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Mapping Intellectual Space of Technology Innovation Management in Korea†

한국 기술혁신연구의 지적생태계 구조

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목 차

국 문 요 약

본 연구의 주요 목적은 한국의 기술혁신관리연구가 어떤 세부 학문분야로 구성되어 있는지를 규명하는 것이다. 우리는 분석을 위하여 견고성이 입증된 저자공동피인용분석 기법을 사용하였다. 분석에 사용된 데이터는 한국의 양대 저널에서 1993년부터 2006년까지 수록된 논문의 인용데이터를 대상으로 하였는데, 제1저자만을 취급했던 기존의 관련연구와는 달리, 우리는 포괄적 연구를 위해 제3저자까지 포함시켰다.

분석은 일단 인용횟수 10회 이상인 239명을 식별한 후, 이들간의 저자공동피인용회수를 기준으로 다시 상위 100명으로 압축하여 분석하였다. 그리고 이 분야에서 높은 저자피인용횟수와 저자공동피인용횟수를 보이는 23인의 주도적 연구자 그룹을 식별하였다. 이 집단의 연구자 당 평균 저작편수는 22.2, 연구자 당 평균 피인용 횟수는 58.5회, 그리고 저작물 건당 평균 피인용 횟수는 2.6회임을 보이고 있었다. 또한 연구자 공동피인용 횟수는 연구자 피인용 횟수의 10배에 달하는 것으로 나타났다.

다른 주요 분석 결과는 한국의 기술혁신연구는 기술/혁신, 기술경영, 기술경제, 개발, 기술가치평가, 그리고 성장과 같은 6개의 영역으로 구성되고 있고, 다음과 같은 특성을 보이고 있다. 1) 대다수의 기술경영 연구진은 경영학자들로, 기술경제와 성장 관련 연구는 경제학자들로 구성된 반면, 기술혁신과 개발 영역은 특정 연구분야가 주도적 역할을 수행하고 있지 않다. 2) 기존의 학문분야를 고려하면, 경영학과 경제학이 기술혁신연구를 주도하고 있음을 보이고 있다. 3) 기술가치평가는 대부분 한국 연구자들에 의해 수행되고 있음을 보이고 있다.

핵심어 : 기술경영, 기술혁신관리, 저자공동피인용

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ABSTRACT

The major purposes of the research are to see the underlying disciplines of technology innovation management which contribute to Korean research. To do that, we employed author cocitation analysis which has been proved to be robust. We compiled all the citations of two major Korean journals between 1993 and 2006. We also included up to 3rd author, which makes a cocitation analysis more comprehensive, compared with the previous analysis for the first author only.

We identified 239 authors who have more than 10 citations. From the cocitation combinations based on the 239 authors, we selected and analyzed 100 most cocited authors. Out of 100 authors a group of 23 authors who command both higher citations and cocitations were chosen for detailed analysis. The results show that the average number of publications is 22.2, the average number of citations to them is 58.5, and the average number of citations to a publication is 2.6. Also, the average number of cocitations is around 10 times that of citations.

The results indicate that there are six major disciplines: Technology/Innovation, Management of Technology, Economics of Technology, Development, Valuation of Technology, and Growth. Noteworthy points are the following. 1) Most of the members of the technology management group are management scholars, and the groups of economics of technology and growth are economists, while the groups of technology innovation and development group are not represented by specific disciplines. 2) Considering the groups overall from the traditional academic disciplines, the main branches are management and economics. 3) The valuation of technology group consists mostly of Korean researchers.

Key Words : management of technology, technology innovation management, author cocitation analysis

I. Introduction

Technology innovation related research has been matured as a single academic discipline and the number of international journals dealing with the field is at least 10. However the field is understood as technology management, a sub field of management and sometimes defined as an intersection of engineering and management in a broader sense. In the broadest scope some scholars define it as all academic areas of managing technology and innovation as follows: Reisman (1994) called this area technology management. Liker (1996), Cheng et al. (1999), Linton & Thongpapanl (2004), and Merino et al. (2006) referred it as technology innovation management and analyzed the related journals. Seol & Park (2008) called it as innovation studies. To make the boundary of our discussion clear we will use the term, technology innovation management.

