education" apparently enhances in-house R&D (H_1-effect). It is worth recalling that DDV is a government-sponsored science park in which local business support agencies have a strong role in promoting commercial use of the scientific research. Panel (c) exhibits that ZSP firms gain an H_2-effect through contact with "research institutes." The adjusted R2 of the eq. (1) is sufficiently high that we are able to infer that this specification of the model has reasonable explanatory power for the three clusters. With these results, we can identify in each high-tech cluster those significant information channels through which in-house R&D efforts are influenced and in which direction, whether increased or decreased (i.e. outsourcing).

For eq. (2), we test that the effects of dense communication related to counterparts are not direct but are instead imparted through their effects on R&D expenditure. As presented in Table 4, this proposition is unsupported, except for the interaction between the communication with "business support agencies" and R&D expenditure in DDV.

Table 4: Regression results related to dense communication and R&D

(a) SDIC	Equation (1)			Equation (2)		
	Coef.	*t*-statistics	*p*-value	Coef.	*t*-statistics	*p*-value
Constant	-0.629	-1.200	0.243	0.117	0.370	0.714
Ln R&D	0.195**	2.210	0.037			
Ln Emp	0.511**	4.380	0.000	0.621**	6.770	0.000
Ln Age1	0.021	0.110	0.910	-0.011	-0.070	0.945
DM1-Supplyer	-0.046	-0.230	0.817			
DM2-Customer	-0.040	-0.180	0.863			
DM3-Research institute	0.094	0.430	0.668			
DM4-Higher education	0.385	1.630	0.115			
DM5-Industrial support agency	-0.130	-0.620	0.544			
DM6-Investor	-0.301**	-1.990	0.058			
(DM1*ln R&D)				0.007	0.190	0.852
(DM2*ln R&D)				0.019	0.510	0.612
(DM3*ln R&D)				0.026	0.690	0.496
(DM4*ln R&D)				0.055	1.330	0.195
(DM5*ln R&D)				-0.035	-0.830	0.412
(DM6*ln R&D)				-0.045	-1.280	0.211
Adj. R^2	0.588			0.112		
F-statistics	10.61			2.08		
Number of observations	34			34		

(b) DDV	Equation (1)			Equation (2)		
	Coef.	*t*-statistics	*p*-value	Coef.	*t*-statistics	*p*-value
Constant	-0.891**	2.590	0.014	0.100	0.280	0.780
Ln R&D	0.230**	2.890	0.007			
Ln Emp	0.355**	3.060	0.004	0.664**	7.120	0.000
Ln Age1	0.293*	1.700	0.099	0.059	0.290	0.772
DM1-Supplyer	-0.177	-1.370	0.178			
DM2-Customer	-0.289*	-1.710	0.097			
DM3-Research institute	-0.157	-1.170	0.249			
DM4-Higher education	0.351*	1.720	0.095			
DM5-Industrial support agency	-0.538**	-3.250	0.003			
DM6-Investor	0.061	0.360	0.725			
(DM1*ln R&D)				0.003	0.100	0.918
(DM2*ln R&D)				-0.017	-0.510	0.612
(DM3*ln R&D)				-0.018	-0.580	0.565
(DM4*ln R&D)				0.034	0.880	0.386
(DM5*ln R&D)				-0.117**	-3.530	0.001
(DM6*ln R&D)				0.017	0.560	0.579
Adj. R^2	0.760			0.634		
F-statistics	58.57			13.85		
Number of observations	44			44		

