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

HAMAGUCHI Nobuaki **Kobe University**
KAMEYAMA Yoshihiro **ICSEAD**

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

Nobuaki Hamaguchi† and Yoshihiro Kameyama††

† Research Institute for Economics and Business Administration, Kobe University
hamaguchi@rieb.kobe-u.ac.jp
†† The International Center for the Study of East Asian Development, kameyama@icsead.or.jp

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Summary This paper presents analyses of the effects of dense communication of industry-academia-government cooperation on enhancement and reduction of in-house R&D activities using survey data of the Seoul Digital Industrial Complex, Daedeok Valley, and Zhongguancun Science Park. Our results show that older firms, presumably with more-experienced personnel, take more advantage of R&D cooperation in large metropolitan areas, whereas in-house R&D of less-experienced younger firms is not influenced greatly by external knowledge. In a science park that is distant from the economic core region, we identified that encouragement by local organization toward R&D by less-experienced younger firms has considerable influence.

JEL classification: O32, R11, O40

Key words R&D cooperation, industrial cluster, Seoul Digital Industrial Complex, Daedeok Valley, Zhongguancun Science Park

1. Introduction

This paper presents an examination of the effects of local interactions through communication with business partners on firms' research and development (R&D) behavior, particularly addressing the case of the research-intensive industrial clusters of Korea and China. We analyze data obtained from a field survey that we conducted in three high-tech industrial clusters: Seoul Digital Industrial Complex (SDIC), Daedeok Valley (DDV), and Zhongguancun Science Park (ZSP). These industrial clusters mainly consist of recently established small and medium-sized firms in the field of information and communication technology (ICT).

Strengthening R&D capabilities is important for countries seeking strategies to move from lower or medium income to rich country status. Starting originally in developed countries, scientific-knowledge-based industries have become partly dispersed to developing countries seeking cost savings. However, unlike assembly types of activities, the spread of such industries is constrained by local factors in developing countries. Hence, knowledge creation is still strongly concentrated globally. The three clusters of our study represent a short list of newly emerging innovative regions competing in the global market. We investigate how local conditions in each cluster influence individual firms' R&D efforts in these successful cases. The results for the three clusters are compared.

One impediment to the establishment of scientific-knowledge-based industries might be an insufficient number of qualified workers. Moreover, being a complex process, a firm's independent R&D effort is insufficient to maintain technological competitiveness: it must be complemented by external resources. Therefore, apart from the availability of qualified workers, existence of interconnectedness among themselves and among institutions to which they belong has a crucial importance.

This perception was first captured by Nelson (1993); it has developed into the vast literature of the national innovation systems. Subsequently, the idea has been applied to geographically smaller systems under the umbrella of regional innovation systems. As surveyed extensively by Cheshire and Malecki (2004), geographic concentration facilitates the said interactive connection within the system of innovation, highlighting the relevance of the regional context of the innovation system. Typically, clusters of knowledge-intensive firms, including the three of our study, are located mainly in large metropolitan areas that facilitate face-to-face communications with essential persons, in spite of higher costs of land and labor. 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-ranking officials and university scientists who are involved in the decision of the technological standards of the next generation. Using them, we try to take any information that might help us to determine the strategy of our company." The attractiveness of certain types of information of this sort would lead many firms to gather in specific regions.

However, it is not always clear how firms' R&D might be affected by being close to others in large metropolitan areas, where people and organizations are diverse, as are the information and knowledge they produce. We might be unable to predict a priori whether cooperation might result in enhancement or saving of own R&D effort because external knowledge can be either a complement or a substitute for each firm. In regard to this empirical matter, our prime question is to identify, through statistical analyses, the characteristics of the effects of local interactions in each cluster on firms' reactions to the extent of in-house R&D effort, specifying the types of counterparts and firms' own characteristics such as the firm's size and age, in addition to the size of the expenditure for R&D.

The structure of the paper consists of four main sections. In Section 2, we begin by reviewing some theoretical background underlying our working hypotheses. Section 3 presents profiles of our research areas. Detailed descriptions of our survey data are provided in Section 4. Then we describe empirical analyses in Section 5. Conclusions follow.

2. Theoretical Background

A central issue of external influence on firms' R&D activities has been knowledge spillover. The literature of industrial organization provides important insights on whether knowledge spillover discourages or enhances individual R&D (see the extensive survey by De Bendt (1996)). Intra-industry spillovers, which pertain when the knowledge outflow is symmetric, might discourage individual efforts of innovation because spillovers limit their appropriability. Consequently, they limit the efficacy of the R&D investment to create a competitive advantage. On the other hand, spillovers might stimulate individual R&D because they might allow synergy to be realized, duplication to be eliminated, and innovation costs to be reduced. Therefore, firms might invest more in R&D with spillovers if a firm's own R&D efforts are necessary to realize spillovers from those of others they are mutually cooperative such that they protect appropriability together while maximizing the benefit of sharing information. High absorptive capacity of firms and intensity of spillovers can be seen even mutually reinforcing. Accumulation of knowledge increases the effectiveness of appropriation mechanisms for the firm's innovation process because of achieved product/process complexity and lead-time. When firms willingly engage in communication with others, they are likely aiming at cooperation in joint-research.

An alternative means of R&D cooperation might be R&D outsourcing based on at-arms-length contracts. Given the market condition of global competition and short product cycle, the temptation to avoid heavy and risky sunk costs through R&D cooperation is strong. By outsourcing, firms substitute their own research efforts for contracted external know-how. Hence, R&D outsourcing is expected to be associated with the lower in-house R&D.

Now let us turn to the original question of the effects of local interactions on firms' reactions to the extent of in-house R&D efforts. Although it might be natural to assume that local interactions within industrial clusters involve knowledge spillover, joint-research and outsourcing, the industrial organization literature is limited because it gives short shrift to the potential influence of firm location on their decisions related to partners of cooperation (related firms or research institutes) and on the patterns (joint-research or outsourcing). 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, but little support for the argument that metropolitan locations are associated with higher levels of outsourcing during the innovation process. The question of how geographical proximity with other agents influence individual firm's in-house R&D remains unclear because they did not investigate the likelihood of joint research (Note 1).