When a boundary of a research field becomes a broader, it is natural to know the constituting disciplines of the field. In the previous research mentioned above, key words provided in individual papers or subjective judgment of researchers has been generally employed to examine the underlying disciplines. But these methods do not provide objective standard for the purpose.

The main purpose of this paper is analyze and examine the disciplines of technology innovation management. In addition, as byproducts of the analysis we look into detail the cocitation patterns and the leading scholars in each discipline. For the analysis we use the data of technology innovation management research published in Korea. Thus we will also examine any difference of technology innovation management research in between Korea and international settings.

The analysis is based on cocitation analysis, which has been considered to be an effective method in identifying the disciplines of certain research field. Since we can assume that when a set of authors are highly cocited together, they may be grouped as a body of similar scholars. This paper will show the disciplines of technology innovation management

II. Author Cocitation Analysis

1. Cociation analysis

Cociation analysis is to analyze the characteristics of authors or publications which are cited together. We call author cocitation analysis when the analysis is done on authors. A full spectrum of methodology for cocitation analysis was clearly defined by McKain (1990) ranging from data handling such as collection and manipulation to analyzing techniques of factor analysis, clustering and multidimensional scaling. She also showed the ways of interpreting the results of the computer outputs. She also deliberately described how to interpret and validate the results, warning subjective interpretation based on personal knowledge. Ding et al. (1999) argued that a cocitation analysis can be enhanced significantly when combined with factor analysis to give a more accurate and useful picture of the multidimensional scaling results.

Cocitation analysis emerged in the early 1970's (Grafield, 1974; Small, 1973) and much research on the topic has been accumulated. There are 162 scholastic journals and 606 references dealing with cocitation analysis during 1973-2008.[1] It is noticeable that cocitation research has been advanced along with information technology advancement: Database technology which became mature in the 1980's enabled active research and graphics technology in the 1990's made another epoch for in depth cocitation research.

Research on cocitation analysis can be grouped into three areas. First one is the study of specific academic field: For example, Crawford and Crawford (1980) in psychology and Culan in MIS; Recently Ball and Rigby (2006) in technology management and Nerur et al. (2008) in strategic management.

The second is to study on research methodology. Zit and Bassecouland (1994) reviewed the methodology adopted by the researchers on cocitation analysis. Gmür (2003) compared diverse methods on clustering. Since it is impossible to list all the related methodologies in this paper, we provide a brief summary of disputed points of methodology. First disagreement is on how to treat the diagonal elements of a cocitation matrix. The diagonal elements refer to the cocitation of the same author or

1) http://garfield.library.upenn.edu/histcomp/co-citation/index-tl-7.html

publication. The second is on the coverage of authors in author cocitation analysis: first author, up to second author, or all of the authors. The third dispute is on the way of clustering similar authors.

The third research area is to visualize cociation relationships, which includes White and McCain (1998), Liu (2005), and Leydesdorff (2008).

2. Related research in Korea and main theme of this paper

The analysis of academic articles on technology innovation in Korea is shown in Namn, Park, and Seol (2005) which covers the journals such as Journal of Technology Innovation, and Journal of Korea Technology Innovation Society, and Journal of Venture Management. A social network analysis of authors was used to analyze the relationship of coauthors based on the above mentioned two journals (Namn and Seol, 2007). Seol and Park (2008) discussed the characteristics of both articles and authors cited in the preceding two journals.

From the literature we can see that there is no cocitation analysis in Korea, especially in technology innovation area. Landscape of technology innovation can be described as follows: The area has a relatively short history compared with other disciplines and it attracts researchers from diverse academic fields since its theoretical foundation is based on the theories of multidisciplinary fields. For these reasons, it is not clearly defined that what research themes consist of and what research areas should be included in technology innovation research. The main purpose of this paper is to answer these questions utilizing cocitation analysis methodology.

III. Data and Method

1. Source data of citations

There are two major journals as the outlets for academic papers on technology

innovation management in Korea: Journal of Technology Innovation (JTI in short) and Journal of Korea Technology Innovation Society (KTIS). In this study we use our own database which covers all 557 articles (263 from JTI; 293 from JTIS) and 15,790 citation records (8,386 from JTI; 7,427 from KTIS) published during 1993 through 2006.

