Analysis of the Structure of Technology Spillover on Industries by Analyzing Patents

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Abstract

The objective of this paper is to examine the structure of technology spillover from UAV (Unmanned Air Vehicle) technology on other industries by analyzing patents. The network analysis of the USPTO (United Stated Patents and Trademark Office) patent data from 1981 to 2000 was adopted to investigate the characteristic change of the technology spillover. The results show that the influence of UAV technology on other industries has grown over the twenty-year period. For weapons system development, this study provides a research basis to estimate the technology spillover effects on industries. Searching a structural hole from the inter-industrial knowledge flow structure may be a useful technique to find core technologies which generate large technology spillover on the other industries.

Keyword: patent analysis, technology spillover, UAV (unmanned air vehicle)

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1. Introduction

Nowadays most economists of both advanced countries and newly industrialized countries concur that technological innovation functions as motive power for persistent economic growth. As knowledge-based economy arrives, technological innovation and diffusion structure are considered as important factors to transform economic system to knowledge society (OECD, 1996). In economic structure of Korea with insufficient endowed resources, the existence of mechanism that effectively creates knowledge and rapidly diffuses it to main economic groups will play a significant role in developing industrial competitive power.

Technological knowledge is a basic source of creating economic effects and a cardinal point of knowledge-based economy in creating, diffusing, and using technological knowledge. Most technological innovations go through drastic changes in the processes of application and utilization, and it continues to advance through being combined with other knowledge in the cases of completely new goods or processes. While the past approach of understanding involved a strict division of discovery, invention, innovation, and diffusion, lately a perspective places more emphasis on interactions and connection between processes (Lundvall, 1988; Rosenberg, 1982).

Of previous researches related to the flow of technological knowledge, Verspagen

(1997), Verspagen & Loo (1999) use two dimensions of technological area that creates spillover and technological area that receives spillover in order to present a method that builds a technology flow matrix model and measures technology spillover. Los (1997) analyzes technological connection with technological area and industrial area as separate axes. Jeffe & Trajtenberg (2002) examine knowledge from university and governmental research institutes or centers, and international knowledge diffusion through patent citation analysis, while Muller & Schnitzer (2006) studied technological transfer and spillover at Industrial Joint Ventures. Mueller & Culbertson (1986) analyzed inter-industry technological flow in the U.S. food-processing industries through patent analysis. Studies using inter-industry relations table have analyzed structural interconnectedness and the flow of technological knowledge between industries (Karkacier et al., 2005; Scherer, 1982; Griliches et al., 1984). Research through network analysis has compared innovation flow between Italy and Germany and technological systems between countries or compared inter-industry knowledge flow by using disembodied knowledge flow such as research & development personnel (Leoncini et al., 1996; Schartinger et al., 2002).

Units of analysis in previous research are at the level of industry or technology. In case of research and development of an aggregate of particular technology, it is difficult to understand structural forms and characteristics of spillover that various technologies included in weapons system have on other industries.

After analyzing patent information that makes up an aggregate of technologies such as Unmanned Air Vehicle (UAV), this study examines the structure and characteristics of technology spillover that affect industry by using Cites per Patent (CPP) on patent citations in other industries.

2. Theoretical Background

2.1. Patent Analysis

Patents are objective and standard technological information, so they can be put to a good use in viewing not only technological levels but also the flow and trends of technological innovations (Archibugi, 1992; Archibugi et al., 1996; Brockhoff, 1992; Jacobsson, 1996; Mogee, 1991).

Patents are to protect the inventions created and developed by individuals or companies, but also they are ultimately to promote industrial development. Thus, utilization of patent information can be used as an instrument to lead industrial advancement. Due to a lack of the materials to explain essential qualities and characteristics of technologies, research on technological changes have remained at a conceptual level, but it is expected to address certain issues by making use of patent information (Trajtenberg, 2002).

Citation relationship among patents is used to study the diffusion of technological information, to evaluate the values and effects of technologies (Hall et al., 2000; Jaffe et al., 1999; Karki, 1997), or to analyze the volume of flow and spillover of technological knowledge (Ham et al., 1998; Jaffe et al., 1999).

