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Network, Channel, and Geographical Proximity of Knowledge Transfer: The Case of University-Industry Collaboration in South Korea

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Abstract The relationship between geographical proximity and academics' formal and informal knowledge-transfer activities in the network is analyzed with a mixed research method. With social network analysis as a basis, we have explored the networks between academics and firms in the 16 regions of South Korea. The result shows Seoul and Gyunggi are identified as central nodes, meaning that the academics in other regions tend to collaborate with firms in these regions. An econometric analysis is performed to confirm the localization of knowledge-transfer activities. The intensity of formal channels measured by the number of academic papers is negatively, but significantly associated with the geographical proximity. However, we have not found any significant relationship between the formality of the channels and geographical proximity. Possibly, the regional innovation systems in South Korea are neither big enough nor strong enough to show a localization effect.

Keywords University-industry collaboration, formal and informal channels, geographical proximity, social network analysis, South Korea

I. Introduction

During the last few decades, the importance of the exploitation of university research has been echoed in academia as well as in policy communities. Firstly, in order to strengthen university-industry linkages, governments have implemented a variety of policy measures (e.g. the establishment of technology transfer offices in universities) not only in developed countries but also in developing countries (Etzkowitz et al., 2000; Sutz, 2000; Dagnino and

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Velho, 1998). Additionally, in order to develop effective conditions encouraging collaborations between academia and industry, a great number of research projects have been carried out.

Furthermore, some studies on universities' activities in European countries at the intermediate level of development or in transitional phases, such as Portugal, have been presented recently (Horta, 2010 and 2008). University-industry linkages in Asian countries such as South Korea (hereafter Korea), which has recently entered the developed countries group, have displayed different features from those in both the developed and developing countries. In this vein, some Korean researchers in Korea (Seung and Kim, 2010; Song and Hwang, 2006) portray Korea as a post catch-up country. Unlike the strong research universities in developed countries (e.g. MIT and Stanford University), Korean universities' academic research has barely been connected to industrial innovation directly, in spite of the government's strong encouragement (Eom and Lee, 2010). However, universities have various channels to industry. In particular, Korean universities have contributed to industry through informal channels, such as graduates and consulting, during the last half of the century. Considering the specific characteristics of the Korean universities mentioned above, this research aims to provide an investigation of the network structure of Korean universities and firms.

The data in this study are based not merely on a large-scale survey of Korean academics but also on the national census of Korean scientists. This enables us to collect the personal details of Korean academics, information on their industrial partners, and their knowledge-transfer activities. In particular, it is hard to collect data on both academia and industry and on their interactions simultaneously. Based on this unique data, we adopt a mixed approach combining social network analysis and econometric methods. Social network analysis provides us with a description of the geographical network of academics and firms. In terms of the econometric approach, we can test some hypotheses of the relationship between geographical proximity and knowledge-transfer activities through formal channels (e.g. contracted research) and informal channels (e.g. consultancy and conference).

II. A Literature Review

1. Network of University-Industry Collaboration

Regarding university-industry collaboration encouraging technological innovations, several scholars provide extensive reviews, particularly on the relationship between the internal (e.g. size and legal status) and external (e.g.

location and industrial background) characteristics of the two actors (i.e. universities and firms) and their knowledge-transfer activities (e.g. Agrawal, 2001; Rothaermel et al., 2007). However, relatively little attention has been paid to the linkages between the two actors themselves, although university-industry linkage is, arguably, one of engines of innovation in a network of innovative actors. Also, this has been a basic assumption of the system approach of innovation studies (e.g. National Innovation System and Triple Helix), as innovation in the system are vitalized by the strong interaction and harmony between actors in the system.

During the last few decades, scholars in innovation studies have started to analyze the relationship between the network structure, actors, and innovation processes and performance (Kastelle and Steen, 2010). Moreover, based on a bibliometric analysis, van Der Valk and Gijbers (2010) found that the application of SNA in innovation studies can be categorized into three themes: collaboration between the organization and individuals; communication between the organization and individuals; and different kinds of linkages between technological fields and sectors. With regard to the first and the second themes, a few studies have directly applied social network analysis (SNA) to analyze university-industry linkages.

Those research studies are based on the SNA of patent data. Analyzing co-authored patent data, Lissoni (2010) found that inventors' relationships to co-inventors from universities are stronger than those of co-inventors from industry. Balconi and Laboranti (2006) have investigated the links between academics and their industrial partners based on EPO and USPTO patent data in the field of microelectronics. They have found that strong university-industry links are positively related to the quality of scientific performance based on descriptive statistics. Based on patent data, Balconi et al. (2004) maintain that academic inventors are more centrally and strongly connected to the network of Italian inventors.

2. Channels of University-Industry Collaboration

Universities and firms are collaborating through various knowledge channels. The knowledge channels can be defined as: the way of exchanging knowledge between different actors. These are categorized in several ways: collaborative research and knowledge-transfer mechanisms (Brodosky, 1980; Blume, 1987); collaborative and entrepreneurial modes (Stankiewicz, 1986); and formal and informal channels (OECD, 1999). These categorizations are based on the channels' characteristics such as the codification of knowledge, commercialization and so on. OECD (2002) categorizes joint laboratories, spin-offs, licensing, and research contracts as formal channels, and the mobility of researchers, co-publication, conference, informal contacts, and flow of graduates to industry as informal channels.

The OECD report also maintains that "the formal mechanism of the industry-science relationship is the tip of the iceberg," saying that more than half of U.K. firms regard universities as an important innovation source, but only 10 % of the firms have formal channels. That is to say, the interactions between academics and firms heavily depend on informal channels. In a similar vein, some argue that in terms of knowledge transfer, the informal links are more important for a firm's innovation than the formal links, such as papers and patents (Cohen et al., 2002; Levin et al., 1987). Furthermore, Geuna and Mowery (2007) assert that the study of the informal channels is very important because of its scarcity; moreover, interactions between the two channels are promising research topics in this area.