Data processing is as follows: First, we selected a set of 239 authors who had been cited 10 or more times from the source database. Of 239 authors 80 are from domestic and the remaining 159 are from the abroad. Second, based on the set of 239 authors, we obtained 17,431 cocitation combinations from the source citation data. Third, we selected 100 most frequently cocited authors from the cocitation combinations. Using the set of 100 authors and the source citation database, we again filtered out cocitations, which amounted to 13,567 pairs. Fourth, we categorized the 100 authors selected at the third phase into 4 groups based on the numbers of citations and cocitations. From the groups, for further analysis we selected a group of researchers whose citations and cocitations are higher than the average frequencies.

The main discussion of this paper deals with the set of cocitations of the third phase of data preparation. While the data set can be described in aggregative ways, it is difficult to refer the data in terms of individual research works. Thus, the detailed analysis on the works of individual authors will be confined to the special group identified in the fourth phase.

2. Method

We use three techniques to identify research areas of technology innovation management in Korea. Two of the three techniques are a factor analysis and clustering analysis. The last one is the subjective judgments of this paper's three authors. Based on the judgments we examine whether the members of a factor or a cluster share similarities each other and the members can be represented by a nominal name. In this way we can validate the results of factor and clustering analyses by the subjective judgments. We also use a visualization technique to show the relationship among the top researchers, which is useful to see the inherent characteristics of research in technology innovation

of Korea.

In addition there are two minor points to mention regarding data manipulation. First issue is how many of authors are to be accounted for deriving cocitation data, when a cited work has several coauthors. Second one is how to deal with diagonal values of a cocitation matrix. We discuss the coverage of authors now, postponing that of diagonal values later. Most of the research was based on the SCI or SSCI, where conference papers were not included for citation compilation. ISI Thompson database from which most of the bibliometric data come has a shortcoming; author of a paper is only represented by the first author. Of course the first author is the most important, but when we find the cocitation pairs using the first author, the intellectual search space will be very limited. For the reason, Persson (2001) pointed out the limitation of the official citation database where even though a paper is coauthored, the paper is only maintained by a first author name. He tested the validity of results: first author versus full authors. The result shows that the validity of full author model is much higher. The computation complexity for the cocitation is very high. Considering the limitation of first author cocitations and the computation complex, we take into account up to the third author.

3. Basic Statistics of cocitations

Basic statistics of the cocitations of 100 authors are in 〈Table 1〉. In the table it is noted that the works on technology innovation management in Korea heavily depend on the foreign scholars, since more than 70% of the authors are from the abroad. The number of cocitations by Korean authors indicates the number of cocitation pairs composed of one or two Korean authors. Note that the sum of the 6,697 and 20,437 is the twice the number of cocitations identified in the previous section since we just consider associations of authors. The distribution of cocitations by foreigners is dispersed widely: higher average number of cocitations and greater standard deviation.

〈Table 1〉 Basic statistics of Top 100 Authors

	Korea	Foreign
Authors	29	71
Cocitations	6,697	20,437
Average cocitations / author	230.9	287.8
Minimum cocitations	88	62
Maximum cocitations	760	1,144
standard deviation	154.3	215.3

From the 13,567 cocitations of 100 authors who are considered to be highly influential in the innovation research in Korea, we created the cocitation matrix. Each cell of the matrix is the count of cocitation of a pair of authors.

Regarding the diagonal values of the cocitation matrix, there are several approaches. McCain (1990) and White & McCain (1998) treated the diagonal values as missing values. Culnan (1986) and Eom (1996) calculated the diagonal values by taking the three highest frequencies for each author and dividing by two. On the other hand, Ahlgren et al. (2003) suggested that the number of self cocitation should be used for the diagonals. However, little difference among those approaches has been noticed (Eom, 1996). During the course of statistical analysis White & McCain (1998) substituted the diagonal values as the mean of each author. Along this line we simply treated the diagonals as the mean frequency of each author.

From the cocitation matrix the corresponding Pearson correlation coefficient matrix can be derived. A correlation of two authors measures the explaining power of author cocitation; the higher the correlation, the more similar the two authors. So it is called a similarity matrix.