(c) ZSP	Equation (1)			Equation (2)		(N =207)
	Coef.	*t*-statistics	*p*-value	Coef.	*t*-statistics	*p*-value
Constant	-0.080	-0.310	0.760	0.041	0.130	0.898
Ln R&D	0.180**	2.950	0.004			
Ln Emp	0.556**	6.370	0.000	0.707**	10.010	0.000
Ln Age1	-0.053	-0.390	0.700	-0.051	-0.370	0.714
DM1-Supplyer	0.279	1.430	0.155			
DM2-Customer	-0.237	-1.210	0.227			
DM3-Research institute	-0.248**	-2.010	0.047			
DM4-Higher education	0.048	0.300	0.767			
DM5-Industrial support agency	-0.020	-0.130	0.895			
DM6-Investor	0.115	0.780	0.439			
(DM1*ln R&D)				0.049	1.240	0.219
(DM2*ln R&D)				-0.038	-1.280	0.202
(DM3*ln R&D)				-0.029	-1.140	0.258
(DM4*ln R&D)				0.020	0.660	0.513
(DM5*ln R&D)				0.024	0.880	0.381
(DM6*ln R&D)				0.058	1.650	0.103
Adj. R^2	0.698			0.655		
F-statistics	35.00			45.28		
Number of observations	120			120		

Note: *, ** respectively represent significance at the 10% and 5% level.

Finally, working with eq. (3), we obtain the estimation result presented in Table 5. Here, the interaction term is ($YD_k \times DM_j \times \ln R\&D$), where $k = 1,2$ and $j = 1$–6. In other words, we examine whether the effects of H_1 or H_2 through R&D expenditure might depend on firm age. More concretely, with YD_1 (YD_2), the more (less) experienced a firm, the more (less) effective is the influence of external knowledge on in-house R&D effort.

First, results for SDIC in panel (a) show that more experienced firms with dense communication with "suppliers" tend to rely more on R&D outsourcing, whereas frequent face-to-face contact with "research institutes" and "higher education" are associated with more active in-house R&D. Because these effects were not identified by eq. (1) in Table 4, we might conjecture that the "know-who" cultivated through experience is necessary to take advantage of external knowledge in a large metropolitan area such as Seoul. In contrast, in-house R&D of firms with short experience is not influenced greatly by external knowledge.

Next, the result for DDV shown in panel (b) shows that more experienced firms' interaction with "business support agencies" is related with outsourcing. This result closely resembles that obtained in eq. (1) in Table 4 without a distinction of firm age. Interestingly, using YD_2, we can identify that less-experienced firms tend to increase in-house R&D by engaging in dense communication with "higher education." In a science city like DDV, the supply of human resources from "higher education" provides important support to the growth of start-up firms.

Finally, in panel (c), regarding ZSP firms, we can observe that frequent face-to-face contact with "suppliers" and "financial institutions" might engender greater in-house R&D effort if firms are more experienced. It is noteworthy that these effects were not significant in eq. (1) of Table 4 and were observable only for more experienced firms. In contrast to DDV, communication effects specific to less-experienced firms were not confirmed in ZSP despite its environmental similarity: it is surrounded by many universities.

Table 5: Regression results related to dense communication, R&D, and business experience

(a) SDIC	Equation (3)			Equation (3)		
	Coef.	*t*-statistics	*p*-value	Coef.	*t*-statistics	*p*-value
Constant	0.251	0.880	0.386	0.265	0.530	0.600
ln Emp	0.593**	4.730	0.000	0.594**	4.570	0.000
ln Age1	-0.012	-0.060	0.955	-0.030	-0.160	0.877
(YD1*DM1*ln R&D)	-0.195*	-1.730	0.096			
(YD1*DM2*ln R&D)	-0.038	-1.250	0.223			
(YD1*DM3*ln R&D)	0.080**	2.630	0.015			
(YD1*DM4*ln R&D)	0.296**	2.770	0.011			
(YD1*DM5*ln R&D)	-0.008	-0.300	0.763			
(YD1*DM6*ln R&D)	0.133	1.120	0.274			
(YD2*DM1*ln R&D)				0.053	1.400	0.175
(YD2*DM2*ln R&D)				0.046	0.970	0.342
(YD2*DM3*ln R&D)				-0.038	-0.730	0.472
(YD2*DM4*ln R&D)				0.021	0.390	0.698
(YD2*DM5*ln R&D)				-0.039	-0.550	0.585
(YD2*DM6*ln R&D)				-0.062	-1.150	0.260
Adj. R^2		0.625			0.520	
F-statistics		11.64			2.09	
Number of observations		34			34	