However, it is difficult to extract data on the informal channels due to its tacitness. Therefore, the research on industrial collaboration tends to focus on formal channels such as patents, papers, and contracted research, rather than on informal channels such as exchange of personnel, non-contracted consultancy, and unofficial contact. In addition, in catch-up countries, not only research on formal collaboration channels but research on informal collaboration channels is not so abundant compared to developed countries (De Campos, 2009).

3. Geographical Proximity of University-Industry Collaboration

Several studies on the geographical location of universities make us understand that the geographical proximity of a university to industry is a significant factor for the universities' entrepreneurial activities. An empirical study by Friedman and Silberman (2003) shows that in the U.S., universities located in a region with a concentration of high-tech industries are more likely to be involved in knowledge-transfer activities. Mansfield and Lee (1996) show that the companies closer to universities are more likely to provide R&D funding to the universities in the U.S. Based on a significant positive correlation between the R&D expenditures of the U.S. universities and the patenting activity of local firms at the state level, Jaffe (1989) focuses on the localized knowledge-spillover activities of universities. In the case of Germany, Audretsch et al. (2004) confirms that geographical proximity is an important factor for human resource flow between universities and industry. One step further, Hewitt-Dundas (2011) found that firms' characteristics, such as the size, sales profile, location, absorptive capacity, and innovation activity, are related to their propensity to create links to local universities rather than non-local universities.

Regarding the relationship between geographical proximity and the formality of channels, informal channels are more important for the exploitation of the knowledge-localization effect, because geographical closeness tends to increase face-to-face contacts and the exchange of tacit knowledge among innovative actors in the same region. In other words, the spill-over effect of non-market knowledge is likely to be localized (Jaffe et al., 1993). According to Breschi and Lissoni (2009), regarding the reason for the localization effect of informal knowledge exchange, the co-inventor network is localized because the mobility of the inventors is confined to the region. However, most research is based on formal and codified data such as patents and papers. Moreover, it is hard to find studies investigating the relationship between geography and knowledge-transfer activities in the existing literature.

Accordingly, in order to fill the gap in the existing research suggested above, this study adopts the mixed approach of social network analysis and regression analysis. In particular, this study focuses on the link (i.e. university-industry linkage) as well as the characteristics of the nodes (i.e. gender, age, and geographical location) of the two actors. In other words, in the university-industry network, the two actors are regarded as nodes, and the linkages are demonstrated as links. Accordingly, based on this approach, we can explore the structure of university-industry linkages in Korea.

Hence, the three main research questions can be suggested as:

- How are academics and firms interconnected in terms of knowledge channels across geographical boundaries?
- Are there any differences between the formal and informal networks of academics and firms?
- Is geographical proximity related to academics' formal and informal knowledge-transfer activities?

III. Data and Methodology

The web-based survey questionnaire was distributed to 18,523 professors in 56 Korean universities in science and engineering from the 28th of May until the 11th of June in 2007. The process took two weeks to complete; moreover, in order to increase the response rate, e-mails encouraging replies were sent to the professors who had not replied to the survey after one week. Overall, 2,395 professors participated in this survey, which means that the response rate was 12.93 %. In order to check the response bias, an independent two sample T-test was carried out according to various characteristics of the academics, such as career, gender, discipline, the country of training, and location.

The questions in the first section of the survey questionnaire gathered demographic details of the participants (e.g., age, gender, affiliated university, region, discipline, when the doctoral degree was conferred, where the doctoral degree was conferred, and when he or she was appointed as faculty). The second part asked where the participant's industrial collaborators were located in terms of the 16 provinces of Korea and overseas partners. The collaborations mentioned were limited to the most recent activities (i.e. within the last three years).

This study explores the university-industry network structure in terms of the characteristics of the channels of knowledge transfer (e.g. the degree of formality) as well as the characteristics of the actors (e.g. geographical proximity or closeness to Seoul). To do this, we applied a mixed methods approach combining a social network analysis and an econometric approach.

On the one hand, in order to apply social network analysis to our data, an asymmetrical matrix was created based on the "who collaborates with whom" question in the second section of the survey. The process of generating a U-I collaboration matrix is as follows. First, in an Sij matrix, where i and j are nodes (in this case, provinces), the value between i and j represents their cooperation relations. The value in each cell lists how many faculty members in each province collaborated with private companies in their own province and in other regions. Second, since the number of faculty respondents per province varied, the original values were normalized based on the proportions that were divided by the total number of participants. Lastly, several network metrics were calculated after binarization. A threshold level is the network density. Density is calculated as the sum of the values of the observed collaboration activities between provinces, divided by the number of cells in the matrix.

On the other hand, in order to carry out a regression analysis on the relationship between geographical proximity and knowledge-transfer activities, dependent and independent variables are operationalized. The dependent variables are academics' performances, such as papers published and patents applied for, resulting from the collaboration with firms during the last three years. The independent variable is whether an individual academic collaborates with firms located in the same region or with firms in the capital area. Based on the personal profiles provided by KRF (the Korea Research Foundation) and on replies to the survey, variables such as career stage, discipline, gender, and the country of training are included in the models as variables representing individual characteristics.

Firstly, the age and the square value of it are included in the model, as it is well known that the relationship between age and academics' productivity is an inverse-U shape. Secondly, the disciplines of the academics are divided into six categories: natural science (e.g. physics, mathematics, statistics, etc.), chemistry, bio-technology, engineering, medical science, and agricultural science. Thirdly, the gender of the academics based on the KRF data is encoded as a binary variable, as gender differences can be related to social factors such as the degree of networking with industry (Murray & Graham, 2007). Fourthly, the country of training may influence the academic activity. In particular, those academics who studied overseas might be regarded as productive professors in terms of research as well as industrial collaboration. Furthermore, the academics who trained in the U.S. (a country that already introduced academic entrepreneurship during the 1980s) are more likely to have been exposed to a strong culture of university-industry linkages than domestically trained academics.