IV. Cocitation Patterns

1. Citations versus cocitations

Distribution of authors by the number of citations and cocitations is on 〈Table 2〉:

Quadrant IV, low citations but high cocitations, and quadrant II, high citations but low cocitations. All the authors in Quadrant IV are foreign scholars.Their research area deals with general themes. In general these authors contribute to the creation of new knowledge by allowing other knowledge to be fused. Also it is noted that the authors are big guys in the field. So their role can be considered to be boundary spanner (Cross & Prusak, 2002) connecting different fields of knowledge. In quadrant II, 7 out of 9 authors are Koreans. Research subject of these Korean authors is very specific and independent, so inside the specific field their works are highly cited, but from the outside of their research circle they are not. Their role in the intellectual domain is peripheral specialists (Cross & Prusak, 2002).

〈Table 2〉 Classification of authors

Citation		
High	**II** 9 (Korea: 7)	**I** 25 (Korea: 6)
Mean (271.3)		
Low	**III** 62 (Korea: 6)	**IV** 4 (Korea: 0)
	Low	Mean (34.3) High
	COCITATION	

In quadrant I there are 25 authors who attracted high citations and cocitations. Six out of 25 are Korean authors. The frequency of citations to Korean scholars includes self-citations. To make comparison reasonable between Korean and foreign authors, we removed the self-citations from the citation count, and 1 Korean and 1 foreign author are removed. One foreign author was heavily cited by his Korean student. The adjustment made the number of quadrant I be 23 (Korean 5, foreign 18). 〈Table 3〉 lists the number of citations and cocitations to 23 authors.

〈Table 3〉 Top 23 Authors after removing self citation

Author	Cocitation	Citation	Author	Cocitation	Citation
Nelson, R.	1,144	122	Winter, S.	481	35
Freeman, C.	1,038	98	Utterback, J.	478	52
Pavitt, K.	777	74	Clark, K.	409	45
Lundvall, B.	769	68	Mowery, D.	402	37
Kim, L.S.	760	93	Soete, L.	394	35
Dosi, G.	732	46	Lee, J.J.	350	83
Rosenberg, N.	671	65	Scherer, F.	349	41
Malerba, F.	643	50	Rothwell, R.	348	36
Song, W.C.	604	58	Griliches, Z.	331	75
Porter, M.	579	79	Mansfield, E.	290	40
Cohen ,W.	549	51	Seol, S.S.	275	175
Lee, K.R.	494	90			

The relationship between citations and cocitations in quadrant I can be summarized into two points. First, the more an author is cited, the more the author is cocited. The correlation coefficient of citation and cocitation for foreign authors is 0.81. Second, the magnitude of cocitation is 1.6 – 15.9 times of citation. Excluding Korean authors whose data are quite different from those of foreigners, the range of the magnitude is between 4.4 and 15.9, the average is 10.2, and the standard deviation is 2.57. The fact that the cocitation is 10 times of citation means that on the average a group of 10 scholars are cited as a set.

2. Cocited Materials and Authors

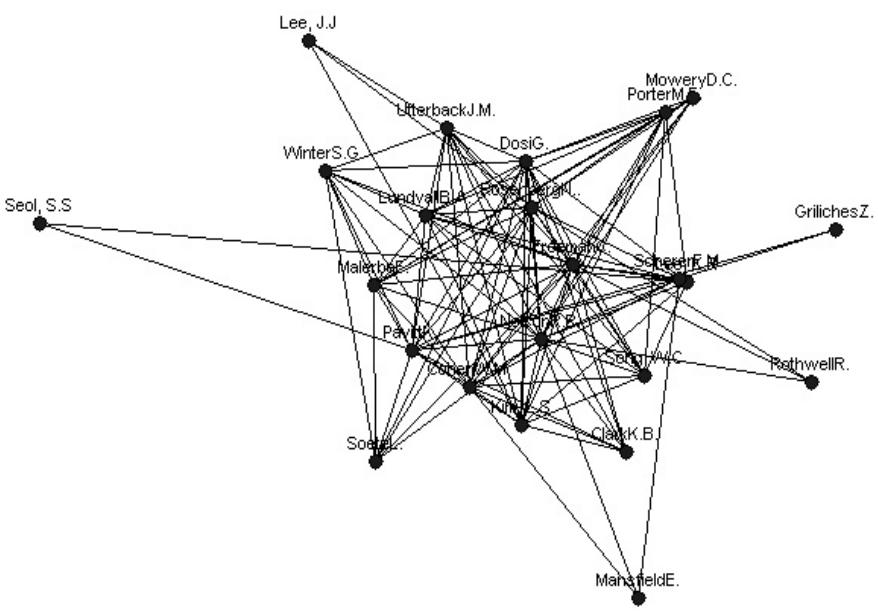
Since we have a large set of authors and their contributions to be analyzed, we just focus on the authors and their publications in quadrant I. The highest frequencies of cocitations between journal articles, books, and between articles and books are 7, 26, and 9, respectively. These publications with the highest frequencies will be definitely included in the highly cited group. In other words, cocitation statistics should be placed within a category of citation statistics, thus if a publication has many citations,

the publication tends to be cocited frequently.