Within the scope of the regional system of innovation, Audretsch and Feldman (1996) and Varga (1998) were interested in the knowledge flows from universities and research institutes to local firms in metropolitan areas. 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. Tracking the channels of knowledge spillover, Varga (1998) points out the importance of 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.

Using an analytical perspective, casting universities as the anchoring component of a knowledge-based cluster simplifies our understanding of agglomeration, assuming that knowledge spillovers diminish as firms move away from universities. Moreover, the problem of appropriability becomes irrelevant for the university-firm link (Cassiman and Veugelers, 2002). This is a restrictive assumption, however, to understand why a knowledge-intensive cluster exists because the spatial formation of economic structure could be explained as a consequence of interactions of mobile firms without considering any fixed agents.

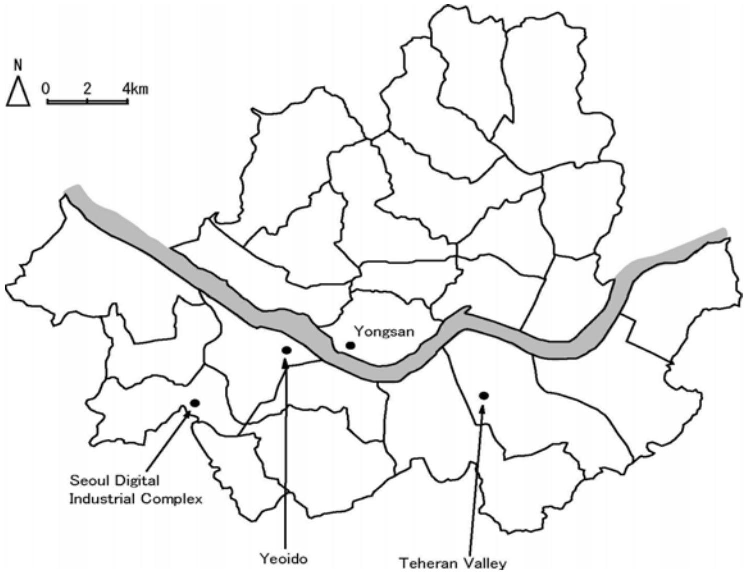
Based on the foregoing review, we will classify firms' reactions into two types whether they will increase or reduce in-house R&D efforts by interacting more with other agents in the same industrial cluster. In the former case, firms jointly engage in knowledge creation whereas, in the latter case, firms benefit from wider opportunity of outsourcing. We will also distinguish whether the counterparts are firms (suppliers and customers) or anchoring local institutions (such as universities) to identify the channels of knowledge flow. These points will be taken to formulate the working hypotheses of our empirical study presented in Section 5. Before that, we will portray the major profile of our survey regions and report some summary statistics of the collected firm level data in following sections.

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 situated in a southwest area of Seoul (see Fig. 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 was almost two million square meters, accommodating six thousand firms and more than 80 thousand workers (Note 2).

Figure 1: Map of 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 (see Fig. 1). That development was prompted by the 1997 financial crisis, which caused massive layoffs of engineers from large business groups (*Chaebol*) and drastically decreased job opportunities for students, some of whom resorted to establishment of venture companies. Since then, the Teheran Valley has grown very rapidly, supported by the boom of 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 either failed or relocated (Sohn and Kenney, 2007). Some moved to

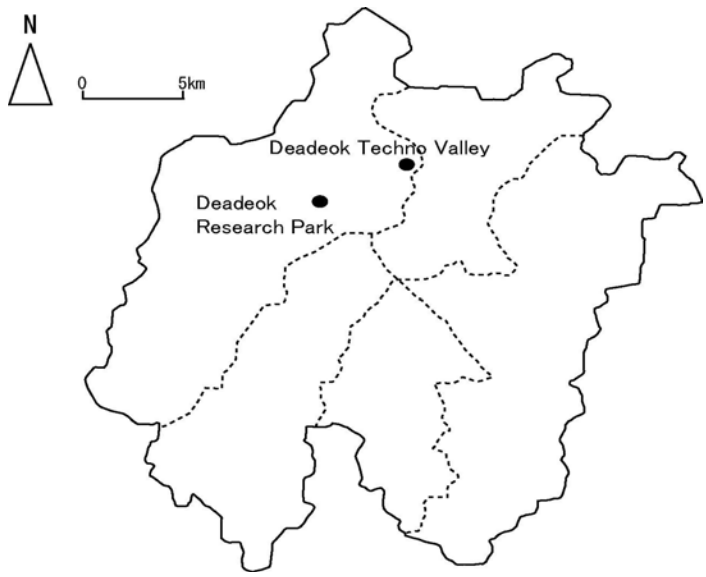
SDIC and Daedeok Valley, attracted by the benefits of government support measures. The Teheran Valley is increasingly occupied by digital content firms, which require frequent interaction with their customers, who are concentrated in the Gangnam District.

3.2. Daedeok Valley

The Daedeok Valley (DDV) is an industrial complex of Korea's central region. It is located in the Yuson District of the Daejeon Metropolitan Area, which is 150 km south of Seoul (see Fig. 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 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 (The Daedeok Research Complex was renamed Daedeok Innopolis in 2005). 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 developed area of 56 million square meters. As of 2006, the area's six universities, along with 824 high-tech companies and 63 research institutes, employed approximately 12 thousand researchers with master's and doctoral degrees: they constitute about 10% of all research workers in Korea (Note 3). 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.