The data collected from the personal profiles and from the replies to the questionnaire provide us with contextual variables, such as the size of the laboratory, the characteristics of the universities affiliated with, and the intensity of business R&D in the region. These variables are employed as predictors rather than as control variables.

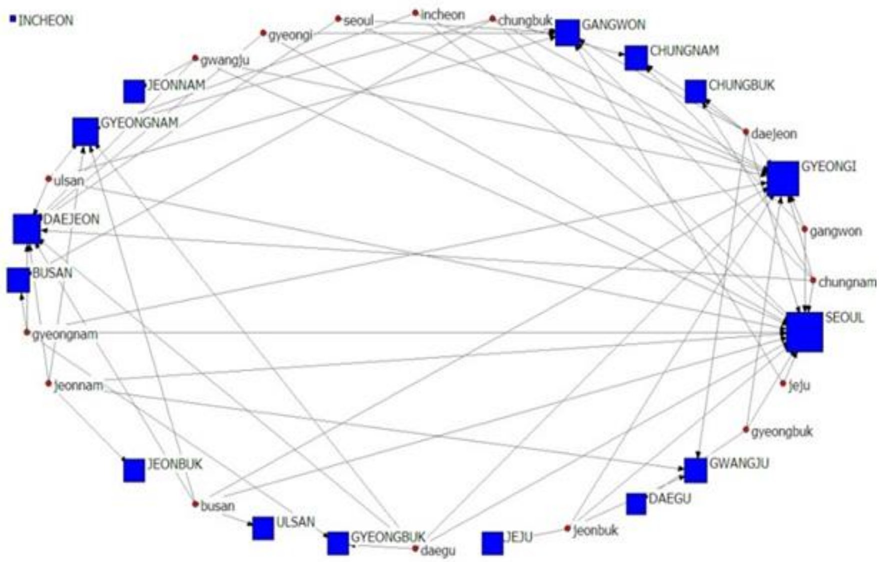
Firstly, the size of the laboratory is measured by the sum of the number of postgraduate students and postdoctoral students in the laboratory operated by the academics. Secondly, institutional characteristics (e.g. founding year, legal status, location, and size) of the universities can influence the knowledge-transfer activities of the academics. Thirdly, the business R&D intensity of the region is measured by the amount of the expenditure on business R&D, based on data from the MOST (Ministry of Science and Technology) survey (MOST, 2007). The regions are classified into 16 categories consisting of the capital, six metropolitan cities, and eight provinces in the network analysis, while these categories are redefined in the regression analysis according to the clustered shape of the network.

Additionally, the formality of the channels is adopted as a dependent variable in another regression model. In our survey questionnaire, informal channels are non-contracted consultancy, attendance at industrial conferences, sharing research facilities, and dispatch of students, while formal channels are contracted consultancy, contracted teaching, creation of patents and papers after collaboration, contracted research, participation in companies, and starting a company. Based on this categorization, academics that are inclined to choose formal channels or informal channels are identified. According to the descriptive statistics, 164 and 681 academics were identified as choosing informal and formal channels, respectively. The other 1550 academics are located in a grey area. As the dependent variables are categorical and discrete, multiple logistic regression analysis testing the relationship between formality and geographical proximity is adopted here.

IV. Results and Discussion

This section presents a descriptive explanation of the university-industry network, as well as statistical tests of the relationship between geographical proximity and the formality of knowledge-transfer channels between academics and firms.

1. Networks of University-Industry Collaboration

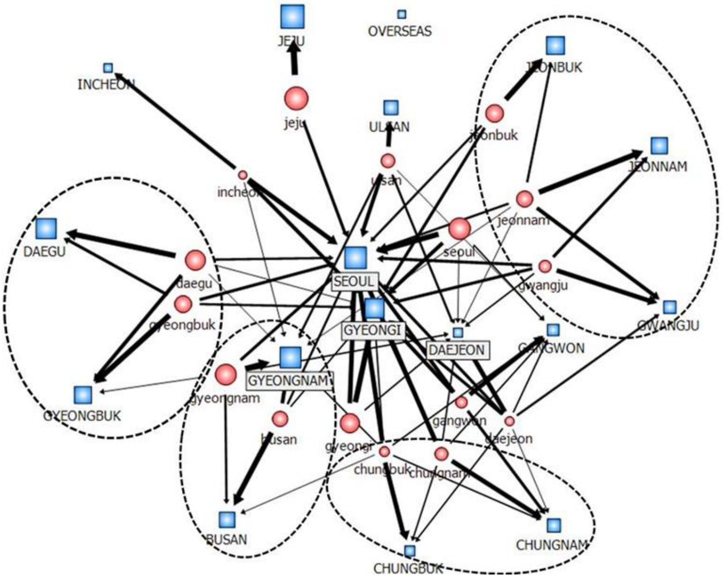


Note: Nodes expressed as circles are academics, while those expressed as squares are firms.
The size of the squares is proportional to the nodes' closeness centrality.

Figure 1 Inter-regional collaboration network using a Circle Lay-out Algorithm

In Figure 1, the squares are drawn bigger based on their closeness centrality. We measured the networked location of the node's relationships with other nodes within an inter-regional collaboration network, or the node's closeness centrality (Wasserman & Faust, 1994; Freeman, 1979). The simplest definition of a node's closeness centrality is that central nodes, in this case, private firms in regions, must be the nearest in the sense that they have the shortest path to other nodes in the network (Wasserman & Faust, 1994, 178). Therefore, Figure 1 reveals which regional firms are central and peripheral in terms of U-I collaboration. For example, popular industrial partners are concentrated in Seoul, Gyeonggi, and Daejeon. Interestingly enough, the companies in Incheon were found to be isolated from a simplified U-I network. This is probably due to the dominance of Seoul. Note that the closeness centrality value of SEOUL is 1, with GYEONGI (0.852) and DAEJEON (0.719) following. Closeness centrality values fall between 0 and 1. Larger values indicate the least distance.

