Quantifying the National Innovation System: Inter-regional Collaboration Networks in South Korea

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Abstract

This article identifies the underlying patterns of collaboration and scientific co-authorship among geographically dispersed Korean researchers, using the most reliable longitudinal citation data available. The network indicators of centrality, network density, and network fragmentation are used to present the evolving network of co-authorship relations among sixteen Korean provinces and metropolitan areas. Our results confirm that the density of scientific communication flows has deepened in terms of the inter-connectedness of networks, while the centrality of Seoul as the primary research hub has declined. Fragmentation analysis does reveal, however, that Seoul is still the research broker for the country. To create still more change in Korea's research topography, there must be a renewed focus on regional innovation centers and linkages between heterogeneous research entities.

Keywords: R&D collaboration, network analysis, Korean NIS, centrality, density, fragmentation

I. INTRODUCTION

For the past three decades, the national innovation system (NIS) of South Korea (hereafter Korea) has undergone a transition not far removed from its pattern of remarkable economic growth. Sector-specific growth across the country, however, has left imbalances with regard to Korea's geographical distribution of research and development (R&D) activities. It is well documented that geographic proximity and collaboration among researchers yields benefits on a number of levels (Saxenian, 1994; Saxenian & Hsu, 2001), that the number of knowledge generating institutes has beneficial effects for technological performance (Van Looy, et al. 2006), and that NIS strength is a positive function of publication output (Van Looy, et al. 2006). This is particularly emblematic of a collaboration between heterogeneous structures, such as the benefit of clustering between universities and entrepreneurial firms (Miner, et al. 2000), or when firms cite results of research by research institutions in close proximity (Storper 1995, 1997; Goldstein & Drucker 2006).

Excessive concentration, though, ultimately limits research potential beyond the core. Geographic propinquity of R&D in Korea is represented primarily by the Seoul "macrocluster" (Sohn & Kenney 2007), so countering evidence such as that offered here represents a major shift. Decentralization policies have played a part in this shift which, according to some, has hindered high-technology growth in Korea through government intervention and failure (Sohn & Kenney 2007). Successful decentralization – measured by increased research output beyond Seoul – is also a function of policies calling for interaction between universities, firms, and government research institutes. Among Korea's seven metropolitan areas (each with populations more than one million) and nine provinces, Seoul is unique in terms of its role as socio-economic hub and population center with one-fifth of the country's citizens. In recent years, though, the Korean government has faced mounting pressure about the degree to which national research policies facilitate or impede knowledge diffusion throughout the country and the academic community (Yang, 2008). Improvements in technology innovation capabilities nationwide can improve efficiency in Korea's overall R&D (Hwang, 2002), and we posit that the shortcomings and inefficiencies in R&D capabilities are due to network-level obstacles, particularly the lack of collaborative networking.

With Seoul's dominant R&D output, such interactions are expected to affect relations across regional boundaries, especially between Seoul and the periphery. In this way, we build on earlier studies which examine how advantage can be created through "triple helix" relations at the regional level (Cooke & Leydesdorff, 2006). Studies of the triple helix phenomena are founded largely on the claim that those types of relations are the core of knowledge-based innovation, stimulating ideas across institutional boundaries (Etzkowitz, 2008). More importantly, R&D collaboration seems to correlate with decentralization (Surowiecki, 2005). Yet, in Korea, these triple helix relations between universities, industry, and the government have not been strong enough to raise Korea's R&D capabilities to those of more technologically advanced nations (Park, So, & Leydesdorff, 2009), which can be attributed to over-centralization.

There is endogeneity in the relationship between decentralization and triple helix structures, as the strength of the triple helix structures in a particular region is a function of decentralization efforts by the government. Simultaneously, decentralization as evidenced by publications beyond Seoul is a stronger predictor of innovation when such innovations are manifested through triple helix structures. The effects of a policy to affect growth of the NIS periphery, shown here through analyses of R&D collaboration, undoubtedly impact the scale and scope of triple helix relations. We describe both patterns of S&T development in Korea and confirm that there remain geographically manifested network obstacles to a fully functioning NIS.