Figure 2: Map of Daedeok Valley



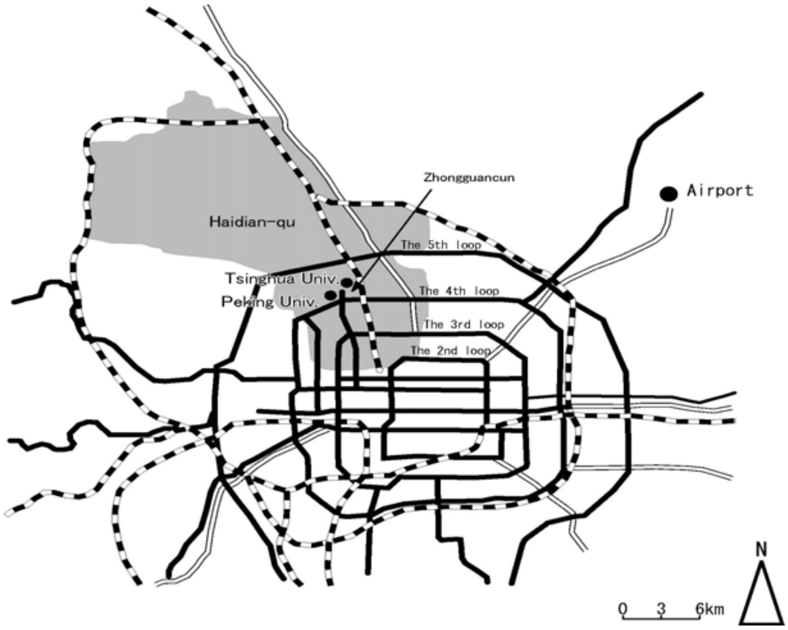
In an earlier evaluation, Shin (2001) presented the criticism that the research park with DDV has created few networks among research institutes. Yusuf (2003) found that DDV has not developed into a full-fledged innovative cluster because of the lack of the following attributes: cultural and social amenity, easy access to financial and commercial centers, 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, despite the view of DDV venture entrepreneurs that "they did it all," through provision of low-cost space and information sharing, the area's science parks and incubators contributed to their success to a greater degree than the entrepreneurs appreciate.

3.3. Zhongguancun Science Park

The core of the Zhongguancun Science Park (ZSP) is in the 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 (see Fig. 3). In the early 1980s, computer-related private businesses (retail, parts and components, maintenance) emerged around universities to form *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.

According to Tan (2006), the restructuring of academic institutions in response to state budget cuts and the introduction 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 establish venture companies. Some spin-off companies have received investment from universities. Among such companies are today's large high-tech conglomerates 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.

Figure 3: Map of Beijing



High-tech venture companies have also become more numerous. 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 using a set of benefits including 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.

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 related to 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 "software packages (including information processing)" in SDIC and DDV, and "electronic parts and devices," "software packages" and "information processing" in ZSP.

The questionnaire was designed to elicit responses describing the manner, purpose, and frequency of firms' contact with business partners such as "suppliers," "customers," "research institutes (as science research functions of universities)," "higher education institutes (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 that were registered by local business support agencies: the Korea Industrial Complex Corporation (KICOX), the Daedeok Valley Venture Association (DVVA), and the Zhongguancun Science Park Management Committee. The survey was conducted by telephone or on direct visits (Note 4). The useful replies were 50 each in SDIC and DDV, and 207 in ZSP.

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 (from the year of establishment)	Year	6.80	5.58	0.82	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
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 (from the year of establishment)	Year	6.72	3.02	0.45	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
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 (from the year of establishment)	Year	6.54	8.67	1.33	53.00	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
Number of Production Items		11.74	71.81	6.11	1000.00	0.00

Note: Some firms in 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.

Table 1 shows summary statistics. The average age of firms in the three industry clusters is matched at about seven years. Apparently, 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 their respective countries. They appear to be highly oriented to R&D, such that about 40% of all employees are research staff engaged in R&D, with a high ratio of R&D expenditures against total sales revenues in each cluster: 20% in SDIC, 22% in DDV, and 26% in ZSP.

The respective numbers of product items, serving as a proxy for the level of product differentiation and responsiveness to the market are shown as 23 in SDIC, 11 in DDV, and 12 in ZSP. Greater product variety in the SDIC compared to that in DDV is an indication of its strong market-orientation, deriving locational advantage from its location in Seoul, whereas DDV is characterized by greater production of patents based on its proximity of scientific research centers.

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 basic R&D stage. Not surprisingly, it is common among the three clusters that most firms contact their "suppliers" and "customers" with higher frequency, as evidenced by the response of "1–3 times a month" and "once a week or more." Especially, more than half of the firms in SDIC gave the latter response (Note 5). 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 institutes” and “business support agencies” are scarce in Korea and more frequent in ZSP.

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 agencies” and “financial institutions,” 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 suggests that the relationship with “suppliers” is fundamentally at arms length, guided by price, but human relationships are more important in sales. In light of the information that firms in ZSP have a higher incidence of contact with “business support agencies”, we can infer a strong influence of incentives offered by public policies in that region.

Table 2: Frequency of business partner contact (%)

(a) SDIC						(N = 50)
	Suppliers	Customers	Research institutes	Higher education institutes	Business support agencies	Financial institutions
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)
	Suppliers	Customers	Research institutes	Higher education institutes	Business support agencies	Financial institutions
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)
	Suppliers	Customers	Research institutes	Higher education institutes	Business support agencies	Financial institutions
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

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

(a) SDIC						(N = 50)
	Suppliers	Customers	Research institutes	Higher education institutes	Business support agencies	Financial institutions
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)
	Suppliers	Customers	Research institutes	Higher education institutes	Business support agencies	Financial institutions
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)
	Suppliers	Customers	Research institutes	Higher education institutes	Business support agencies	Financial institutions
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 to be 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 their higher frequency of contact. 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. Empirical analysis of dense communication and R&D activities

5.1. Specification of four hypotheses

The emphasis of these analyses is on whether localized inter-organizational R&D cooperation stimulates in-house R&D or reduces it in favor of outsourcing. We consider that the higher frequency of face-to-face contact represents stronger cooperation. Furthermore, we will distinguish the impact by partners of cooperation. Our research strategy relies on the following competing hypotheses.