When main ideas of patent citation analysis are frequently cited by patents applied after a particular patent, it indicates that the particular patent contains significant technological progress that becomes a foundation for the development of subsequent patents (Karki, 1997).

2.2. Technology Spillover

Technology spillover means external effects of technological knowledge newly created by R&D activities of a company or an industry on productivity growth of other companies or industries (Bernstein et al., 1988; Jaffe, 1986; Verspagen et al., 1999).

Traditionally researchers of technological innovation divided spillover into embodied spillover and disembodied spillover (Bharadwaj et al., 2005; Bin Xu et al., 1999; Cohen et al., 1989; Kim et al., 2004). The former indicates technology spillover generated from a process in which a machine or equipment manufactured by new technology is transferred from one industry to the other through inter-industry transactions. Since this kind of spillover effect manufactured by new technology generally has higher efficiency than previous one, it implicitly captures its contribution to productivity advancement of a buyer. The latter involves the flow of technological information through human network such as patents or academic journals or the diffusion of new technology through movement of research personnel or reverse engineering.

2.3. Methods to measure Technology Flow

The methods to measure technology flow relationship include a method to use patent flow, a method to use innovation flow, and a method to use inter-industry relations table.

The first method of using patent flow is to estimate the flow of technical knowledge by using a matrix table of patent invention industry and user industry. By expanding Leontief's idea of input-output analysis, Schmookler (1966) proposes a type of input-output matrix table with innovation industry in rows and use industry in columns, and inventions for process industry in diagonal matrix.

The method that uses technological innovations make three-dimensional matrix table with an area of creation for individual innovation, an area of usage, main areas in which innovation companies are active and uses this to examine the flow relation of technical knowledge (Pavitt, 1984).

Lastly, the method that uses inter-industry relations table is to determine flow relation of technical knowledge through inter-industry relations of the table. Knowledge flow using input-output analysis underlines that the flow of technical knowledge is generated in proportion to trading volume of intermediate goods and capital goods from supply industry to demand industry.

3. Research Methodology of Spillover Structure

3.1. Measurement of Technology

3.1.1. Calculation of Technical Knowledge

It is necessary to calculate the volume of technical knowledge of each industry in order to understand inter-industry knowledge flow. OECD suggests R&D personnel, R&D investment, patent, technology balance of payments as the indexes to measure the volume of technological knowledge and made and presented a manual related the indexes (OECD, 1996).

In this study, the volume of technical knowledge was measured by using the number of patent registration and used it as an index to estimate inter-industry knowledge flow with CPP (a patent using patented technology) as a proxy variable.

3.1.2. Cites per Patent (CPP)

CPP is an index to show the impact of patents owned by a country or a company on subsequent activities for technological innovation, and it allows examining technological significance of a patent, a level of activities for innovations by a certain country or company, and the value of innovative achievements. CPP is calculated by obtaining the average number of citation of patent registered in a certain year (or period) by subsequent patents (Korea Institute of Patent Information, 2005).

$$CPP_t = \frac{\sum_{i=1}^{n_t} c_i}{n_t}$$

n_t : number of patent registered in t-year

C_i : cited number of i-patent

Patent citation information analysis is based on citation analysis of articles in the fields of science and technology. After Garfield created the Science Citation Index (SCI) in the 1960s, citation analysis for scientific and technological articles began to be applied to patents. It was followed by empirical research on if patent citation information is actually linked to important technological achievements (Carpenter et al., 1981), and research results found from various perspectives have shown intimate relations between cited information of patent and technological significance, the value of innovative accomplishments, and market value of a company.