Additional research on the relationship between networks and decentralization is not extensive and, where available, deals primarily with the geographic expanse which is China. Chang and Shih (2005) compare the Chinese and Taiwanese NISs in a network analysis framework using input-output data and R&D expenditures by sector, concluding that Taiwan is more centralized. Liu and Chen (2003), in their study of Chinese regional innovation systems, point out that there are differences of scale between each region, based on socioeconomic factors and triple helix-related phenomena of firms, universities, and research institutes. In one of the more recent studies of regional innovation networks in Korea using social network analysis, universities outside of Seoul were found to have helped foster the growth of regional innovation networks. Inside Seoul, though, universities work hard to provide knowledge to local industry, particularly the firms' R&D institutes, which are the basis of Seoul's innovation network (Sohn, Kim, & Lee 2009). This is consistent with Sohn and Kenney's (2007) outline of the challenges to decentralization and discussion of the role of universities in transferring technology to the private sector. They fail, though, to look at the connection between decentralization and university-firm networks. We offer here a more accurate account of Korean networks, accounting not only for centralization, but also centrality, network density, and network fragmentation.

The following empirical analysis of the links and associations among Korean research resources is divided into four additional sections. Section 2 outlines the existing standard of relations and decentralization-related events in the history of the Korean NIS. Section 3 presents the theoretical and methodological underpinnings for use of centrality, density, and fragmentation indicators, and Section 4 presents the results from the application of longitudinal patent data to these three indicators. The fifth section connects our results to present and future research policy structures, with major implications for Korea's underrepresented regions and untapped triple helix potential.

II. NETWORKS AND THE KOREAN NIS

The evolution of S&T policies in Korea can be subdivided into three stages of technological development, each of which has impacted the growth of networks in differing degrees (Lee, 2000). Foreign technology imitation is the predominant means of acquiring technological capability initially. The internalization stage begins when local engineers are capable of developing products or constructing new plants through indigenous efforts or when domestically manufactured products become technically superior to products manufactured in foreign countries. The generation stage occurs when there are capabilities to introduce market-leading products and state-of-the-art core technology. In Korea, the imitation stage took place from 1962-79, the internalization stage from from 1980-89, and the generation stage from 1990 to the present (Lee, 2000).

The imitation stage was exemplified with industrialization efforts through the reverse engineering of existing foreign technologies. Throughout the 1960s and 1970s, minimal investments in R&D were required in pursuit of simple product manufacturing. Reverse engineering rarely occurs in a vacuum, requiring multi-level interactions among firms, universities, and public R&D institutes (Kim, Nelson, & Eds, 2000). The government recognized the need to internalize foreign technologies for the manufacturing sector, allocating such duties to the newly established Korea Institute of Science and Technology (KIST) in Seoul in 1966. This process continued through KIST spin-offs such as the Electronics and Telecommunications Research Institute (ETRI) in Daejeon. In pursuit of research in electronics, the government helped foster public and private research institutes and actively encouraged information transfer in a triple helix construct through licensing and consultations. The Korea Institute for Electronics Technology (KIET) in Kyeonggi province helped coordinate and disseminate semiconductor R&D with firms and facilitated inflows of international technology transfer and market research (UNIDO, 2005). By the mid-1980s, the Korean conglomerates had surpassed KIET's R&D capabilities, so the institute sold off much of its fabrication infrastructure to the private sector (Wade, 1990), signifying the success of the internalization stage.

Innovation policy in the internalization stage was based on the implementation of functional incentives, such as tax-based incentives for R&D, rather than sectoral incentives. These incentives enhanced the private firm's capacity for innovation and accumulating in-house R&D capabilities, and were coupled by public R&D investments under the National R&D Program (NRDP) of MOST. Universities and private firms could both participate in such a program, competing against GRIs to acquire R&D project funding. These policies targeted balanced development of research capabilities within universities, GRIs, and private firms, and the fostering of networks among researchers, but decentralization policy from the early 1980s was primarily focused on expanding the Seoul macrocluster to include proximate regions (Sohn & Kenney, 2007)

There were major efforts to foster linkages from the early 1990s. From 1992-94, the Industry-Academy-Research Institute Cooperative Research Center (IARCRC) was established under STEPI (known then as KIST) to transfer technology from GRIs to industries, provide free technological consultation, and to provide specialized information in various technological fields. The financial crisis of 1997-98 prompted a marked shift in Korea's policy orientation to address some of these alignments, particularly the 21st Century

Frontier Technology R&D Program. With goals of reforming Korean universities and raising the quality and number of researchers, during President Kim Dae-Jung's administration (1997-2002), the government developed policies to reinforce human resources in S&T in order to move toward an innovation-driven knowledge economy (Lee & Kwun, 2003) and reorient the generation stage. For example, several regional universities were supported from 1999 through the Brain Korea (BK) 21 project, the largest university project ever promoted in Korea, utilizing $38 million per year for seven years. Other policies were also implemented to tap into underutilized research resources in provincial universities, particularly the strengthening of industry-university ties (MEST, 2009; Moon & Kim, 2001; RAND, 2007).