The statistics of 23 high performing authors (quadrant I) are summarized as follows: 22.2 publications per author were cited, each author was cited 58.8 times, and each publication attracted 2.6 citations. However, the number of authors whose singular publication has citations more than ten is just two; R. Nelson and C. Freeman. The seminal publications are Nelson (1993), Nelson and Winter (1982), Freeman (1987), Freeman (1991) and Freeman & Soete (1997).

It is noteworthy that some authors who are not the first author at all are grouped in quadrant I; two out of 23 are the examples. Some of them contribute to publications regardless of the order of authorship; R. Nelson, C. Freeman, and K. Pavitt are in this category. Also, few of them work most of the cases as a first author; M. Porter and B. Lundvall are the representative authors.

The degree of strength among the 23 authors in terms of cocitations is give in (Figure 1), rendered by Spring algorithm embedded in NetMiner which is a tool for network analysis. In the figure the distance between any two authors is approximately proportional to the similarity of the two authors. For clear visualization purpose, only



(Figure 1) Strength of cocitations among 23 authors

if there exist 12 or more cocitations between a pair of authors, the links are shown to be active in the figure.

3. Themes of Highly Cited and Cocited Materials

Cited and cocited publications contributed by the authors in quadrant I can be categorized into several groups. First group is related to research in national systems of innovation, led by Freeman (1987) and followed by Lundvall (1988, 1992), Nelson (1993), Nelson & Rosenberg (1993), and Freeman (1991). When a journal article deals with this type of subject, theories on competitiveness by Porter (1998a, 1998b, 1998c), innovation and innovation system in Korea by Kim (1997), and innovation system of Korea by Lee & Song (1998) were included in the cocitation along with the leading figures. Classical books by Nelson & Winter (1982) and Rosenberg (1983), textbooks by Freeman (1982), Freeman & Soete (1997) and Dosi et al. (1988), and research in sectoral system by Breschi & Malerba (1997) and Malerba (2002) are also commonly cocited publications in national system of innovation research. Edquist (1997) and Patel & Pavitt (1994) are also cocited in national system of innovation.

Another group deals with facts on innovation, which is much smaller than national system of innovation, but bigger than other research areas. This area is supported by dynamic process by Utterback & Abernathy (1975), Abernathy & Utterback (1978), and Utterback (1994), sectoral patterns by Pavitt (1984), technological paradigm by Dosi (1982), absorptive capacity by Cohen & Levinthal (1990), and architectural innovation by Henderson & Clark (1990).

4. Cocitations between domestic and foreign

We can consider a pair of cocitation as a link between two cited authors. Since any two authors can be cocited many times, the link is weighted. 〈Table 4〉 shows the degree of link exchanges between the countries of authors. Since we do not care

about the direction of the link, the weights in 〈Table 4〉 are counted twice. We notice that the link exchange activity between foreign scholars is highest, about three times that between Korean scholars.

On the other hand, regarding the cocitations between Korean scholars it is conjectured that an apparent phenomena is the cocitations among the researchers on the valuation of technology, a new branch of research in Korea. They have accumulated their own research records. The research group is narrowly focused, but the members in the group are very cohesive for generating knowledge.

〈Table 4〉 Cocitations between domestic and foreign authors

	Korea (29)	Foreign (71)
Korea (29)	2,464 (85)	4,233
Foreign (71)	4,233	16,426 (228)

Note: ( ) means average

V. Identification of Major Groups

1. Factor Analysis

The cocitation matrix can be used to generate a correlation matrix. From the correlation matrix, we can measure the correlation between the pairs of two authors. It measures the inter-author proximity in terms of their cocitations. The higher the positive correlation, the more similar two authors are in the perceptions of citers (McCain, 1990). We assume that 100 authors or variables describe the intellectual sphere of technology innovation management in Korea. Since the dimension of the sphere is too high, we need to make the size of dimension smaller. A factor analysis is a useful technique for that. Based on the correlation matrix, we performed a factor analysis using SPSS 12.0.1.