Figure 2, using a spring lay-out algorithm, shows the structure of the network more specifically. According to Figure 2, the capital area around Seoul and Gyeonggi stands at the center of the network, and other non-capital regions are interconnected to one another. Actors located in Seoul and Gyeonggi, particularly the firms, are connected to all of the rest of the regions. In other words, firms in the two regions are strongly connected to academics in most of the regions. We also found that several geographically adjacent clusters (see the four dotted circles in the figure) are linked to the hub (i.e. firms in Seoul and Gyeonggi) of the network. For example, academics and firms in Daegu-Gyeongbuk and Gwangju-Jeonnam (i.e. the two regions in the southeast and southwest parts of Korea, respectively) are closely connected to each other (see Appendix Figure for the geographical location of the 17 regions in Korea).



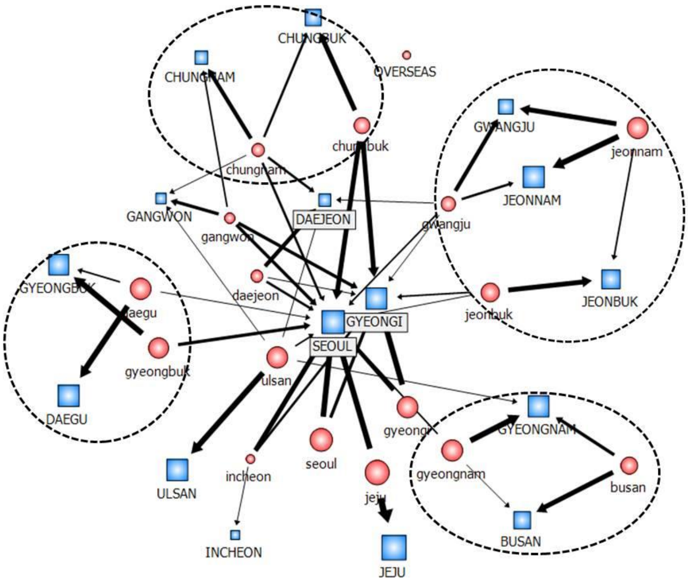
Note: Nodes expressed as circle are academics, while those expressed as squares are firms. The size of the nodes is proportional to the collaboration within each region, and the widths of the links are the relative intensity of the collaboration between the academics and firms. This is the same in Figures 3 and 4.

Figure 2 Inter-regional collaboration network using a Spring Lay-out Algorithm

Concerning the patterns of academics and firms within the network, distinctive patterns between the capital area and non-capital area have been identified. Firstly, firms located in Seoul and Gyeonggi tend to be linked with all the other regions of Korea, regardless of their geographical proximity. Yet, academics in the capital region collaborated mostly within the same region while hardly conducting any collaboration with the firms in the non-capital area. Secondly, the tendency of firms and academics is shown in the opposite direction. Different from the firms in the capital area, the scope of collaborating firms in the non-capital area is quite limited to the neighboring regions. For instance, the firms in Jeonbuk primarily collaborated only with academics in Jeonbuk and Jeonnam. Even though the firms' extent of collaboration was locally confined, academics were so actively involved in the collaboration with firms that their range of collaboration is widely extended over the whole country.

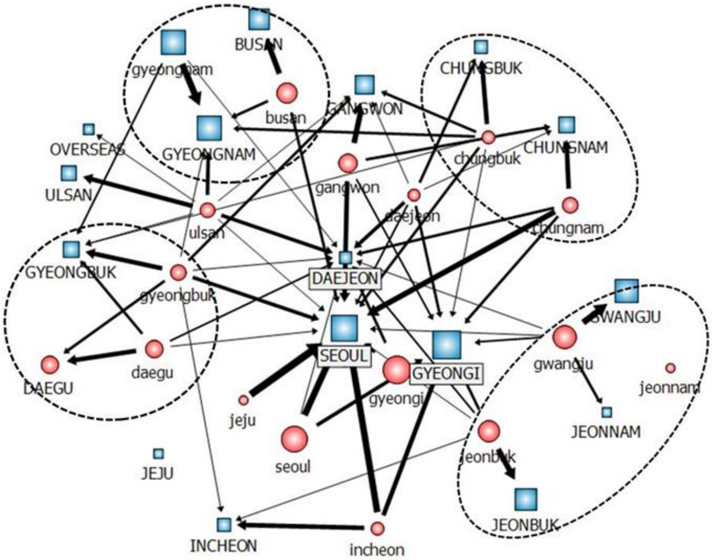
Nevertheless, there are two outliers in this network, Incheon and Daejeon. Incheon geographically belongs to the capital region, but the network pattern of firms is similar to that of the non-capital area. In other words, the collaborating pattern of the firms in Incheon is confined to the adjacent areas (i.e. Seoul and Gyeonggi). At the same time, Incheon's academics tend to collaborate mostly with firms in Seoul, Gyeonggi, and Incheon, which shows a similar pattern among academics in the capital area. This may be due to the fact that it is highly dependent on the Seoul and Gyeonggi provinces in terms of R&D resources. In addition, Daejeon is the outlier taking a transitional position in the network. In spite of its location in the non-capital region, the overall range of firms collaborating with academics is much wider than that of the other non-capital areas. Despite this characteristic of collaborating firms in the capital area, the academics are diversely connected with other regions, which is the general characteristic of non-capital area's academics.

We have mapped the formal and informal networks of university-industry collaboration separately, as shown in Figures 3 and 4. However, we do not find a remarkable difference between the structures of the two networks. In other words, the formality of the university-industry linkage might not be related to the geographical proximity. In order to investigate this thoroughly, we adopted a statistical method based on regression analysis testing the relationship between geographical proximity and the formality of the channels in the next subsection.



Note: Size of the nodes is proportional to the collaboration within each region.

Figure 3 Inter-regional formal collaboration network using a Spring Lay-out Algorithm



Note: Size of the nodes is proportional to the collaboration within each region.