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

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

Here, inter-firm cooperation refers to that with suppliers and customers. H_1 states that external knowledge is a complement rather than a substitute for in-house R&D. If the data support H_1, we can infer that interaction within the cluster enhances R&D activity of each firm, leading to local joint knowledge creation. 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.

We also introduce the following hypotheses:

Hypothesis 3 (H_3): Firms that use cooperation with local organizations such as universities, research institutes, business support agencies, and financial institutions report higher in-house R&D activities.

Hypothesis 4 (H_4): Firms that use cooperation with local organizations such as universities, research institutes, business support agencies, and financial institutions report lower in-house R&D activities.

Hypothesis H_3 captures effects of incoming spillovers from local organizations on individual R&D. Although this outcome is plausible based on the theories reviewed in Section 2, we cannot rule out the possibility that local organizations serve firms as intermediaries or direct counterparts of technological outsourcing. In fact, H_4 represents this option. The distinction of mentioned organizations enables us to identify the relevant source of spillovers in each cluster. Because many firms in Chinese science parks such as ZSP are spin-offs from universities and research institutes, they might maintain a tight relationship with their original laboratory of the university, performing joint studies and accepting university students as research assistants or trainees.

We consider the following reduced form model to investigate these hypotheses.

$$\ln RES_i = \alpha_0 + \alpha_1 \ln Emp_i + \alpha_2 \ln Age1_i + \alpha_3 \ln R\&D_{ii}$$

$$+\beta_1 DM_{1i} + \beta_2 DM_{2i} + \beta_3 DM_{3i} + \beta_4 DM_{4i} + \beta_5 DM_{5i} + \beta_6 DM_{6i} + \mu_i \quad (1)$$

Therein, RES_i represents the number of research staff employed by the company. In the following, we treat RES_i as an indicator of in-house R&D efforts in each firm because having more (less) own research personnel should be interpreted as greater (lesser) reliance on own technology. A smaller RES_i implies dependence on other firms' technologies, and therefore can be interpreted as outsourcing of knowledge creation. As independent variables, $R\&D_i$ signifies the firm's R&D expenditure, whereas Emp_i and Age_i respectively express firm characteristics of the employment size and the years in operation from establishment; 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 through 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 (RES_i). We introduce dummy variables, which are denoted as $DM_1 - DM_6$, where subscripts respectively signify counterparts: 1= "suppliers", 2= "customers", 3= "research institutes", 4= "higher education institutes", 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 (Note 6). 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 β s if H_1 and H_3 are supported. Alternatively, the sign is expected to be negative if H_2 and H_4 hold.

Taking eq. (1) as a benchmark case, we extend the model by incorporating the interaction terms of the R&D expenditure and communication dummies. This enables us to examine whether the correlation implied by H_1 – H_4 between levels of R&D efforts and the intensity of communication with any business counterpart described above depends crucially on higher R&D expenditure of each firm. This model is given as the following.

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

The following extension is made to investigate whether dense communication affects in-house R&D specifically when the firm age is greater, stipulating that older firms can draw more advantages from external knowledge. Letting a dummy variable YD_1 represent a “more-experienced older firm,” we assign 1 if Age_i of a firm i is greater than the average firm-age of the sample group of each cluster; we assign 0 if it is less than the average. Consequently, the model will be the following.

$$\ln RES_i = \alpha_0 + \alpha_1 \ln Emp_i + \alpha_2 \ln Age_i + \alpha_3 \ln R\&D_{i\,i}$$

$$+\beta_1(DM_{1i}\bullet YD_{1i})+\beta_2(DM_{2i}\bullet YD_{1i})+\beta_3(DM_{3i}\bullet YD_{1i})$$

$$+\beta_4(DM_{4i}\bullet YD_{1i})+\beta_5(DM_{5i}\bullet YD_{1i})+\beta_6(DM_{6i}\bullet YD_{1i})+\mu_i \qquad (3)$$

Alternatively, we let a dummy variable YD_2 represent a "less-experienced younger firm," which we assign 1 if Age_i of a firm i is below the average firm-age of the sample group of each cluster and otherwise 0, and use YD_2 instead of YD_1 in eq. (3). This substitution enables us to examine if the effects of communication on innovation is especially relevant on younger firms that might find wider varieties of opportunities from cooperation than already assimilated older firms.

As a final extension, we modify the model by incorporating the interaction of the three variables: i.e., communication, experience, and R&D expenditure. This specification represents the case in which communication affects R&D, especially when a firm is both older and has higher R&D expenditures. This model will therefore be the following.

$$\ln RES_i = \alpha_0 + \alpha_1 \ln Emp_i + \alpha_2 \ln Age_i$$

$$+\beta_1(DM_{1i}\bullet YD_{1i}\bullet \ln R\&D_i)+\beta_2(DM_{2i}\bullet YD_{1i}\bullet \ln R\&D_i)$$

$$+\beta_3(DM_{3i}\bullet YD_{1i}\bullet \ln R\&D_i)+\beta_4(DM_{4i}\bullet YD_{1i}\bullet \ln R\&D_i)$$

$$+\beta_5(DM_{5i}\bullet YD_{1i}\bullet \ln R\&D_i)+\beta_6(DM_{6i}\bullet YD_{1i}\bullet \ln R\&D_i)+\mu_i \qquad (4)$$

As in eq. (3), we can examine the case of younger firms by substituting YD_2 for YD_1.