Other efforts to increase overall research output and productivity have had a negligible effect on network creation, and consequently, decentralization. Since then, government investment has targeted basic and applied research capabilities at top science and engineering universities through a number of programs in order to boost basic research output for industry application: Science Research Centers (SRC), Engineering Research Centers (ERC), National Research Labs (NRL), and Information Technology Research Centers (ITRC). These programs, though, are predominantly concentrated in Seoul and its surrounding environs (Shapiro, 2007), and they cannot be expected to foster networks beyond the capital city. The exception has been the Regional Research Centers (RRC), which have succeeded in coordinating region-specific innovation, especially when innovation clusters are not fully developed and the costs of initiating them are not excessively high. The RRCs enabled intra-regional collaboration with no additional costs, for either the manufacturing firm using the technology or the researchers themselves (Lee, 2001).

President Roh Moo-Hyun (2002-2007) subsequently formulated a grand strategy for reforming the Korean research system by strengthening national and regional innovation systems (Hong, 2005). This national policy of Roh's presidential term focused on restructuring the resource allocation between the Seoul metropolitan area and provincial universities and achieving balanced regional development. The emphasis on regional development still continues under President Lee Myung-Bak with his call for increases in gross domestic expenditures on R&D from 3.2 percent of GDP in 2006 to 5 percent in 2012 (Lee, 2009). Enhancement of regional innovation capacity is also a component of President Lee's 577 Initiative[1].

To analyze these changes within the stages of the Korean NIS, we measure output by research articles published in ISI-rated journals.[2] Korean authors increased their share of Science Citation Index (SCI) publications from 0.99 percent in 1996 to 2.86 percent in 2006, which Park and Leydesdorff (2008) attribute to the ability of Korean provinces to improve their research portfolio by enhancing their network positions in terms of connectedness and/or brokerage.

III. NETWORK QUANTIFICATION METHODS

The method applied here is rooted in social network analysis using the following three indicators: degree centrality, degree centralization, density, and fragmentation. Social network methods deal with an S_{ij} matrix where *i* and *j* are *nodes* and the value between *i* and *j* represents their internal *relations*. Wasserman and Faust (Wasserman & Faust, 1994) explain that there can be various node types in this network analysis, such as people, subgroups, organizations, or collectives/aggregates like Korean provinces, the latter of which is the node

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[1] Lee's national S&T plan is often called the "577 Initiative". "5" refers to government strategies to boost a share of R&D investment in GDP to the 5 percent by 2012 from the 3.23 percent in 2006; the first "7" represents the governments focus on seven S&T fields; the second "7" indicates Korea's goals to join the world's seven-most technologically advanced countries by 2012.

[2] Institute for Scientific Information. ISI was recently renamed Thomson-Reuters, but "ISI" continues to be widely used.

type considered here. Wasserman and Faust (Wasserman & Faust, 1994) also state that relations are specific substantive connections between a set of nodes, and that one or more types of relations can be measured for a single set of nodes, enabling a three-fold analysis of centrality, density, and fragmentation among Korean geographic regions.

These methods of social network have been well established in the social sciences,[3] but they have also played an influential role in social studies of science technology, information science, and scientometrics (Otte &Roussea, 2002; Thelwall, 2004), addressing a long-recognized understanding in academia that individual researchers frequently communicate and collaborate with scholars beyond the home institution who share similar interests. Scholars (Price, 1963; Crane, 1972) calls this “the invisible college”, which is quantifiable when the directly unobserved relations embedded in scientific networks are disclosed (Barabasi, et al. 2002; Goyal, 2007; Newman, Watts, & Strogatz, 2002). These robust measurements enable us to explore the specific process through which the regional academic system has become more interconnected. In the context of the Korean NIS, social network analysis acknowledges the view that nations aim to strengthen the knowledge-based innovation capacity of their social, cultural, economic, and academic sectors through increasing their regional interest and autonomy (Leydesdorff, 2006; Leydesdorff, Dolfsma, & Panne, 2006).