Figure 4 Inter-regional informal collaboration network using a Spring Lay-out Algorithm

2. The Relations of Geographical Proximity to Knowledge-Transfer Activities and Formality of Knowledge-Transfer Channels

As introduced in Section 3, an economic model using a patent production function as a dependent variable is adopted here. The dependent variables, such as numbers of patents and technology transfers in this study, are count variables (i.e. zero or positive integers). Therefore, a Poisson distribution and negative binomial distribution can be regarded as alternatives for the regression analysis here. According to the descriptive statistics in Table 1, over-dispersion (i.e. the variance is much larger than the mean) is clearly identifiable. This also proved to be statistically significant from the magnitude of the alpha value. [1]Consequently, a negative binomial (NB) model is more appropriate than the Poisson model in this analysis. Furthermore, in both models adopting patents and papers as dependent variables, the Vuong test result indicates that a standard negative binomial (NB) model has a better fit than a zero-inflated negative binomial (ZINB) model. In order to prevent excessive multi-collinearity between the explanatory variables, the variables with a high VIF are excluded. [2]Moreover, highly and significantly related groups of variables are employed in separate regression models. Furthermore, considering the possibility of a heteroscedasticity problem, robust standard errors are calculated.

The descriptive statistics shown in Table 1 provide us with the individual and environmental properties of the Korean academics surveyed. Regarding individual characteristics, the average age and career length of Korean academics are 46.6 and 11.3 years, respectively. About 89 % of these academics are male scientists. Most of them are in the field of engineering (i.e. 42 %) and are trained domestically in terms of their final degree (i.e. PhD). Next, regarding environmental properties, the average size of their laboratory as measured by the number of postgraduates and postdocs is 4.9. As an important knowledge-transfer environment, the characteristics of the universities they are affiliated with are also identified. The average size of the university as measured by the number of academic staff in science and engineering is 469, and 47 % of the universities are public. Most of the universities are located in the capital area, as the average distance to Seoul is 1.74. In particular, 29 % of the academics are in Seoul. The average founding

[1] All the alpha values in the NB and ZINB models introduced here are significantly different from zero at the level of 95 % confidence.

[2] In each model, we exclude several independent variables with a VIF (Variance Inflation Factor) value larger than 10, because those variables are possibly linearly related to other independent variables.

year of the universities is 1941. Most of the universities consist of about six colleges.

Table1 Descriptive satistics

Variable	Observations	Mean	S.D.	Minimum	Maximum
Gender	2392	0.89	0.318	0	1
Age	2395	46.55	7.415	30	77
Career	2392	11.30	8.449	0	40
Discipline	2395				
- Nat. Sci.	279	0.11		0	1
- Chem.	142	0.06		0	1
- Bio.	219	0.09		0	1
- Eng.	1015	0.42		0	1
- Med.	581	0.24		0	1
- Agr.	159	0.06		0	1
Cnt. Trained	2395				
- Korea	1335	0.55		0	1
- US	723	0.30		0	1
- Japan	211	0.09		0	1
- EU	95	0.04		0	1
- others	31	0.01		0	1
Papers*	2355	8.75	9.769	0	100
Patents	2383	1.50	3.442	0	52
Lab. size**	2383	4.90	4.383	0	33
Uni. Cha.					
- Size	2395	469.30	239.87	49	987
- Legal status	2395	0.47	0.50	0	1
- Location	2395	1.74	1.62	0	4
- Found. year	2395	1940.83	29.91	1855	1998
- Generality	2395	5.47	1.06	1	6
Reg. BERD**	2394	2171963.6	2753790.71	19799	1028630
Ext. Collabo.	1790	0.48	0.499	0	1
Cap. Collabo.	1790	0.56	0.497	0	1

*Number of observations are the number of scholars who published at least one paper
**Number of researchers (sum of research students and postdoctoral researchers)
***Unit: million dollars

Moreover, with respect to the two main knowledge-transfer activities, the descriptive statistics show the academics' publishing and patenting activities resulting from the collaboration with industry during the last three years. In terms of papers, the Korean academics produce 9.8 papers and 1.5 patents on average. For knowledge-transfer activities, 48 % of the academics collaborate with firms within the region, and 56 % of them interact with firms in the capital area.

As shown in Table 2 below, we can identify whether the relationship between the geographical proximity and the academics' knowledge-transfer performances is significant or not. In models 1 and 2, external collaboration (i.e. geographically outward) is positively and significantly related to knowledge-transfer activities (i.e. publication of papers). However, in models 3 and 4, we have no evidence on the significant relationship between geographical properties and knowledge-transfer activities as measured by patent applications. Moreover, another geographical variable (i.e. capital orientation) has no significant relationship with formal knowledge-transfer performances in all four models. These empirical results are somewhat different from those found in developed countries' cases, such as in Audretsch et al. (2004), Friedman and Silberman (2003), and Jaffe (1989). This may mean not only that academics' preferences for publication overcome the geographical barriers but also that geographical proximity is negatively related to publication activities. Otherwise, the geographical scale of Korea is not wide enough to create the localization effect of the academics' knowledge-transfer activities in the regions.

Other individual and contextual properties also reveal interesting facts on their relationships to the knowledge-transfer activities. In terms of the individual characteristics, gender is consistently and significantly related to knowledge-transfer activities across the four models. Male academics show better performance in terms of knowledge-transfer activities. This result is in the same vein with many other previous studies on factors influencing the productivity of Korean academics, such as in Kwon and Han (2010) and Oh et al. (2009). The inverse-U shaped relationship between age and paper publications also confirmed the econometric results of the previous research (i.e. Kyvik and Olsen, 2008; Rauber and Ursprung, 2007; Goodwin and Sauer, 2001; Jang, 2010). We have found that the disciplines and the country trained in are strong predictors for knowledge-transfer activities. Next, in terms of environmental factors, the laboratory size, as measured by the number of researchers in the laboratory operated by the academics, is a very strong predicator for knowledge-transfer activities. Also, the influence of several characteristics of the universities they are affiliated with, such as size, legal status, location, founding year, and generality, are investigated. Among these characteristics, legal status (i.e. public or private) is significantly related to patent applications, while location (i.e. distance to Seoul) and founding year are significantly related to paper publications. In other words, the academics in private universities applied for more patents, while the academics closer to Seoul and affiliated with older universities published more papers through collaborations with firms.