To determine the number of factors to be extracted, the scree test and the threshold value of eigenvalue are commonly used (McCain, 1990). The scree test is used to

determine the appropriate number of factors to be extracted based on the scree plot. Cattell (1966) suggested that when the eigenvalue or variance explained suddenly drops and becomes flat for additional inclusion of factors, that is the point where we stop increasing the size of factors. Based on the scree plot, we chose the eigenvalue 2.0, since if we use the general threshold of eigenvalue 1.0, the number of factors becomes too big. We came up with 9 factors. We used VARIMAX rotation for calculating factor loadings. The nine factors account for 72.64% of variance. Variables with factor loading greater than 0.4 are shown in 〈Table 5〉.

〈Table 5〉 Factors and corresponding variables with factor loadings

Factor	Name	Authors / Loadings	Eigen value
1	Technology/ Innovation	Stankiewicz, R., Saxenian, A., Carlsson, B., Cooke, P., Edquist, C., Malerba, F., Johnson, B., Tassey, G., Teubal, M., Foray, D., Lundvall, B., Rosenberg, N., Dosi, G., Porter, M.E., Sung, T.K., Freeman, C., Nelson, R., Lee, K.R, Chung, S.Y, von Hippel, E., Breschi, S., David, P., Winter, S., Mowery, D., Song, W.J, Soete L., Pavitt, K., Schumpeter, J.	17.72
2	Management of Technology	Tushman, M., Anderson, P., Clark, K., Leonard-Barton, D., Van de Ven, A., Pisano, G., Shuen, A., Levinthal, D., Teece, D., Utterback, J., Nonaka, I., Eisenhardt, K., Dodgson, M., Fujimoto, T., Metcalfe, J., Henderson, R., Perez, C., Kim, Y.B, Cohen, W., Rothwell, R., Bessant, J., Walsch, V.	14.72
3	Economics of Technology	Schmookler, J., Lee, W.Y, Levin, R., Jang, J.K, Scherer, F., Griliches, Z., Mansfield, E., Acs, Z., Hong, S.K, Yoon, M.S, Jaffe, A., Shin, T.Y, Park, B.M, Link, A., Kamien, M., Ahn, D.H	10.53
4	Development	Dahlman, C., Westphal, L., Bell, M., Amsden, A., Lall, S., Hobday, M., Hamel, G., Lee, J.J, Prahalad, C., Bae, J.T, Cho, H.D, Kim, I.S, Lee, K.	9.14
5	Valuation	Seol, S.S, Park, J.O, Hur, E.N, Smith, G., Hyun, B.H, Park, Y.T, Yoo, S.H, Kim, J.H, Narin, F.	5.52
6	Growth	Katz, M., Shapiro, C., Romer, P., Arrow, K.	4.49
7		Patel, P, Lee, J.J	4.11
8		Lee, J.W, Choung, J.Y, Hwang, H.R, Cooper, R.	3.65
9		Williamson, O., Kim, K.S	2.77

Note: When a variable appears on more than one factor, we assigned the variable to the factor with the biggest loading.

Note that an author can appear on more than one factor. Among 100 authors considered all of them are assigned to one or more factors. 24 authors appear in more

than 1 factor. If that is the case, we examined the loadings and selected the highest factor for that author. For example, 4 authors appeared on both factor 2 and 4, but we placed them only on factor 2. Similarly, 9 authors on factors 7, 8, and 9 were removed and placed on factor 2 and 4, since they had higher loadings on these factors. The data manipulation increased the similarities among the authors in each group, while decreasing the authors on factor 7, 8, and 9. In this way the number of factors decreased from 9 to 6, and we were able to name the six factors.

2. Clustering

To compare the results of the factor analysis we also performed clustering on our data. Since six out of nine components were identified as meaningful, we performed a top-down clustering algorithm or K-means, where K=6 using the correlation. For the clustering we used the Euclidean distance measure based on the centroid of a cluster. Since Ahlgren et al. (2003) claimed the Pearson's correlation coefficient is not a good choice for cocitation analysis, we also tried the cosine distance measure using the raw cocitaiton matrix. The clusters we obtained are on 〈Table 6〉.