Journal article data used for this research is drawn from the Web–based A&HCI, SSCI, and SCI databases of the Web of Science (WoS), and is based on articles published from 1974 to 2006. The Arts & Humanities Citation Index (A&HCI), the Social Science Citation Index (SSCI), and SCI are the three specific data sets used, but they have not been subdivided in the ensuing analysis. The combined use of three R&D spheres (humanities,

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[3] See, for example, recent work by Borgatti et al. (Borgatti, Everett, & Freeman, 2002).

social sciences, and natural & engineering sciences) provides a more complete view of Korea's S&T capabilities, which is consistent with Moon and Lee (2005). It should be noted that the A&HCI publications are extremely few in this Korean database, with the combined matrix consisting primarily of SCI and SSCI publications.[4]

The data gathering process required that all journal articles published by residents in Korea be collected and classified according to the authors' province. Note that *nodes* are provinces. Relations are the numbers of journal articles coauthored by researchers in different provinces. The number of ISI-listed journal articles coauthored by researchers located in two or more different provinces allows us to scrutinize patterns of collaboration within and between Korean regions and focus on article production which ultimately feeds innovation, such as patents. Patents, of course, are based on prior scientific and technological knowledge, and patent applications on a global scale have increasingly cited journal articles. In the U.S., for example, over 60 percent of U.S. patents cite articles written by academic scientists and engineers (National Science Board 2010), so there are expected spillovers from publications to the industrial R&D sector (Jaffe 1989; Acs, et al. 1991; Mansfield & Lee 1996).[5] As well, co-authorship relations are a widely used proxy for the dynamics and complexities of university-industry-government relationships (Wagner, 2008).

The first index drawn from the publications data measures the sum of the node's relations with other nodes within an inter-provincial co-authorship network, or the node's *degree centrality* (Wasserman, &Faust, 1994; Freeman, 1979). The simplest definition of node's degree centrality is that central nodes, in this case, provinces, must be the most active

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[4] The share of A&HCI publications represented by the total number of total publications, total citations, and total cited articles, respectively, is 0.2 percent, 0.02 percent, and 0.06 percent.

[5] It is well-established that basic research produced at universities and elsewhere positively impacts the innovations which ultimately arise from the private sector, regardless of the nature of the relationship between academia and firms, both in the U.S. (Mansfield 1991, 1995, 1998) and Germany (Beise & Stahl 1999).

in the sense that they have the most ties, in this case co-authorships, to other nodes in the network (Wasserman, & Faust, 1994, p. 178).. Further, the dgree centrality measure depends on the size of relations and must be normalized for comparisons across networks of different sizes.[6] In the inter-provincial co-authorship network, the most central nodes are the region with scientists who have coauthored the most research articles with their peers in different regions.

In addition to node's degree centrality, degree centralization is a frequently used measure of how influential the most central node's activity is in the network (Wasserman, &Faust, 1994). In terms of the inter-provincial co-authorship network, higher degrees of degree centralization indicate that inter-provincial collaboration is concentrated in the most central province. Thus, high index (expressed as percentage) values indicate that all other provinces beyond the most central province have fewer opportunities for collaborations. A centralized network may also reflect an uneven distribution of means of research, co-authorships in this case, such that resources are concentrated in the central nodes of the network. This is particularly useful in revealing which provinces are in the research core and which are at the periphery.

A second index generated from publications data captures the *density* or cohesive properties in the network (Wasserman, &Faust, 1994). Density refers to the total number of relations among nodes divided by the possible number of relations; for example $(N * (N - 1))/2$ for a symmetrical matrix, where N indicates the number of relations among nodes. The inter-provincial network is presented as a value graph, which is a matrix of the frequencies of co-authorship between researchers in different regions. Thus, the density in the value graph is the average of the matrix, calculated as the sum of the observed relations between provinces

[6] See Wasserman & Faust(1994), pp. 178-179 for full details of the standardization calculation.

divided by the number of cells in the matrix, which is consistent with a parallel application in Park and Leydesdorff (2009).[7] In a co-authorship network, thus, density describes how closely scientists work with peers in other provinces to publish their research and allows us to investigate the extent to which the inter-provincial research activity occurs. A time series analysis of density values shows qualities of “networkedness” of Korean scientific collaboration, which is key in planning, implementing, and evaluating national research policy.

The third and final index drawn from publications data measures helps identify those nodes whose involvement in the network is crucial (Trotter, et al. 2008). *Fragmentation*[8] values are calculated after binarization by dichotomizing the matrix based on the density value. A fragmentation value close to 1 indicates that the removal of the particular node from the network would fragment the network, while a value near 0 means that the removal of the particular node would not prevent the remaining nodes from staying connected. In terms of the inter-provincial co-authorship network, losing an node with a value close to 1 would have a significant impact on the national collaboration network and would seriously damage the connections among Korean researchers.