Table 2 Estimation of the formal knowledge-transfer activities

Models Variables	Model 1 (papers)	Model 2 (papers)	Model 3 (patents)	Model 4 (patents)
Gender	.235 (.135)+	.259 (.132)*	.415 (.187)*	.485 (.177)**
Age	.081 (.059)	.073 (.057)	.159 (.065)*	.161 (.065)*
Age^2	-.0007 (.0006)	-.0006 (.0006)	-.002 (.0007)*	-.002 (.0007)*
Discipline				
- Chemistry	.212 (.170)	.192 (.165)	.317 (.213)	.268 (.208)
- Biology	-.229 (.161)	-.201 (.161)	.200 (.219)	.213 (.226)
- Engineering	.571 (.124)***	.584 (.121)***	.289 (.177)+	.288 (.178)+
- Medical	.192 (.143)	.202 (.142)	-.014 (.193)	-.019 (.197)
- Agricultural	.499 (.166)**	.513 (.167)**	.271 (.230)	.305 (.228)
Country trained				
- US	-.246 (.077)***	-.230 (.078)**	-.086 (.090)	-.133 (.093)
- Japan	.057 (.124)	.015 (.114)*	-.013 (.112)	-.011 (.109)
- EU	-.170 (.138)	-.155 (.134)	.108 (.219)	.074 (.010)
- Other	-.003 (.283)	-.011 (.257)	-.098 (.232)	-.138 (.235)
Ext. Collabo.	.129 (066)*	.150 (.066)*	.048(.079)	.100 (.087)
Cap. Collabo.	.053 (067)	.058 (.078)	-.030(.080)	-.117 (.101)
Laboratory size	.064 (.007)***	.067 (.007)***	.071 (.010)***	.073 (.010)***
Uni. Character.				
- Size		-.0002 (.0002)		-.0001 (.0002)
- Legal status		-.018 (.075)		-.232 (.098)**
- Location		.085 (.031)**		.004 (.037)
- Found. year		-.003 (.001)*		-.001 (.002)
- Generality		.038 (.036)		-.005 (.044)
Regional BERD		.00003 (.00001)+		.00001 (.00002)
Constant	-1.964 (1.387)	4.272 (2.973)	-4.439 (1.560)	-2.263 (.3.877)
Log p-likelihood	-3829.1337	-3818.3905	-2534.0729	-2526.5734
Wald chi² (d.f.)	212.16 (15)***	227.64 (21)***	101.85 (15)***	103.05 (21)***
No. of obs.	1624	1623	1571	1570

[1]regression coefficients are calculated based on robust standard errors

*p<0.05, **p<0.01, ***p<0.001, +p<0.1

As introduced in Section 3, we can investigate the relationship between the formality of the channels and geographical proximity. Different from the results shown in Table 2, we have not found any significant relationship between the formality and geographical proximity (i.e. two variables measuring collaborations with external and capital firms in the table below).

This result is different from the empirical evidence found in western countries (e.g. Audretsch et al., 2004). The other individual and environmental factors (except disciplines) are not significantly related to the formality of the channels. This probably results from the fact that the dependent variable in this model (i.e. intensity of formal channels) is different, in a strict sense, from the dependent variable (i.e. choice of channels) in the previous model. Nevertheless, the disciplines of academics are significantly related to their choice of the channels' formality.

Table 3 Estimation of the formality of knowledge-transfer channels

Models Variables	Model 1 (formal)	Model 2 (formal)	Model 3 (informal)	Model 4 (informal)
Gender	.153 (.209)	.135 (.209)	.301 (.284)	.326 (.283)
Age	.109 (.091)	.073 (.092)	-.055 (.099)	-.063 (.100)
Age^2	-.0011 (.0009)	-.0011 (.0010)	-.0005 (.0010)	-.0006 (.0010)
Discipline				
- Chemistry	-.023 (.345)	-.039 (.346)	1.219 (.437)**	1.209 (.437)**
- Biology	-.052 (.317)	-.027 (.318)	1.059 (.422)*	1.046 (.422)*
- Engineering	.801 (.224)***	.790 (.224)***	1.164 (.361)**	1.187 (.363)**
- Medical	.243 (.253)	.259 (.255)	.805 (.392)*	.795 (.394)*
- Agricultural	.234 (.314)	.244 (.313)	1.459 (.230)***	1.471 (.420)***
Country trained				
- US	-.059 (.136)	.064 (.137)	-.075 (.172)	-.070 (.179)
- Japan	-.069 (.194)	.015 (.114)	.009 (.244)	.003 (.244)
- EU	.190 (.281)	.197 (.283)	-.024 (.378)	-.019 (.379)
- Other	.165 (.522)	.176 (.525)	-.093 (.574)	-.119 (.575)
Ext. Collabo.	.035 (118)	-.007 (.123)	-.099(.147)	-.066(.153)
Cap. Collabo.	-.134 (130)	-.214 (.142)	-.085(.150)	-.063(.175)
Laboratory size	.018 (.012)	.017 (.013)	-.013 (.018)	-.009 (.018)
Uni. Character.				
- Size		.0003 (.0003)		-.0002 (.0004)
- Legal status		-.064 (.137)		-.149 (.192)
- Location		.103 (.055)		.005 (.067)
- Found. year		-.001 (.002)		-.0003 (.003)
- Generality		.038 (.036)		.106 (.098)
Regional BERD		.00003 (.00003)		.00001 (.00003)
Constant	-4.25 (2.18)	-2.064 (5.422)	-1.203 (2.346)	-2.09 (6.739)
Log p-likelihood	-1617.4977	-1612.2283	-1617.4977	-1612.2283
Wald chi² (d.f.)	67.68 (30)***	78.27 (42)***	67.68 (30)***	78.27 (42)***
No. of obs.	1782	1781	1782	1781

[1]regression coefficients are calculated based on robust standard errors

*p<0.05, **p<0.01, ***p<0.001, +p<0.1

In contrast to previous studies, the intensity of the formal channels as measured by the number of papers is negatively and significantly related to geographical proximity. However, we do not find any significant relationship between the formality of channels and geographical proximity. Possibly, a highly-qualified collaboration tends to overcome geographical barriers, as academics are more interested in publishing papers than in patents. Otherwise, regional innovation systems in Korea are neither big enough nor strong enough to show a localization effect. In this vein, the government policy for strengthening regional innovation system is needed to include an innovative measure such as empowerment of R&D planning and implementation. Furthermore, universities' evaluation system is required to consider disciplinary differences with regard to academics' performances.