5.2. Estimated results

We estimate the four specifications given in the previous subsection 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 efforts (RES) are positively correlated with R&D expenditure ($R\&D$) and the firm size, as indicated 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, the firm age from their year of establishment might not contribute directly to in-house R&D efforts. Regarding the communication dummies, panel (a) shows that SDIC firms exhibit an H_4-type effect associated with lower in-house R&D efforts by maintaining a closer relationship with "financial institutions" such as banks and so-called *angel* investors. In other words, if firms have dense communications with local financial institutions, it is likely that they can obtain information related to opportunities for outsourcing a part of the R&D process. Similarly, panel (b) shows that the DDV firms have an H_2-type effect channel through "customers" and an H_4-type effect through "business support agencies," although communication with "higher education" apparently enhances in-house R&D (H_3-type effect). It is worth recalling that DDV is a government-sponsored science park for which a local business support agency has a strong role in promoting commercial use of the scientific research. Panel (c) exhibits that ZSP firms gain an H_4-type effect through contact with "research institutes." The adjusted R^2 of eq. (1) is sufficiently high that we can infer that this specification of the model has reasonable explanatory power for the three clusters. Using these results, we can identify in each high-tech cluster those significant information channels through which in-house R&D efforts are influenced and their direction, whether increasing or decreasing (i.e. outsourcing).

For eq. (2), we test whether the effects of dense communication related to counterparts are enhanced by higher R&D expenditure. As presented in Table 4, except for the H_4-type effect in the case of communication with “business support agencies” of DDV firms and the H_3-type effect in that with “financial institutions” of ZSP firms, communication effects identified in eq. (2) disappear. This outcome implies that, with higher own R&D expenditure, the relevance of cooperation with other firms and organizations within the cluster tends to become insignificant.

Next, working with eq. (3), we obtain the estimation results presented in Table 5. First, panel (a) shows that more experienced SDIC firms have an H_2-type effect through intense communication with “customers” implying R&D outsourcing, whereas frequent face-to-face contact with “research institutes” and “higher education institutes” enhance in-house R&D (H_3-type effect).

Second, the result for DDV shown in panel (b) demonstrates that both older and younger firms gain an H_4-type effect through contact with “business support agencies.” This is consistent with Table 4 without a distinction of firm age. Interestingly, comparison of the parameter of $DM_5 \bullet YD_1$ and $DM_5 \bullet YD_2$ shows that the H_4-type effect is stronger for younger firms, suggesting the effective role of support agencies for startup firms in DDV.

.

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

(a) SDIC						
	Eq. (1)			Eq. (2)		
	Coef.	*t*-value	*p*-value	Coef.	*t*-value	*p*-value
Const.	-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 Age	0.021	(0.110)	(0.910)	-0.011	(0.070)	(0.945)
DM1-Supplier	-0.046	(0.230)	(0.817)			
DM2-Customer	-0.040	(0.180)	(0.863)			
DM3-Research Institute	0.094	(0.430)	(0.668)			
DM4-Source of Human Capital	0.385	(1.630)	(0.115)			
DM5-Industrial Supporting Agency	-0.130	(0.620)	(0.544)			
DM6-Investor	**-0.301***	**(1.990)**	**(0.058)**			
Cross (DM1*ln R&D)				0.007	(0.190)	(0.852)
Cross (DM2*ln R&D)				0.019	(0.510)	(0.612)
Cross (DM3*ln R&D)				0.026	(0.690)	(0.496)
Cross (DM4*ln R&D)				0.055	(1.330)	(0.195)
Cross (DM5*ln R&D)				-0.035	(0.830)	(0.412)
Cross (DM6*ln R&D)				-0.045	(1.280)	(0.211)
Adj. R^2		0.588			0.112	
F-statistics		10.61			2.08	
Obs.		34			34	
(b) DDV						
	Eq. (1)			Eq. (2)		
	Coef.	*t*-value	*p*-value	Coef.	*t*-value	*p*-value
Const.	**-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 Age	**0.293***	**(1.700)**	**(0.099)**	0.059	(0.290)	(0.772)
DM1-Supplier	-0.177	(1.370)	(0.178)			
DM2-Customer	**-0.289***	**(1.710)**	**(0.097)**			
DM3-Research Institute	-0.157	(1.170)	(0.249)			
DM4-Source of Human Capital	**0.351***	**(1.720)**	**(0.095)**			
DM5-Industrial Supporting Agency	**-0.538****	**(3.250)**	**(0.003)**			
DM6-Investor	0.061	(0.360)	(0.725)			
Cross (DM1*ln R&D)				0.003	(0.100)	(0.918)
Cross (DM2*ln R&D)				-0.017	(0.510)	(0.612)
Cross (DM3*ln R&D)				-0.018	(0.580)	(0.565)
Cross (DM4*ln R&D)				0.034	(0.880)	(0.386)
Cross (DM5*ln R&D)				**-0.117****	**(3.530)**	**(0.001)**
Cross (DM6*ln R&D)				0.017	(0.560)	(0.579)
Adj. R^2		0.760			0.634	
F-statistics		58.57			13.85	
Obs.		44			44	
(c) ZSP						
	Eq. (1)			Eq. (2)		
	Coef.	*t*-value	*p*-value	Coef.	*t*-value	*p*-value
Const.	-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 Age	-0.053	(0.390)	(0.700)	-0.051	(0.370)	(0.714)
DM1-Supplier	0.279	(1.430)	(0.155)			
DM2-Customer	-0.237	(1.210)	(0.227)			
DM3-Research Institute	**-0.248****	**(2.010)**	**(0.047)**			
DM4-Source of Human Capital	0.048	(0.300)	(0.767)			
DM5-Industrial Supporting Agency	-0.020	(0.130)	(0.895)			
DM6-Investor	0.115	(0.780)	(0.439)			
Cross (DM1*ln R&D)				0.049	(1.240)	(0.219)
Cross (DM2*ln R&D)				-0.038	(1.280)	(0.202)
Cross (DM3*ln R&D)				-0.029	(1.140)	(0.258)
Cross (DM4*ln R&D)				0.020	(0.660)	(0.513)
Cross (DM5*ln R&D)				0.024	(0.880)	(0.381)
Cross (DM6*ln R&D)				**0.058***	**(1.650)**	**(0.103)**
Adj. R^2		0.698			0.655	
F-statistics		35.00			45.28	
Obs.		120			120	