IV. RESULTS

Centrality and centralization analysis

According to our centrality analysis of articles published from 1974 to 2006 using an inter-provincial co-authorship matrix for all categories, including the Arts & Humanities

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[7] The use of density as a summarization tool to compare networks reveals longitudinal variation particularly if the link values in the matrix are not small, as seen the Korean case (Nooy, Mrvar, & Batagelj, 2006).

[8] Fragmention value was calculated using a standard routine available at the Key Player prorgam included in the most popular social network software UciNet for Windows. See Borgatti et al. (Borgatti, Everett, & Freeman, 2002) for full details of the mathematical definition of fragmentation value.

Citation Index (A&HCI), the Social Science Citation Index (SSCI), and SCI, Seoul was identified as the top city for research collaboration with other provinces in Korea.[9] In the most recent year 2006, scientists located in Seoul produced 6,836 scientific articles with peers in other provinces, but this has not been consistent over time, as the normalized centrality value for Seoul has been on the wane for the last ten years. Seoul's normalized centrality value peaked in 1990 at 34.38 and then decreased and plateaued, as shown in Figure 1. Other provinces appear to be emerging as collaborative research centers, particularly Daejeon and Kyeonggi, the former emerging as a research center through the establishment of S&T-related government institutions in the second half of the 1980s. Kyeonggi province, however, has emerged as a collaborative research center due to the fact that it literally surrounds Seoul and includes a number of Seoul's satellite cities. With the emergence of these new important nodes, the influence of Seoul has weakened since 1990. The centralization value peaked in 1989 at 33.01 percent and reached 18.47 percent in 2006, indicating that Korean researchers have increasingly co-authored academic publications with peers working in different regions other than Seoul since the 1990s.

[Table 1 here]

[Figure 1 here]

Density analysis

Figure 2 illustrates that inter-provincial co-authorship networks have become more cohesive over the last three decades, beginning with 0.004 in 1974 and ending with 48.779 in 2006. Note that these values are all log-transformed in the figure, for scaling purposes. This change over time is an indication of a rapidly increasing degree of collaboration among geographically dispersed researchers and institutions.

[9] These indices (A&HCI, SSCI, and SCI) have long been established as indicators of research output, impacting research group status and subsequent funding decisions (Van Raan, 1988).

[Figure 2 here]

In the case of SSCI, Korean scientists began publishing their research output regularly in ISI-rated journals from 1992, with prior SSCI publications of Korean scientists only in 1984 and 1990. The SSCI-co-authorship network exhibits an increasing density value over time (0.011 in 1992 to 0.636 in 2006), despite a slight decrease in 1996 and 1997 (0.029 in 1996 and 0.028 in 1997).

Fragmentation analysis

Changes in network variation may be difficult to distinguish using the above network metrics, so fragmentation analysis is a particularly useful method to complete a picture of R&D collaboration in Korea. The results of this analysis are summarized in Table 1 and confirm the results from the centrality analysis: Seoul has been the key node for the last three decades. In addition, the fragmentation value declined when Seoul was removed from the network, as seen in Figure 3. There is a key difference between the fragmentation and centrality analyses, namely that Seoul was not selected as the most important node from 1992 to 1994. Daejeon was identified as the key node in both 1992 (fragmentation value: 0.331) and 1993 (0.426) and Busan (0.426) in 1994 for the co-authorship network. These results are presented in Table 1.Beyond centrality analysis, this fragmentation analysis reveals the function of regional areas, especially when linking the periphery to the core.

[Figure 3 here]

V. CONCLUSION

We have presented a social network analysis of longitudinal data to examine the long-term transformation of research collaboration within Korea. The use of three network indicators – *centrality* (sum of connections), *density* (cohesive properties), and *fragmentation* (identification of key nodes) – present an image of an evolving Korean NIS in which Seoul no longer dominates the R&D landscape but is still the most important player.

The fact that Seoul no longer dominates on the scale that it always has is a remarkable and, as of yet, undiscovered empirical finding. We attribute Seoul's plateauing centrality to the emergence of Daejeon and Kyeonggi province as research collaboration centers. Daejeon primarily arose as a function of government intervention while Kyeonggi province has benefitted from its proximity to Seoul. Inter-provincial co-authorship networks in Korea have become more cohesive over the last three decades, indicating increased collaboration among geographically dispersed researchers and institutions. Although Seoul was identified as the key node over the last three decades, it did not remain the most important node from 1992 to 1994, which we attribute to the R&D collaboration goals of specific programs, such as the IARCRC and efforts to foster ties among universities, firms, and government research institutes.