V. Conclusion

In this paper, we have explored the university-industry network, geographical proximity, and formal and informal academics' knowledge-transfer activities. First of all, with a survey and social network analysis as a basis, we have explored the structural characteristics of the networks between academics and firms in the 16 regions of Korea. According to the results, Seoul and Gyunggi are identified as central nodes. That is, the academics in other regions tend to collaborate with firms in these regions. The rich resource conditions in terms of R&D expenditure can be one explanation (Shapiro et al., 2010). However, other regions such as Jeju, Jeonbuk, and Daegu, with a relatively small amount of R&D expenditure, have shown strong intra-collaboration. In addition to the central hub of the network, we have also identified several peripheral clusters grounded upon geographical proximity.

Next, we have tried to find the relationship between geographical proximity and formal and informal channels between academics and firms. In terms of the localization of knowledge-transfer activities, we have not found any evidence to support it. In contrast to our expectation, only formal knowledge-transfer activities (i.e. paper publications resulting from university-industry collaboration) are significantly related to inter-regional collaboration rather than intra-collaboration. These results may be due to a weak knowledge exchange between academia and industry within the region. In other words, knowledge-transfer activities are occurring across the country rather than locally. Therefore, at the current stage, the policy scope of university-industry collaboration in Korea requires optimization, not at the regional level, but at the national level. However, in the future, by strengthening local knowledge-transfer, regional innovation systems can be vitalized.

In terms of limitations of this study, first of all, we measure the knowledge-transfer activities as the number of papers published and patents applied for, which are the intensity of formal channels rather than intensity of informal channels, such as frequency of informal consulting. Instead, in our research, we have measured the informal channel as the academics' choice of formality. Secondly, the endogeneity problem limits our interpretation of the statistical findings in terms of the direction of causality of the two variables (i.e.

knowledge-transfer activities and inter- or intra-regional collaboration). Therefore, we interpret the regression results as relationships rather than causality. Thirdly, our cross-sectional data also limits our interpretation of the causality relationship between various factors and knowledge-transfer activities. Finally, in terms of generalizability to other catch-up and post catch-up countries, we need a meticulous theoretical framework as well as richer empirical evidence on the university-industry linkage in a country-specific innovation system.

References

Agrawal, A. (2001) University-to-industry knowledge transfer: literature review and unanswered questions, International Journal of Management Reviews, 3(4), 285-302.

Audretsch, D., Lehmann, E. and Warning, S. (2004) University spillovers: does the kind of science matter? Industry and Innovation, 11, 193-205.

Balconi, M., Breschi, S., and Lissoni, F. (2004) Networks of inventors and the role of academia: an exploration of Italian patent data, Research Policy, 33(1), 127-145.

Balconi, M. and Laboranti, A. (2006) University-industry interactions in applied research: the case of microelectronics, Research Policy, 35(10), 1616-1630.

Blume, S. (1987) The Theoretical Significance of Co-operative Research, in Blume, S. et al. (eds.) The Social Direction of the Public Sciences, Sociology of the Sciences Yearbook, Vol XI.

Borgatti, S.P., Everett, M.G. and Freeman, L.C. (2002) Ucinet for Windows: Software for Social Network Analysis, Harvard: Analytic Technologies.

Breschi, S. and Lissoni, F. (2009) Mobility of skilled workers and co-invention networks: an anatomy of localised knowledge flows, Journal of Economic Geography, 9, 439-468.

Brodsky, N., Kaufman, H., and Tooker, J. (1980) University/industry cooperation: a preliminary analysis of existing mechanisms and their relationship to the innovation processes, New York, Center for Science and Technology Policy, Graduate School of Public Administration, New York University.

Cohen,W.M., Nelson, R.R. and Walsh, J.P. (2002) Links and impacts: the influence of public research on industrial R& D, Management Science, 48, 1-23.

Dagnino, R. and Velho, L. (1998) University-industry-government relations on the periphery: the university of Campinas, Brazil, Minerva, 36, 229-251.

De Campos, A. (2009) A review of the literature on university-industry links: towards an integrated approach in the study of influencing factors, Third Conference on Micro Evidence on Innovation in Developing Economies, Institute for Applied Economic Research, United Nations University and University of Maastricht (UNU-MERIT), Brasilia, Brazil, May 10-12, 2009.