〈Table 6〉 Clusters of authors

Cluster	Authors
1	Nelson, R., Dosi, G., Rosenberg, N., David, P., Winter, S., Freeman, C., Lundvall, B., Perez, C., Mowery, D., Song, W.J, Pavitt, K., Cohen, W., Levinthal, D., Carlsson, B., Schumpeter, J., Lall, S., Utterback, J., Metcalfe, J., Rothwell, R., Johnson, B., Malerba, F., Dodgson, M., Bessant, J., Soete, L., von Hippel, E., Teubal, M., Walsh, V., Kim, I.S, Cho, H.D
2	Teece, D., Clark, K., Tushman, M., Pisano, G., Shuen, A., Anderson, P., Amsden, A., Lee, K., Lee, J.J, Bae, J.T, Hobday, M., Dahlman, C., Bell, M., Van de Ven, A., Prahalad, C., Hamel, G., Westphal, L., Fujimoto, T., Kim, Y.B, Lee, J.W, Choung, J.Y, Nonaka, I., Cooper, R., Eisenhardt, K., Hwang, H.R, Leonard-Barton, D.
3	Hong, S.K, Park, B.M, Griliches, Z, Jang, J.K, Park, Y.T, Ahn, D.H, Lee, W.Y, Yoon, M.S
4	Tassey, G., Porter, M., Saxenian, A., Lee, K.R, Lee, J.J, Sung, T.K, Chung, S.Y, Breschi, S., Foray, D., Edquist, C., Patel, P., Stankiewicz, R., Kim, K.S, Cooke, P.
5	Seol, S.S, Park, J.O, Hyun, B.H, Hur, E.N, Smith, G., Yoo, S.H, Kim, J.H
6	Scherer, F., Schmookler, J., Arrow, K., Shapiro, C., Jaffe, A., Kamien, M., Katz, M., Mansfield, E., Link, A., Acs, Z., Williamson, O., Shin, T.Y, Levin, R., Henderson, R., Romer, P., Narin, F.

One hundred authors were clustered into 6 groups. Characteristics in some clusters can be easily figured out, but those of others cannot be. It is not clear to find similarity among the authors in clusters 1, 2, and 4, in terms of research areas, geographical distances, academic backgrounds, etc. The result of the factor analysis seems to be better compared with the three clusters.

On the other hand, cluster 3 consists of economists specializing in productivity issues and most of them are Korean. Economists are also major force of cluster 6, but mixed with research in productivity and growth. Considering the overlapping of cluster 3 and 6, the factor analysis works better than the clustering analysis.

Meanwhile most of the member of cluster 5 are Korean and nearly similar to the member of factor 5 of factor analysis.

3. Results

From the observations based on the factor analysis and clustering analysis, we can conclude the following:

The six factors derived by the factor analysis can be represented as six areas of technology innovation management. It is very difficult to assign name to the first group: technology school in a narrow meaning, or technology and innovation etc. The areas, however, are named as technology and innovation, management of technology, economics of technology, development, valuation of technology, and growth.

The biggest group of 28, factor 1, encompasses most of the scholars doing research on technology and innovation. We note that five Korean researchers are in the group. Three out of the five received their Ph.D. degrees from the European universities which are famous for technology innovation research.

Factor 2 consisting of 22 represents management of technology, factor 3 of 16 authors is related with economics of technology.

Development group or factor 4 with 13 authors mainly deals with the development of technology and economy, and the major research issue of factor 6 is growth oriented by traditional economists. Most members of development group are specialized

in management of technology, and most members of growth group are economists.

Factor 5 of 8 researchers is specialized in the valuation of technology. Most of them are Koreans, and F. Narin is exceptional due to his nationality and low factor loading. The group actually has emerged in Korea around the year 2000, and has grown to become the second largest research group after the group of national innovation system. Seol (2000 a, b) are highly cited works in this group with 9 citations respectively.