3.1.3. Matrix of Knowledge Flow

<Figure 1> is a matrix of knowledge flow drawn from patent citation analysis. Its Y-axis is set to be cited industries of UAV technology; X-axis is citing industries of UAV technology; and, the numbers expressed in each cell is the number of citations for each patent. Technical knowledge flows from cited industry to citing industry; so, since a certain industry on the X-axis cites a patent that belongs to an industry on the Y-axis, it is defined that a direction of knowledge flow is from Y-axis to X-axis.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1																											
2																											
3																											
4																											
5																											
6																											
7																											
8								173			2	5	8	5				6	96				7		8	31	
9																											
10																											
11																											
12								1				43	1						4								
13							1	3					23	2			4	2	18			5		3	6	23	
14																											
15							1	1							39		23	1		2	1	6	6	2	6	62	5
16																											
17																	28				1	6	6		4	57	
18							1	1											16								
19							28	37			1	43	21	10	6		5	24	178	1	10	40	52	3	112	160	16
20																											
21																											
22								3				7	67				14	6	7		1	29		4	68	55	6
23								11					5	2			1	11	35		2		30		12	26	
24								3					1						3			4		4			
25						2		1				21	161	1		2	35	25	39		6	75	15		250	181	28
26						2		21				7	60	3		2	44	17	32		5	31	11		123	190	16
27																			1			2			8		

<Figure 1> Matrix of Knowledge Flow

3.2. Network Analysis

Network analysis is a quantitative method to analyze linkage structure between nodes in a system by using graphs (Leoncini, R. et al., 1996; Scott, 2000; Wasserman et al., 1997). Knowledge flow matrix between technology and industry can be dichotomized into the following knowledge network and a matrix itself is considered as a network. Knowledge network, Gv, is composed of industries (N), inter-industry connected relationship (L), and the degree of inter-industry knowledge flow (V).

$$K \equiv > \; Gv(N, L, V)$$

Since connected relationship of technological knowledge network is composed of inter-industry knowledge flow, inter-industry connection one-to-one corresponds to the degree of connection.

3.2.1. Indexes of Technology Network

In this study, two indexes - density and centrality - are calculated to understand structural characteristics of knowledge network. First, density means the degree of linkage between nodes in a network and is a concept to express how many relations exist between components within a network (Wasserman et al., 1997). In order to understand systematic connection of a network, network density can be estimated as follows.

$$D = \frac{l}{g(g-1)}$$

A denominator is a number of cases when a connection is made by inflow and outflow between all nodes and g means the number of industries. A numerator, l, is an actual total number of connection between nodes within a network. As density increases, systematic connection of a network increases. This means that inter-industry connections are dense and there is more possibility for knowledge created in one industry to reach other industries of a network.

Second, centrality is an index to indicate the degree of which one node is located in a center of a network. Measurement of centrality can be divided into many forms depending on research subjects and researcher’s interest. This study deals with linkage degree centrality, closeness centrality and betweenness centrality (Wasserman et al., 1997).

Degree centrality is a concept to see the degree of linkage with other nodes and measures the number of other dots connected to one dot as follows.

$$C_D^O = \sum_j l_{ij}, \quad \overline{C_D^O} = \frac{\sum_{i=1}^{g} [C_D^O(n^*) - C_D^O(n_i)]}{(g-1)(g-2)}$$

$$C_D^I = \sum_j l_{ij}, \quad \overline{C_D^I} = \frac{\sum_{i=1}^{g} [C_D^I(n^*) - C_D^I(n_i)]}{(g-1)(g-2)}$$

Subscript indicates an index of degree centrality and superscripts, O and I, means the relationship of knowledge inflow and outflow. Centrality index indicates the number of nodes that are subject to knowledge inflow and outflow of a node, and is an index to distinguish influential industries in an analysis of the structure of technology spillover. Centralization index is measured by dividing an industry with the largest centrality index by the maximum centrality index that an industry with the sum of differences of centrality index of each industry can have, and it expresses the degree of impact that a certain industry can have on the overall system. As this index value is bigger, a system is thought to have a structure centralized on a certain node (industry) and it is useful to explain hierarchy of a system.

Degree centrality index is interested in direct linkage between nodes, and even though they do not compose direct connection flow relations, knowledge inflow and outflow are possible through several steps of flow relations. What is estimated in consideration of this are closeness centrality and betweenness centrality indexes.

For closeness centrality, a distance between two nodes is a core concept, and it is estimated in a similar manner with degree centrality index in consideration of knowledge flow that can occur through several steps. Usually the nodes with high degree centrality index are found to have high closeness centrality index. Betweenness centrality is a concept to measure performance degree of an intermediary role when one node builds a network with other nodes and it measures how much one node is connected to other nodes in a path of knowledge flow. In explaining knowledge spillover, this is a very important index in terms of identifying an industry that plays a pivotal role in connecting knowledge flows among different industries.