Increased collaboration bolsters the NIS, so the declining centrality of Seoul and the increasing knittedness of local provinces indicate that individual researchers and organizations have become more interconnected through expanded exchanges and collaboration. Decentralization of scientific articles leads to greater innovation for the simple reason that more science leads to increased technological performance (Van Looy, et al. 2006). Focusing on regionalism diverts funding away from Seoul and towards universities and institutes with less output and efficiency. We do not believe that this is sufficient justification to focus on Seoul, as Sohn and Kenney (2007) conclude, given the benefits of networking and the connection between successful R&D collaboration and decentralization (Surowiecki, 2005).

With the continuance of this trend, Korea's innovation output will have the opportunity to match that of the world's technology leaders. However, this momentum can be maintained only if the Korean government provides strong funding support and implements sophisticated policies which reflect the complex network structure of national and inter-regional collaboration (Yang, 2008). This pattern was successfully instituted from the early 1990s but it must be revived to provide more attention to regional centers and inter-regional collaboration.

The greatest policy challenge of all, however, will be the deliberate diminishing of Seoul's position as the sole research broker. Like industrial policies, research policies can be viewed in terms of two main elements: functional interventions and selective interventions. Selective interventions to facilitate triple helix interactions in Korea are offered in the literature (Shapiro, 2007), but elaboration is needed. It is a controversial prescription, as the selective targeting areas of the country beyond Seoul goes against its role as the virtual core of Korea for over two thousand years. The evidence offered here of a decentralization shift is particularly noteworthy, and it can be continued simply with increases in a region's knowledge-based infrastructure and within-region networks (Huggins, et al. 2008). In the presence of a macrocluster like Seoul, regionalism will also result as an externality of inter-connectedness between the macrocluster and individual regions.As research is increasingly done through the medium of the Internet, it should be noted, the physical boundaries between Korea's provinces may be more easily transcended. New developments in digital technologies facilitate not only scientific collaboration, but also new methods of scientific collaboration. Cyber-conferencing, online data archiving, and shared access to research tools are just a few examples of how web-based research technologies and practices can solve long-distance coordination problems and keep researchers informed in real-time about new issues and challenges. The Korean government's competitive regional development programs during the 1990s produced a number of regional “technoparks” and innovation centers (Hong, 2005). These facilities can be remodeled to use cutting-edge technology and enable scientific exchanges between provincial researchers separated by great distances. When completed, these publicly funded research centers will also contribute to intra-national collaboration by linking geographically remote researchers and reducing institutional constraints to cooperation among university, industry, and government scientists.

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Tables and Figures

Figure 1. Longitudinal trends of Seoul's normalized degree centralities and overall degree centralization