(b) DDV	Equation (3)			Equation (3)		
	Coef.	*t*-statistics	*p*-value	Coef.	*t*-statistics	*p*-value
Constant	-0.503	-0.880	0.387	0.141	0.290	0.777
ln Emp	0.649**	6.400	0.000	0.645**	5.440	0.000
ln Age1	0.345	1.000	0.324	-0.021	-0.060	0.950
(YD1*DM1*ln R&D)	0.000	-0.010	0.994			
(YD1*DM2*ln R&D)	-0.034	-0.670	0.509			
(YD1*DM3*ln R&D)	-0.028	-0.600	0.553			
(YD1*DM4*ln R&D)	-0.012	-0.140	0.893			
(YD1*DM5*ln R&D)	-0.096*	-1.740	0.091			
(YD1*DM6*ln R&D)	0.045	0.780	0.438			
(YD2*DM1*ln R&D)				0.016	0.470	0.643
(YD2*DM2*ln R&D)				-0.005	-0.130	0.896
(YD2*DM3*ln R&D)				0.011	0.300	0.765
(YD2*DM4*ln R&D)				0.090**	2.320	0.026
(YD2*DM5*ln R&D)				-0.191**	-4.010	0.000
(YD2*DM6*ln R&D)				0.015	0.400	0.691
Adj. R^2		0.559			0.592	
F-statistics		12.32			15.10	
Number of observations		44			44	

(c) ZSP						(N =207)
	Equation (3)			Equation (3)		
	Coef.	*t*-statistics	*p*-value	Coef.	*t*-statistics	*p*-value
Constant	0.082	0.260	0.799	-0.081	-0.260	0.799
ln Emp	0.669**	8.550	0.000	0.724**	11.950	0.000
ln Age1	0.002	0.010	0.989	0.025	0.170	0.869
(YD1*DM1*ln R&D)	0.121*	1.930	0.056			
(YD1*DM2*ln R&D)	-0.080	-1.130	0.263			
(YD1*DM3*ln R&D)	-0.057	-1.550	0.124			
(YD1*DM4*ln R&D)	0.004	0.120	0.904			
(YD1*DM5*ln R&D)	0.074	1.540	0.126			
(YD1*DM6*ln R&D)	0.081*	1.780	0.078			
(YD2*DM1*ln R&D)				-0.027	-0.530	0.599
(YD2*DM2*ln R&D)				-0.012	-0.390	0.696
(YD2*DM3*ln R&D)				-0.035	-1.080	0.281
(YD2*DM4*ln R&D)				0.036	0.870	0.388
(YD2*DM5*ln R&D)				0.010	0.260	0.798
(YD2*DM6*ln R&D)				0.021	0.710	0.482
Adj. R^2		0.663			0.642	
F-statistics		78.34			22.47	
Number of observations		120			120	

Note: *, ** respectively represent significance at the 10% and 5% level.

The foregoing analysis adds new insights to the existing literature. First, communication externalities related to innovation within an industrial cluster, especially those which are based on scientific knowledge, constitute a complex phenomenon taking effect in different ways in different contexts. The benefit of communication externality might appear either in the greater possibility of outsourcing of the innovation process, resulting in specialization and reduction of fixed cost, or in stimulus to in-house R&D efforts enabling firms' product differentiation and growth. Looking into the interaction more closely, these two effects coincide in the same cluster. Results show one effect related to dense communication with particular business counterparts and another effect in connection with other counterparts. In some cases, the extent to which firms enjoy benefits of externalities depends on their duration of experience. Our results show that duration of experience makes a greater difference in SDIC, which is located in a large metropolitan area, where know-who grants particular value, whereas DDV provides encouragement to R&D of less-experienced firms. The relationship with research institutes is important in ZSP, independently of firm age. Similarly to the case of SDIC, firms with longer experience in ZSP are able to take advantage of communication externalities.