3.2.2. Structural Hole

Structural holes, which is a concept suggested by an American sociologist named Ronald Burt, indicate the positions where one node is not overlapped in connecting with other nodes and can be connected to other nodes only through the agent.

In Structural Hole Theory, overlapping is perceived as not providing additional new information, so overlapped relations are considered as waste. Thus, according to this theory, efficient positions on network are structural holes without this waste. Perfect structural holes mean points where one node is connected to other nodes without overlap; because it is difficult for perfect holes to exist in reality, structural holes are generally used to indicate the positions with a considerably small number of overlaps. In the case of structural holes, as connected relations with other nodes without overlap increases, its effect increases. One of the most important effects of the nodes located in structural holes is pointed out to be superiority of information assurance (Burt, 1992). Since the nodes located in structural holes have various connections, its effect is based on the fact that it can come in touch with diverse information.

In order to make it easy to analyze structural holes in technological knowledge network, inter-industry connections with relatively weak degree are ignored and their connections with main industries are focused. For this, Gv in K matrix is dichotomized into G_D as follow depending on cutoff values to perform network analysis on the basis of this (Scott, 2000; Wasserman et al., 1997).

$$G_V \equiv> \ G_D(N, L_D)$$

$$L_D = \{ l_{ij} \}$$

$$\text{where, } l_{ij} = 1 \text{ for } v_{ij} > \text{cutoff}$$

$$l_{ij} = 0 \text{ for } v_{ij} \leq \text{cutoff}$$

l_{ij} expresses knowledge flow from i-node to j-node, and when the value is 1, it means that knowledge flow bigger than cutoff value exists.

4. Empirical Analysis

4.1. Data Collection and Classification

This study uses the number of patent registrations provided by the United States Patents and Trademark Office (USPTO) in order to investigate the structure of technology spillover on other industries. By using the Aureka program of the U.S. Tomson Co., the data on UAV categorized by the U.S. patent classification system was sampled. As shown in Table 1, the period of analysis was from 1981 to 2000, divided into 4 sections. Industries that construct UAV and industries to which spillover occurs were considered only for the first spillover. Based on this data, the structure of technology spillover on other industries was analyzed by using a network analysis program, Ucinet 6.0.

<Table 1> Data Collection

	1981-1985	1986-1990	1991-1995	1996-2000
Number of patent	37	86	113	209
Number of citation	450	1015	1119	1891
Number of UAV industry	13	16	18	17
Number of spillover industry	20	22	22	24

When the USPTO patents were analyzed, most of single patents include many technological areas. Therefore, when a given patent is categorized by the U.S. patent classification (USPC) system, a problem arises regarding distribution. In this case, there are the first technology classification, multiple counting, and fractional counting (Korea Institute of Patent Information, 2005). In this study, the second method, multiple counting, was applied centering around technology groups to analyze the structure of technology spillover on other industries.

When the countries to which UAV technology groups are spilled over are analyzed, mostly they are cited as the U.S. patents and some spillover occurs in diverse countries including WO (World Intellectual Property Organization), EPO (European Patent Office), GB (United Kingdom), and DE (Germany). However, because its frequency is low and patent classification system is different from the USPC, the analysis in this study is carried out with focus on the USPC system.

<Table 2> Industrial Classification

1.Agriculture, 2.forestry and wood manufacturing, 3.fishery, 4.mining, 5.foodstuffs manufacturing, 6.textile manufacturing (excluding sewing clothing), 7.coke/refining oil & nuclear fuel manufacturing, 8.chemistry products & sewing/shoes pulp manufacturing, 9.medical and pharmaceutical products manufacturing, 10.rubber & plastic products manufacturing, 11.nonmetallic minerals manufacturing, 12.primary metal industry, 13.assembled metal products manufacturing, 14.computer and office equipment manufacturing, 15.motor/generator & electricity converter manufacturing, 16.electricity service/electric control equipment manufacturing, 17.battery/lighting manufacturing, 18.semiconductor & other electronic parts manufacturing, 19.communication machinery/broadcasting equipment manufacturing, 20.medical equipment manufacturing, 21.precise instrument manufacturing, 22.shipping equipment manufacturing, 23.electricity/gas & steam, 24.construction, 25.transportation, 26.communication, 27.data processing