4. Multidimensional Scaling

McCain (1990) suggested that a multidimensional scaling is a useful graphical tool for author cocitation analysis since it enables analysts to capture hidden patterns in a set of data through a visual map. The map gives an intuitive way of interpreting the dispersion of variables. Multidimensional scaling uses a correlation cocitation matrix. Authors with high similarities are placed close together and authors with high dissimilarities are placed farther apart in a map.

Similarly to McCain's analysis (1990) where two dimensions such as "style of work" and the degree of mathematics involved were detected, we performed the scaling based on PROXSCAL in SPSS to map the authors onto 2 dimensions. But the normalized raw stress is 0.503, and the DAF (Dispersion Accounted For) value is only 0.497. Note that DAF value refers to the ratio of the variance explained. These results indicate that the multidimensional scaling is not statistically significant for the data of technology innovation management in Korea.

The reason might be explained as follows. As in the factor analysis where we were not able to name three out of nine factors in the factor analysis, the dependent variable, the number of cocitations, might depend on other sources as well as the demand of knowledge augmentation. Another reason might be that the cocitation dataset contains 3,118 links among authors. Since we have 100 authors, the maximum number of links is 4950 (= 100 x 99 / 2). The density of the links is 63%. Authors in a high density network tend to be connected to most of the remaining authors. The

high density of our dataset might be the reason for failure of the mapping onto a small dimension.

VI. Concluding remarks

The major purposes of the research are to see the underlying disciplines of technology innovation management which contribute to Korean research. To do that, we employed author cocitation analysis which has been proved to be robust. For the source data we compiled all the citations of two major Korean journals between 1993 of inception year and 2006. We also included up to 3rd author in the cocitation analysis to make the analysis more comprehensive. For the analysis we used three methods: factor analysis, clustering analysis and subjective method of assigning meanings to each discipline. We found the first two analyses can be employed for complementary reasons.

Along with cocitation analysis we also included the relation between citation and cocitation and the cocitation patterns since we recognized them during the course of data analysis. The major findings are the following. The number of cocitations to some authors is small, even though the number of citations to those is high, and vice versa. We were able to group 100 authors with 4 groups in terms of citations and cocitations. We derived and analyzed 23 authors, so-called 'big guys', who command both higher citations and cocitations, excluding self-citations. They show that the average number of publications is 22.2, the average number of citations to them is 58.5, and the average number of citations to a publication is 2.6. Also, the average number of cocitations is around 10 times that of citations.

The results indicate that there are six major disciplines: Technology/Innovation, Management of Technology, Economics of Technology, Development, Valuation of Technology, and Growth. The magnitude of group size is the order as in the preceding sentence. Noteworthy points are the following. First, most of the members of the technology management group are management scholars, and the groups of economics of technology and growth are economists, while the groups of technology innovation

and development group are not represented by specific disciplines. Second, considering the groups overall from the traditional academic disciplines, the main branches are management and economics. Third, the valuation of technology group consists mostly of Korean researchers.

The analysis of this paper is based on studies in Korea. Therefore, the results may be different from those in a specific country or the whole world. For example, the theme of the national innovation system in Korea, the most frequently cited and cocited in our analysis, reflects the prevailing discussions of research circles to support the Korean National Innovation System Initiative which the Korean government initiated its policy since 2002. The technology valuation, the next popular area in Korea, is also an academic forum to uphold the so called "venture boom" emerged during the end of 1990s.

This study did not consider longitudinal aspects. Since the technology development in Korea has been rapidly pursued, required innovation research must be dynamic. For the future research we need to accommodate the dynamics.

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설성수

고려대학교에서 "정보기술혁신의 경제성 분석"으로 박사학위를 취득하고 한남대학교 경제학과 교수로 근무 중이다. 한국기술혁신학회 학회장을 역임했고, 주요 연구분야는 기술혁신, 가치평가, 지식활동분류 등이다.

남수현

뉴저지 럿거스 대학에서 경영학 박사학위를 취득하고 현재 한남대학교 경영정보학과 교수로 재직 중이다. 주요 연구분야는 네트워크 기반 지식추출, 지식경영, 사회네트워크 등이다.

박정민

이화여자대학교 생물학과를 졸업하고, 한남대학교에서 경제학 박사학위를 취득하였다, 한국기초과학지원연구원 정책연구부 선임연구원으로 재직 중이다. 주요 연구분야는 바이오기술혁신, 가치평가, 연구장비정책 등이다.