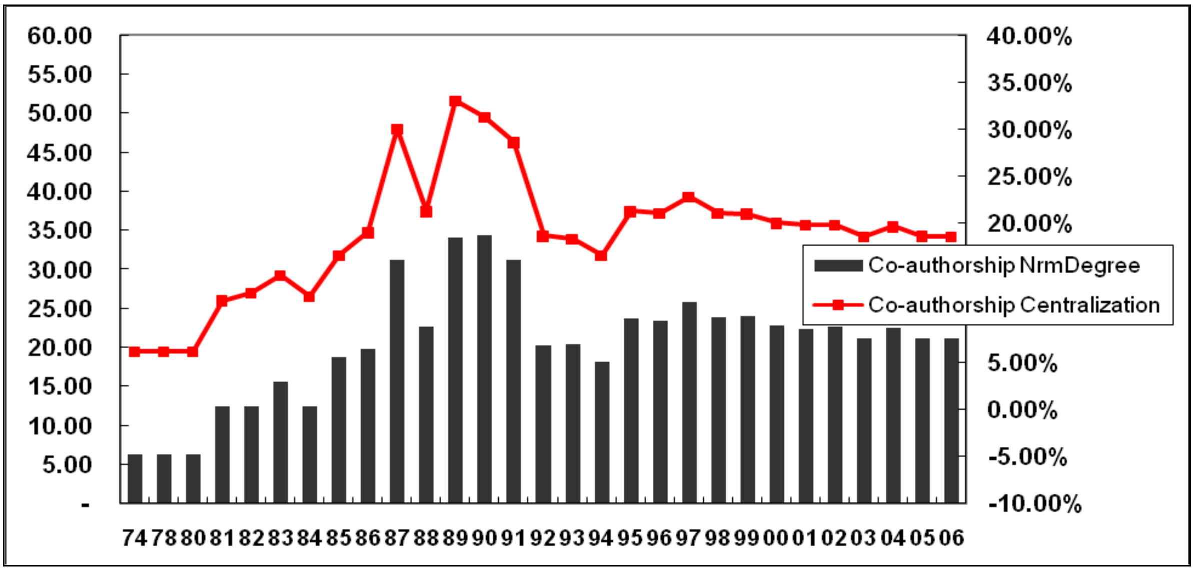

Figure 2. Density values from 1974 to 2006 for SCI-only, SSCI-only

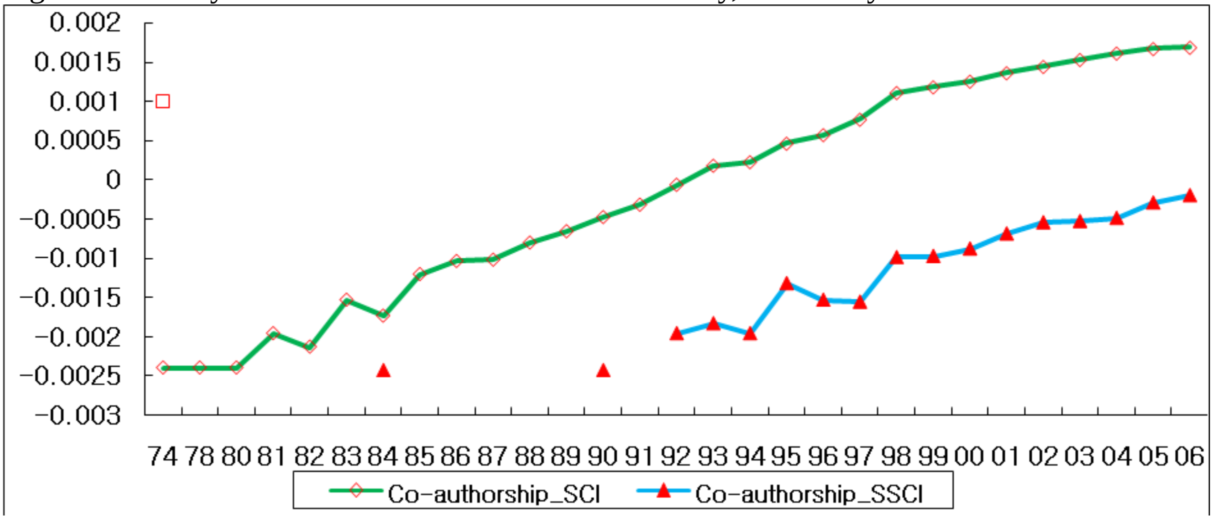

Figure 3. Longitudinal trends of fragmentation value when Seoul is removed

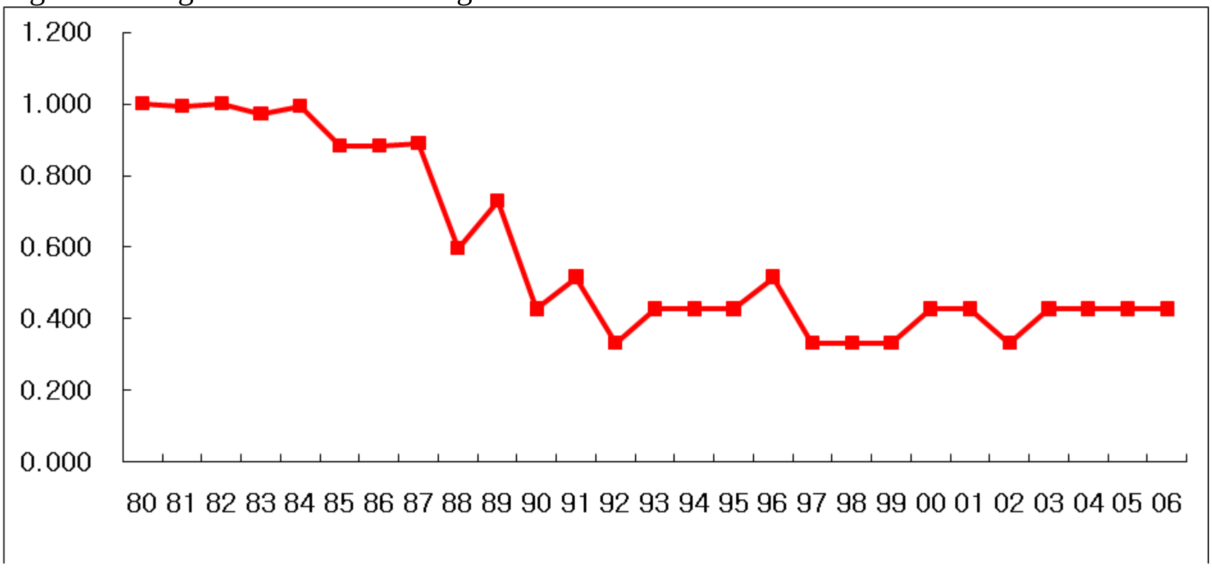

Table 1. Longitudinal analysis of fragmentation: publication for all categories

Year	Fragmentation - One key node removed	Fragmentation - Two key nodes removed	Fragmentation - Three key nodes removed
1980	Seoul(1.000)	Seoul/Kyeonggi(1.000)	Seoul/Kyeonggi/Kyongnam(1.000)
1981	Seoul(0.993)	Seoul/Kyeonggi(1.000)	Seoul/Kyeonggi/Kyongnam(1.000)
1982	Seoul(1.000)	Seoul/Kyeonggi(1.000)	Seoul/Kyeonggi/Kyongnam(1.000)
1983	Seoul(0.971)	Seoul/Kyeonggi(0.993)	Seoul/Kyeonggi/Kyongbuk(1.000)
1984	Seoul(0.993)	Seoul/Kangwon(1.000)	Seoul/Kangwon/Kyeonggi(1.000)
1985	Seoul(0.882)	Seoul/Chungnam(0.949)	Seoul/Chungnam/Inchon(0.985)
1986	Seoul(0.882)	Seoul/Jeonnam(0.971)	Seoul/Jeonnam/Pusan(0.993)
1987	Seoul(0.890)	Seoul/Chungnam(0.985)	Seoul/Chungnam/Kyeonggi(0.993)
1988	Seoul(0.596)	Seoul/Kwangju(0.897)	Seoul/Kwangju/Chungnam(0.963)
1989	Seoul(0.728)	Seoul/Kyeonggi(0.875)	Seoul/Kwangju/Kyongbuk(0.949)