First, to analyze the structure of technology spillover on other industries, it is necessary to prepare a connection table that is the standard. The number of categories in Korean Standard Industrial Classification is 27, and the industries that can be related to the U.S. patented technologies were selected including manufacturing and service industries and its categories were combined or divided and adjusted to have them classified as shown in <Table 2> (Lee, Y.Y. et al., 2004). Finally, the first spillover technology and UAV technology analyzed by the USPC system were connected with the Korean Standard Industrial Classification System.

4.2. Systematic Connection of Spillover Structure

Systematic connection of the structure of technology spillover on other industries can be generally examined through density analysis. As the UAV CPP varies by industry, valued network was applied to reflect the original data between industries to seek for more accurate network expressions.

<Table 3> shows density for each period and compares and analyzes standard deviation to divide and analyze them depending on inter-industry self-citation relation. When density changes in spillover structure of UAV technology are examined, persistent growth is observed in all periods except for the 1991-1995 periods, which indicates that the relationship between UAV technology and other industries becomes close as time went by. When citations in the same industry are included, density is more than doubled from 26 in the early 1980s to 54 in the late 1990s. This demonstrates that as UAV industry develops, inter-industry relationship becomes closer.

Standard deviation for the number of connections by year also continuously increases, which means that the structure of UAV technology spillover onto other industries was initially shaped around particular industries, but spillover was gradually expanded to other diverse industries.

<Table 3> Comparative Analysis of Density and Std Dev

	Self-Citation excluded		Self-Citation included	
	Density	Std Dev	Density	Std Dev
1981-1985	20.6053	33.3907	26.6880	45.0002
1986-1990	24.1195	41.5841	38.5287	104.5325
1991-1995	20.2228	43.6738	32.4150	98.8281
1996-2000	32.3623	92.2512	54.5911	242.9131

4.3. Structural Characteristics on Technology Spillover

In order to accurately perform a comparative analysis of the structural characteristics on UAV technology spillover onto other industries, valued network that can reflect the inter-industry difference of UAV CPP was applied to estimate the indexes of degree, closeness, and betweenness centralities as well as centralization. <Table 4> organizes partial centrality indexes by period for 27 segments of industry. <Table 5> shows main high-order industries analyzed by period and index type.

UAV-related core industries are communication, transportation, communication machinery/broadcasting equipment manufacturing throughout all periods, maintaining basic structural form; yet it was expanded to peripheral industries as time went by. Core technology groups of communication, transportation, and communication machinery/broadcasting equipment manufacturing are US Patent Class 342 (Communications: directive radio wave systems and devices (e.g., radar, radio navigation)), Class 701 (Data processing: vehicles, navigation, and relative location), and Class 244 (Aeronautics), respectively. After the mid-1980s, data processing with Class 705 (Data processing: financial, business practice, management, or cost/price determination) as its core technology emerged as a core industry, and so did semiconductor & other electronic parts manufacturing with Class 348 (Television) technology group after the mid-1990s.

The industries onto which UAV technology spillover intensively occurred are communication, transportation, and communication machinery/broadcasting equipment manufacturing, and assembled metal products manufacturing in the early 1980s and data processing and semiconductor & other electronic parts manufacturing afterwards emerged as core industries that utilize UAV technology.

In case of classification by the flow of technological knowledge, the industry that continues to release technical knowledge to other industries throughout all periods is communication machinery/broadcasting equipment manufacturing. It is because 244 (Aeronautics) technology group, which is a core technology group in aviation technology, is included in this industry. UAV technological knowledge is mainly absorbed to communication. After the mid-1980s, it was absorbed to computer and office equipment manufacturing.