Eom, B. and Lee, K. (2010) Determinants of industry-academy linkages and, their impact on firm performance: the case of Korea as a latecomer in knowledge industrialization, Research Policy, 39, 625-639.
Etzkowitz, H., Webster, A., Gebhardt, C. and Terra, B.R.C. (2000) The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm, Research Policy, 29, 313-330.
Friedman, J. and Silberman, J. (2003) University technology transfer: do incentives, management, and location matter? Journal of Technology Transfer, 28, 17-30.
Freeman, L.C. (1979) Centrality in social networks: conceptual clarification, Soc. Networks, 215-39.
Geuna, A. and Mowery, D. (2007) Publishing and patenting in U.S. and European universities, Economics of Innovation and New Technology, 16 (2), 67-70.
Goodwin, T.H. and Sauer, R.D. (2001) Life cycle productivity in academic research: evidence from cumulative publication histories of academic economists, Southern Economic Journal, 61(3), 728-743.
Horta, H. (2008) On improving the university research base: the technical university of Lisbon case in perspective, Higher Education Policy, 21, 123-146.
Horta, H. (2010) The role of the State in the internationalization of universities in catching-up countries: an analysis of the Portuguese higher education system, Higher Education Policy, 23, 63-81.
Kamada, T. and Kawai, S. (1989) An algorithm for drawing general undirected graphs, Information Processing Letters, 31(1), 7-15.
Jaffe, A. (1989) Real effects of academic research, American Economic Review, 79, 957-970.
Jaffe, A., Trajtenberg, M. and Henderson, R. (1993) Geographic localization of knowledge spillovers as evidenced by patent citations, Quarterly Journal of Economics, 108, 577-598.
Jang, D. (2011) An analysis of age difference between 'research achievement outcome peak' and 'research fund support peak', International Journal of Policy Evaluation & Management, 21(2), 47-65. (in Korean)
Levin, R.C., Klevorick, A., Nelson, R.R. and Winter, S. (1987) Appropriating the returns from industrial research and development, Brookings Papers on Economic Activity, 3, 783-820.
Lissoni, F. (2010) Academic inventors as brokers, Research Policy, 39, 843-857.
Mansfield, E. and Lee, J.Y. (1996) The modern university: contributor to industrial innovation and recipient of industrial R&D support, Research Policy, 25, 1047-1058.
Murray, F. and Graham, L. (2007) Buying science and selling science: gender differences in the market for commercial science, Industrial and Corporate Change, 16(4), 657-689.
Kastelle, T. and Steen, J. (2010) Using network analysis to understand, Innovation: Management, Policy & Practice, 12(1), 2-4.
Kwon, K.S and Ben, R.M. (2012) Synergy or separation mode: the relationship between academic research and knowledge transfer activities of Korean academics, Scientometrics, 90, 177-200.
Kwon, K.S. and Song, J. (2009) A study on the factors influencing university-industry channel, STEPI (Science and Technology Policy Institute). (in Korean)

Kwon, K.S. and Han, S. (2010) Who is patenting in a catch-up country's universities? the case of South Korea, The 7th Asialics Conference, Taiwan, 15-17 April, 2010.

Kyvik, S. and Olsen, T.B. (2008) Does the aging of tenured academic staff affect the research performance of universities, Scientometrics, 76(3), 439-455.

Oh, Y.J., Kwon, K.S. and Lee, K. (2009) Research performance of university professors in Korea: a weak point of the national innovation system in Korea? Conference on the University-Industry Linkages and Economic Performance, Seoul National University, Seoul, Korea, 27th Feb.

OECD (1999a) Trends in University-Industry Research Partnerships, STI Review No 23.

OECD (1999b) Special Issue on Public/Private Partnerships in Science and Technology, STI Review No. 23.

OECD (2002) Benchmarking Industry-Science Relationships, OECD.

Rauber, M. and Ursprung, H.W. (2007) Life cycle and cohort productivity in economic research: the case of Germany, CESifo Working Paper No.2093.

Rothaermel, F.T., Agung, S.D. and Jiang, L. (2007) University entrepreneurship: a taxonomy of the literature, Industrial and Corporate Change, 16(4), 691-791.

Seung, J. and Kim, W. (2010) Post catch-up innovation and development of creative talent in Korea: limitations and challenges, STI Policy Review, 1(3), 39-51.

Shapiro, M., So, M.H. and Park, H.W. (2010) Quantifying the national innovation system: inter-regional collaboration networks in South Korea, Technology Analysis & Strategic Management, A special issue on Triple Helix.

Song, W. and Hwang, H.R. (2006) The technological innovation patterns of component suppliers in the post catching-up period: the case study of component suppliers in mobile phone industry, Journal of Korea Technology Innovation Society, 9(3), 435-450. (in Korean)

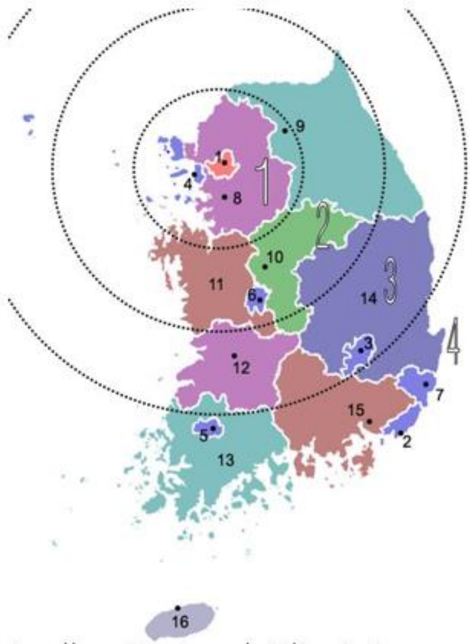
Stankiewicz, R. (1986) Academics and Entrepreneurs, London: Francis Pinter Publishers.

Sutz, J. (2000) The university-industry-government relations in Latin America, Research Policy, 29, 279-290.

Van Der Valk, T. and Gijsbers, G. (2010) The use of social network analysis in innovation studies: mapping actors and technologies, Innovation: Management, Policy and Practice, 12(1), 5-17.

Wasserman, S. and Faust, K. (1994) Social Network Analysis: Methods and applications, New York: Cambridge University Press.

Appendix



1 Soeul (National Capital)
2 Busan
3 Daegu
4 Incheon
5 Gwangju
6 Daejeon
7 Ulsan
8 Gyeonggi-do
9 Gangwon-do
10 Chungcheongbuk-do
11 Chungcheongnam-do
12 Jeollabuk-do
13 Jeollanam-do
14 Gyeongsangbuk-do
15 Gyeongsangnam-do
16 Jeju-do

http://en.wikipedia.org/wiki/South_Korea

Figure1 16 regions in South Korea