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

Table 5: Regression results related to dense communication, R&D, and business experience (1)

(a) SDIC						
	Eq. (3) for *older firms*			Eq. (3) for *younger firms*		
	Coef.	*t*-value	*p*-value	Coef.	*t*-value	*p*-value
Const.	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 Age	-0.012	(0.060)	(0.955)	-0.030	(0.160)	(0.877)
Cross (DM1*YD1*ln R&D)	-0.195*	(1.730)	(0.096)			
Cross (DM2*YD1*ln R&D)	-0.038	(1.250)	(0.223)			
Cross (DM3*YD1*ln R&D)	0.080**	(2.630)	(0.015)			
Cross (DM4*YD1*ln R&D)	0.296**	(2.770)	(0.011)			
Cross (DM5*YD1*ln R&D)	-0.008	(0.300)	(0.763)			
Cross (DM6*YD1*ln R&D)	0.133	(1.120)	(0.274)			
Cross (DM1*YD2*ln R&D)				0.053	(1.400)	(0.175)
Cross (DM2*YD2*ln R&D)				0.046	(0.970)	(0.342)
Cross (DM3*YD2*ln R&D)				-0.038	(0.730)	(0.472)
Cross (DM4*YD2*ln R&D)				0.021	(0.390)	(0.698)
Cross (DM5*YD2*ln R&D)				-0.039	(0.550)	(0.585)
Cross (DM6*YD2*ln R&D)				-0.062	(1.150)	(0.260)
Adj. R^2		0.625			0.520	
F-statistics		11.64			2.09	
Obs.		34			34	
(b) DDV						
	Eq. (3) for *older firms*			Eq. (3) for *younger firms*		
	Coef.	*t*-value	*p*-value	Coef.	*t*-value	*p*-value
Const.	-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 Age	0.345	(1.000)	(0.324)	-0.021	(0.060)	(0.950)
Cross (DM1*YD1*ln R&D)	0.000	(0.010)	(0.994)			
Cross (DM2*YD1*ln R&D)	-0.034	(0.670)	(0.509)			
Cross (DM3*YD1*ln R&D)	-0.028	(0.600)	(0.553)			
Cross (DM4*YD1*ln R&D)	-0.012	(0.140)	(0.893)			
Cross (DM5*YD1*ln R&D)	-0.096*	(1.740)	(0.091)			
Cross (DM6*YD1*ln R&D)	0.045	(0.780)	(0.438)			
Cross (DM1*YD2*ln R&D)				0.016	(0.470)	(0.643)
Cross (DM2*YD2*ln R&D)				-0.005	(0.130)	(0.896)
Cross (DM3*YD2*ln R&D)				0.011	(0.300)	(0.765)
Cross (DM4*YD2*ln R&D)				0.090**	(2.320)	(0.026)
Cross (DM5*YD2*ln R&D)				-0.191**	(4.010)	(0.000)
Cross (DM6*YD2*ln R&D)				0.015	(0.400)	(0.691)
Adj. R^2		0.559			0.592	
F-statistics		12.32			15.10	
Obs.		44			44	
(c) ZSP						
	Eq. (3) for *older firms*			Eq. (3) for *younger firms*		
	Coef.	*t*-value	*p*-value	Coef.	*t*-value	*p*-value
Const.	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 Age	0.002	(0.010)	(0.989)	0.025	(0.170)	(0.869)
Cross (DM1*YD1*ln R&D)	0.121*	(1.930)	(0.056)			
Cross (DM2*YD1*ln R&D)	-0.080	(1.130)	(0.263)			
Cross (DM3*YD1*ln R&D)	-0.057	(1.550)	(0.124)			
Cross (DM4*YD1*ln R&D)	0.004	(0.120)	(0.904)			
Cross (DM5*YD1*ln R&D)	0.074	(1.540)	(0.126)			
Cross (DM6*YD1*ln R&D)	0.081*	(1.780)	(0.078)			
Cross (DM1*YD2*ln R&D)				-0.027	(0.530)	(0.599)
Cross (DM2*YD2*ln R&D)				-0.012	(0.390)	(0.696)
Cross (DM3*YD2*ln R&D)				-0.035	(1.080)	(0.281)
Cross (DM4*YD2*ln R&D)				0.036	(0.870)	(0.388)
Cross (DM5*YD2*ln R&D)				0.010	(0.260)	(0.798)
Cross (DM6*YD2*ln R&D)				0.021	(0.710)	(0.482)
Adj. R^2		0.663			0.642	
F-statistics		78.34			22.47	
Obs.		120			120	

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

Third, in panel (c), more experienced firms in ZSP exhibit an H_1-type in their relationship with "suppliers" and an H_3-type in their relationship with "financial institutions." The former was not identified in Table 4 without the distinction of firm age. The latter supports the argument already presented in Table 4 (eq. (2)), even specifying that the impact of the dense communication with local financial institutions associated with higher in-house R&D is stronger for older firms, which presumably have more-experienced personnel. This result might be attributable to long-term cooperation based on their mutual trust.

Finally, Table 6 exhibits estimation results of eq. (4). First, results for SDIC in panel (a) show that firms which have longer experience and spend more on R&D have an H_2-type through dense communication with "suppliers", whereas their frequent face-to-face contact with "research institutes" and "higher education institutes" are associated with the H_3-type effect. Although the H_3-type effect is the same as Table 5, the H_2-type effect here appears in relation to "suppliers." Second, the result for DDV firms shown in panel (b) identifies the H_4-type effect in contact with "business support agencies" for both older and younger firms, while its magnitude is larger for the latter. We obtained the same results in Table 4 and Table 5, where interaction with R&D expenditure and firm age are considered separately. A novel feature of this presentation is that we identify H_3-type effect in dense communication with "higher education institutes" for firms with shorter experience which spend more on R&D. In a science city like DDV, the supply of human resources from "higher education institutes" provides important support to the growth of start-up firms.