1990	Seoul(0.426)	Seoul/Pusan(0.596)	Seoul/Kwangju/Kyongnam(0.735)
1991	Seoul(0.515)	Seoul/Choungbuk(0.669)	Seoul/Choungbuk/Kyongnam(0.735)
1992	Daejeon(0.331)	Daejeon/Pusan(0.426)	Daejeon/Pusan/Kyongbuk(0.515)
1993	Daejeon(0.426)	Daejeon/Seoul(0.662)	Daejeon/Seoul/Kyongnam(0.787)
1994	Pusan(0.426)	Pusan/Kwangju(0.596)	Pusan/Kwangju/Seoul(0.669)
1995	Seoul(0.426)	Seoul/Daejeon(0.596)	Seoul/Daejeon/Kyeonggi(0.669)
1996	Seoul(0.515)	Seoul/Daejeon(0.596)	Seoul/Daejeon/Chungnam(0.669)
1997	Seoul(0.331)	Seoul/Daejeon(0.515)	Seoul/Daejeon/Kwangju(0.669)
1998	Seoul(0.331)	Seoul/Pusan(0.426)	Seoul/Daejeon/Kyeonggi(0.596)
1999	Seoul(0.331)	Seoul/Pusan(0.515)	Seoul/Pusan/Kwangju(0.515)
2000	Seoul(0.426)	Seoul/Kyeonggi(0.515)	Seoul/Jeonbuk/Kwangju(0.596)
2001	Seoul(0.426)	Seoul/Kwangju(0.596)	Seoul/Daejeon/Kyeonggi(0.669)
2002	Seoul(0.331)	Seoul/Pusan(0.515)	Seoul/Daejeon/Kyeonggi(0.596)
2003	Seoul(0.426)	Seoul/Daejeon(0.515)	Seoul/Daejeon/Kyeonggi(0.794)
2004	Seoul(0.426)	Seoul/Kwangju(0.596)	Seoul/Daejeon/Kyeonggi(0.669)
2005	Seoul(0.426)	Seoul/Kwangju(0.596)	Seoul/Daejeon/Kyeonggi(0.669)
2006	Seoul(0.426)	Seoul/Daejeon(0.515)	Seoul/Daejeon/Kyeonggi(0.846)