6. Concluding Remarks

Numerous empirical studies have examined the nature of agglomeration economies based on knowledge spillover and communication externalities. Most of them simply subsumed that the extent of agglomeration economies is associated with the size of the nearby population because greater interaction can be expected among a larger number of people.

We examined the effects of dense communication, as one sort of communication externality arising from industry-university-government cooperation, on enhancement in-house R&D activities in Korean and Chinese knowledge-based industrial clusters: SDIC, DDV, and ZSP. The salient conclusion of this study is that more attention must be devoted to the complexity of interactions that occur within the industrial clusters. Using the unique dataset of the ICSEAD Survey, we were able to identify that an individual firm might receive at least two types of influence from agglomeration: stimulation of in-house R&D through exchange of ideas; and reduction of R&D by facilitating R&D outsourcing. Such competing effects co-occur within an industrial cluster depending on which business counterparts receive close contact, and depending on a firm's duration of experience. More detailed knowledge of these issues is expected to contribute to more concrete and effective policy recommendations. Such viewpoints are useful for semi-industrialized countries such as Korea and coastal regions of China, which seek to develop a "Silicon Valley model" of a regional innovation system to upgrade their export production.

The findings of the present paper indicate several directions for future research. The first direction is to investigate the regional specialization constituted by diversified agents. Given the scale economy in R&D, as the industry-academia-government cooperation within a cluster is deepened and the connectivity across agents becomes stronger, each constituent of the cluster can be more specialized by concentrating its knowledge resource to more efficient activities. Moreover, while some R&D activities are internal to the cluster, others will be carried out through outsourcing to other regions. The second direction is to discuss the urban policy to provide infrastructure and institutional ground to enhance innovativeness of firms. Since the ICSEAD survey dataset already contains some information regarding the two issues, we hope that we will be able to report the research result in future. Finally, in order to address the exchange of knowledge, it is desirable to observe the interaction among individuals (scientists and engineers) rather than among organizations.

---

[1] For example, Lucas (1988) described that the central role of cities in economic life is of exactly the same character as "external human capital."

[2] Information is given by the Guro District homepage (http://english.guro.go.kr/).

[3] The Daedeok Research Complex was renamed Daedeok Innopolis in 2005.

[4] Relevant information is given on the Daedeok Innopolis homepage: (http://www.ddinnopolis.or.kr/english/).

[5] Sample firms were selected from the directory owned by the agency of industrial support and industrial estate development of each industrial cluster. The selection was not random: the sampling was made by contacting firm managers one by one until the number who agreed to participate was sufficient.

[6] For the questionnaire survey, we separated R&D into three sub-stages, namely "basic research," "product development" and "marketing and commercialization." We asked a question related to the contact with business counterparts for each stage, where as such demarcation is made by respondents. However, in this paper, we analyze only those data of the "basic research" stage, not only because it is the process during which knowledge input matters the most, but also because, in later stages, firms' communication activity is strongly concentrated on customers and suppliers, whereas contact with academic research institutes becomes negligible.

[7] It is presumed that these relationships with higher frequency reflect the existence of regular dealings, for example, deliver of materials and intermediate goods and services at regular intervals. In this case, it is presumed that it does not necessarily connect directly with innovation activity even if there is contact with these counterparts with higher frequency.

[8] As described in Note 6, it is assumed that frequent contact once a week and more is too high for R&D activities. For that reason, we adopt the frequency of more than once per month as dummy variables in our estimations. Moreover, we were unable to obtain any statistically significant result using the frequency of once per week or higher frequency as dummy variables for confirmation.

References:

Adams, J. D. (2002), "Comparative Localization of Academic and Industrial Spillovers," *Journal of Economic Geography*, 2, 253-278.

Anselin, L., A. Varga and Z. Acs (2000), "Geographic and Sectoral Characteristics of Academic Knowledge Externalities," *Papers in Regional Science*, 79, 435-443.