Table 6: Regression results related to dense communication, R&D, and business experience (2)

(a) SDIC						
	Eq. (4) for *older firms*			Eq. (4) for *younger firms*		
	Coef.	*t*-value	*p*-value	Coef.	*t*-value	*p*-value
Const.	-0.583	(1.250)	0.223	-0.535	(0.750)	(0.459)
ln R&D	**0.169****	**(2.150)**	**(0.042)**	**0.177***	**(2.070)**	**(0.049)**
ln Emp	**0.507****	**(4.400)**	**(0.000)**	**0.485****	**(3.890)**	**(0.001)**
ln Age	0.055	(0.300)	(0.767)	0.038	(0.210)	(0.837)
Cross (DM1*YD1)	-0.382	(1.160)	(0.259)			
Cross (DM2*YD1)	**-0.354***	**(1.990)**	**(0.059)**			
Cross (DM3*YD1)	**0.476****	**(2.740)**	**(0.012)**			
Cross (DM4*YD1)	**0.982****	**(3.190)**	**(0.004)**			
Cross (DM5*YD1)	0.001	(0.010)	(0.995)			
Cross (DM6*YD1)	-0.022	(0.060)	(0.956)			
Cross (DM1*YD2)				0.273	(1.090)	(0.285)
Cross (DM2*YD2)				0.214	(0.720)	(0.481)
Cross (DM3*YD2)				-0.228	(0.700)	(0.489)
Cross (DM4*YD2)				0.267	(0.910)	(0.374)
Cross (DM5*YD2)				-0.174	(0.510)	(0.612)
Cross (DM6*YD2)				-0.393	(1.400)	(0.176)
Adj. R^2		0.673			0.603	
F-statistics		16.68				
Obs.		34			34	
(b) DDV						
	Eq. (4) for *older firms*			Eq. (4) for *younger firms*		
	Coef.	*t*-value	*p*-value	Coef.	*t*-value	*p*-value
Const.	**-1.259****	**(3.270)**	**0.002**	-0.232	(0.430)	(0.671)
ln R&D	**0.284****	**(4.080)**	**(0.000)**	**0.215****	**(2.620)**	**(0.013)**
ln Emp	**0.294****	**(2.680)**	**(0.011)**	**0.478****	**(3.670)**	**(0.001)**
ln Age	**0.467***	**(1.820)**	**(0.077)**	-0.142	(0.460)	(0.646)
Cross (DM1*YD1)	-0.111	(0.570)	(0.573)			
Cross (DM2*YD1)	-0.339	(1.210)	(0.234)			
Cross (DM3*YD1)	-0.121	(0.550)	(0.583)			
Cross (DM4*YD1)	0.660	(1.140)	(0.264)			
Cross (DM5*YD1)	**-0.326***	**(1.660)**	**(0.105)**			
Cross (DM6*YD1)	0.101	(0.310)	(0.759)			
Cross (DM1*YD2)				-0.047	(0.230)	(0.816)
Cross (DM2*YD2)				-0.155	(0.710)	(0.480)
Cross (DM3*YD2)				-0.005	(0.020)	(0.981)
Cross (DM4*YD2)				0.334	(1.210)	(0.235)
Cross (DM5*YD2)				**-0.739***	**(1.930)**	**(0.061)**
Cross (DM6*YD2)				0.049	(0.210)	(0.833)
Adj. R^2		0.696			0.666	
F-statistics		18.19			18.52	
Obs.		44			44	
(c) ZSP						
	Eq. (4) for *older firms*			Eq. (4) for *younger firms*		
	Coef.	*t*-value	*p*-value	Coef.	*t*-value	*p*-value
Const.	-0.134	(0.620)	0.536	-0.126	(0.470)	(0.638)
ln R&D	**0.161****	**(3.230)**	**(0.002)**	**0.179****	**(2.650)**	**(0.009)**
ln Emp	**0.547****	**(7.090)**	**(0.000)**	**0.579****	**(6.500)**	**(0.000)**
ln Age	0.004	(0.030)	(0.972)	-0.075	(0.490)	(0.629)
Cross (DM1*YD1)	**0.805***	**(1.970)**	**(0.051)**			
Cross (DM2*YD1)	-0.715	(1.550)	(0.125)			
Cross (DM3*YD1)	**-0.504****	**(2.540)**	**(0.012)**			
Cross (DM4*YD1)	-0.039	(0.180)	(0.857)			
Cross (DM5*YD1)	0.501	(1.220)	(0.224)			
Cross (DM6*YD1)	0.330	(1.160)	(0.247)			
Cross (DM1*YD2)				0.093	(0.460)	(0.643)
Cross (DM2*YD2)				-0.095	(0.520)	(0.601)
Cross (DM3*YD2)				-0.181	(1.400)	(0.166)
Cross (DM4*YD2)				0.111	(0.580)	(0.562)
Cross (DM5*YD2)				-0.122	(0.730)	(0.467)
Cross (DM6*YD2)				0.044	(0.360)	(0.721)
Adj. R^2		0.708			0.642	
F-statistics		58.89			22.47	
Obs.		120			120	

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

Third, in panel (c), older firms with higher R&D expenditure in ZSP exhibit an H_1-type effect in their relationship with "suppliers", which was also found in Table 5. In addition, the other one is an H_4-type effect in their relationship with "research institutes", which was also found in Table 4. Consistently with the comparison in Table 4, the H_4-type effect identified in Table 6 is also significant for more-experienced older firms. Therefore, this effect originates from older firms: dense communication with universities and research institutes stimulate in-house R&D efforts.