Arita, T., M. Fujita and Y. Kameyama (2006), "Effects of Regional Cooperation among Small and Medium-Sized Firms on Their Growth in Japanese Industrial Clusters" *Review of Urban & Regional Development Studies*, 18 (3), 209-228.

Audretsch, D. B. and M. P. Feldman (1996a), "R&D Spillovers and the Geography of Innovation and Production," *American Economic Review*, 86 (3), 630-640.

Audretsch, D. B. and M. P. Feldman (1996b) "Innovative Clusters and the Industry Life Cycle," *Review of Industrial Organization*, 11, 253-273.

Audretsch, D. B. and M. P. Feldman (2004), "Knowledge Spillovers and the Geography of Innovation," in J. V. Henderson and J.-F. Thisse (eds.) *Handbook of Regional and Urban Economics*, Vol. 4, Amsterdam: Elsevier: pp. 2713-2739.

Charlot, S. and G. Duranton (2004), "Communication Externalities in Cities," *Journal of Urban Economics*, 56, 581-613.

Charlot, S. and G. Duranton (2006), "Cities and Workplace Communication: Some Quantitative French Evidence," *Urban Studies*, 43 (8), 1369-1394.

Chen, K. and M. Kenney (2007), "University / Research Institutes and Regional Innovation Systems: The Case of Beijing and Shenzhen," *World Development*, 35 (6), 1056-74.

Egeln, J., S. Gottschalk, and C. Rammer (2004), "Location Decisions of Spin-offs from Public Research Institutions," *Industry and Innovation*, 11 (3), 207-223.

Feldman, M. P. and R. Florida (1994), "The Geographic Source of Innovation; Technological Infrastructure and Product Innovation in the United State," *Annals of Association of American Geographers*, 84, 210-229.

Krugman, P. (1991), *Geography and Trade*, Cambridge-Massachusetts: MIT Press.

Fujita, M. and J.-F. Thisse (2001), *Economics of Agglomeration: Cities, Industrial Location and Regional Growth*, New York: Cambridge University Press.

Fujita, M., P. Krugman and A. J. Venables (1999), *The Spatial Economy: Cities, Regions and International Trade*, Cambridge, MA: The MIT Press.

Hu, A. G. and G. H. Jefferson (2006), "A Great Wall of Patents: What is behind China's Recent Patent Explosion?" (http://courses.nus.edu.sg/course/ecshua/Chinapat%20Jan%202006.pdf) access date: September 7, 2007.

Jaffe, A. B., M. Trajtenberg and R. Henderson (1993), "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *Quarterly Journal of Economics*, 63, 577-598.

Love, J. H. and S. Roper (2001), "Outsourcing in the Innovation Process: Locational and Strategic Determinants," *Papers in Regional Science*, 80, 317-336.

Lucas, R. E., Jr. (1988), "On the Mechanics of Economic Development," *Journal of Monetary Economics*, 22, 3-42.

Shin, D. H. (2001), "An Alternative Approach to Developing Science Parks: A Case Study from Korea," *Papers in Regional Science*, 80, 103-111.

Sohn, D.W. and M. Kenney (2007), "University, Clusters, and Innovation Systems: The Case of Korea," *World Development*, 35, 991-1004.

Sung, T. K., D. V. Gibson and B. S. Kang (2003), "Characteristics of Technology Transfer in Business Ventures: The Case of Daejeon, Korea," *Technological Forecasting & Social Change*, 70, 449-463.

Tan, J. (2006), "Growth of Industry Clusters and Innovation: Lessons from Beijing Zhongguancun Science Park," *Journal of Business Venturing*, 21, 827-850.

Saxenian, A. (1994), *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Harvard Univ. Press, Cambridge, MA.

Varga, A. (1998), *University Research and Regional Innovation: A Spatial Econometric Analysis of Academic Technology Transfers*, Boston: Kluwer Academic Publishers.

Yusuf, S. (2003), *Innovative East Asia: The Future of Growth*, Washington, D.C.: World Bank.