Let us synthesize the foregoing analysis as shown in Table 7. Focusing on inter-firm communication effects H_1 and H_2, we found that intensive contacts with suppliers increase R&D activities of older firms in ZSP. For older firms in SDIC, frequent contact with customers is usually associated with savings of in-house R&D; however, if their R&D expenditure is high, such an effect is observable in the relationship with suppliers. The latter suggests that firms with higher financial capacity can use outsourcing of R&D to suppliers, although they generally depend on innovations made by their customers. Firms in DDV enjoy in-house R&D savings effects from intensive contacts with customers, independently of firm age and R&D expenditure size. However, our result suggests that younger firms in all industrial clusters of our survey are not able to take advantage of inter-firm communications for R&D effectively.

Turning to the communication effects with local organizations expressed by H_3 and H_4, we found that R&D is enhanced through closer relationships with "research institutes" and "higher education institutes" of older firms. In contrast, younger firms derive stimulus for in-house R&D through contacts with “higher education institutes” in DDV. On the other hand, our result suggests that by frequently accessing to “business supporting agencies” in DDV, firms are able to reduce in-house R&D consistently. Although we cannot specify why this is so, we speculate that activities of local venture business associations which promote informal social gathering and exchange of information impart some effects. It is also noteworthy that “research institutes” and “higher education institutes” do not boost in-house R&D in ZSP but “research institutes” might substitute for them, especially for older firms. Although we have no concrete information, this might suggest some degree of commercial orientation of public research laboratories in acting as if they were private business partners of firms, rather than providing knowledge outflow unilaterally. We also found that older firms with higher R&D expenditures tend to expand R&D activities by maintaining more frequent contacts with “financial institutions.” This suggests that to develop a firm technologically after the startup stage, overcoming financial constraints through local relationships might become their major concern.

Table 7: Matrix of Cooperation Mode in Three Clusters

	Expected sign of effects on in-house R&D activities, "RES"	Eq.(1) in Table 4	Eq.(2) in Table 4	Eq.(3) in Table 5		Eq.(4) in Table 6	
			Higer R&D expenditure			*Higer R&D expenditure*	
		All firms	*All firms*	*Older firms*	*Younger firms*	*Older firms*	*Younger firms*
H_1	(+) positive sign	-	-	ZSP-[S]	-	ZSP-[S]	-
H_2	(-) negative sign	-	-	SDIC-[C]	-	SDIC-[S]	-
		DDV-[C]	-	-	-	-	-
H_3	(+) positive sign	-	-	SDIC-[R][H]	-	SDIC-[R][H]	-
		DDV-[H]	-	-	-	-	DDV-[H]
		-	ZSP-[F]	ZSP-[F]	-	-	-
H_4	(-) negative sign	SDIC-[F]	-	-	-	-	-
		DDV-[B]	DDV-[B]	DDV-[B]	DDV-[B]	DDV-[B]	DDV-[B]
		ZSP-[R]	-	-	-	ZSP-[R]	-

Note: [S]=Suppliers, [C]=Customers, [R]=Research institutes, [H]=Higher education institutes, [B]=Business supporting agencies, [F]=Financial institutions

6. Concluding remarks

For this study, we set out to investigate the influence of interaction among different agents within industrial clusters on individual firm-level R&D efforts. We hypothesized possible outcomes of three types: enhancement, slimming-down, and having no effect. Analyses were undertaken to specify types of innovating firms (level of experience and R&D expenditure) and those of partners (firms and local organizations). Relevant hypotheses were tested using an original dataset compiled from questionnaire surveys in three rapidly growing ICT-based industrial clusters in East Asia: Seoul Digital Industry Complex and Daedeok Valley in Korea, and Zhongguancun Science Park in Beijing, China.

Our results show that longer life of firms is a significant factor for success in SDIC and ZSP, which are located in large metropolitan areas where know-who grants particular value through appropriate channels for each firm's R&D level. In-house R&D of firms with short experience is not influenced greatly by external knowledge. In contrast, in DDV, a science park that is distant from the economic core region, we identified the significant influence of encouragement by local organizations on R&D of less-experienced younger firms.

Existing literature related to knowledge externalities in industrial clusters either captures actual channels of local external influences on individual R&D only vaguely, or restricts the focus of examination to unilateral knowledge flow from nearby universities and research institutes to the local firms. The foregoing analysis presents some novel insights with the argument that communication externalities related to innovation within an industrial cluster, especially those that are based on scientific knowledge, constitute a complex phenomenon that exerts its effects in different ways and in different contexts. We were able to identify some significant knowledge flows and their impact on individual R&D, as presented in Table 7.

The findings of the present paper indicate several directions for future research. The first direction is to investigate the regional specialization exhibited by diversified agents. Given the scale economies related to R&D, as industry-academia-government cooperation within a cluster is deepened and the connectivity across agents becomes stronger, each cluster constituent can be more specialized by concentrating its knowledge resources on more efficient activities. Moreover, although 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 urban policies that can provide infrastructure and institutional grounds to enhance firms' innovativeness. The ICSEAD survey dataset already contains some information related to the two issues. Therefore, we hope to be able to describe relevant research results in future reports. Finally, to address the exchange of knowledge, it is desirable to observe interactions among individuals (scientists and engineers) rather than among organizations.

Notes:

Note 1: Baptista and Swann (1998) and Fritsch and Franke (2004) found positive externalities in agglomeration on firms' individual R&D. However, they do not elucidate the internal mechanism underlying such a finding.

Note 2: Information is given by the Guro District HP (http://english.guro.go.kr/).

Note 3: Relevant information is given by the Daedeok Innopolis HP (http://www.ddinnopolis.or.kr/english/).

Note 4: Sampling was made by contacting firm managers one by one, using a directory owned by the industrial support agencies of each cluster. Firms included in those directories tend to be well managed firms. Therefore, our results might have a certain bias toward successful groups in each cluster.

Note 5: It is presumed that these relationships with higher frequency reflect the existence of regular transactions, for example, delivery of materials and intermediate goods and services at regular intervals. In this case, it is presumed that it is not necessarily connected directly with innovation activity, even if there is contact with these counterparts with higher frequency.

Note 6: It is assumed that frequent contact of 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.

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