<Table 4> Partial Centrality Indexes

Industry	1981-1985		1986-1990		1991-1995		1996-2000	
	Out	In	Out	In	Out	In	Out	In
1	0	0	0	0	0	0	101	225
2	0	0	0	3	60	2	0	0
3	0	0	0	1	0	0	0	1
4	0	0	0	0	0	0	0	1
5	0	0	0	0	0	0	0	1
6	0	4	0	0	0	3	0	11
7	0	31	0	1	8	10	0	2
8	168	82	201	119	256	401	474	305
9	0	0	0	0	0	0	0	0
10	0	0	46	6	0	16	8	24
11	0	3	0	30	84	98	9	62
12	6	83	142	281	75	109	84	94
13	67	324	319	265	302	182	214	294
14	0	23	165	266	0	100	113	192
15	116	6	21	9	35	11	77	44
16	0	4	0	2	0	1	0	25
17	74	126	52	129	92	100	17	208
18	18	92	250	189	267	247	458	409
19	569	251	667	281	657	496	875	470
20	0	3	0	44	4	23	268	184
21	0	26	0	20	48	77	179	176
22	238	169	189	236	108	46	57	179
23	105	97	100	162	161	91	127	106
24	11	12	45	32	5	31	90	56
25	592	347	483	552	499	420	1496	1096
26	374	595	749	788	786	978	1808	1811
27	11	71	406	419	274	279	244	724
Mean	87	87	142.037	142.037	137.815	137.815	248.111	248.111
Std Dev	164.39	138.965	207.664	193.243	206.802	215.910	443.801	392.928
Min.	0	0	0	0	0	0	0	0
Max.	592	595	749	788	786	978	1808	1811

<Table 5> Primary Industries on the Centrality Indexes

	Centrality Indexes	Primary Industries
1981 - 1985	Degree	transportation, communication machinery/broadcasting equipment manufacturing, communication
		communication, transportation, assembled metal products manufacturing
	Closeness	precise instrument manufacturing, computer and office equipment manufacturing, coke/refining oil & nuclear fuel manufacturing
		precise instrument manufacturing, computer and office equipment manufacturing, coke/refining oil & nuclear fuel manufacturing
	Betweenness	communication machinery/broadcasting equipment manufacturing, transportation, communication
1986 - 1990	Degree	communication, communication machinery/broadcasting equipment manufacturing, transportation
		communication, transportation, data processing
	Closeness	precise instrument manufacturing, medical equipment manufacturing, nonmetallic minerals manufacturing
		precise instrument manufacturing, medical equipment manufacturing, nonmetallic minerals manufacturing
	Betweenness	assembled metal products manufacturing, communication machinery/broadcasting equipment manufacturing, communication
1991 - 1995	Degree	communication, communication machinery/broadcasting equipment manufacturing, transportation
		communication, communication machinery/broadcasting equipment manufacturing, transportation
	Closeness	computer and office equipment manufacturing, textile manufacturing (excluding sewing clothing), rubber & plastic products manufacturing
		computer and office equipment manufacturing, textile manufacturing (excluding sewing clothing), rubber & plastic products manufacturing
	Betweenness	communication machinery/broadcasting equipment manufacturing, electricity/gas & steam, chemistry products & sewing/shoes pulp

		manufacturing
1996 - 2000	Degree	communication, transportation, communication machinery/broadcasting equipment manufacturing
		communication, transportation, communication machinery/broadcasting equipment manufacturing
	Closeness	electricity service/electric control equipment manufacturing, textile manufacturing (excluding sewing clothing), mining
		electricity service/electric control equipment manufacturing, textile manufacturing (excluding sewing clothing), mining
	Betweenness	communication, chemistry products & sewing/shoes pulp manufacturing, communication machinery/broadcasting equipment manufacturing

After the mid-1990s, it began to be absorbed to agriculture for the first time. It was analyzed that 435 (chemistry: molecular biology and microbiology) plays a leading role in this core technology group.

There are primary industries that perform an intermediary role in the flow of UAV technological knowledge throughout all periods: (1) transportation including traffic facility planning and design technology and traffic operation and management technology, (2) communication that are composed of transmission technology, exchange technology, radio wave technology, and wireless and mobile communication technology, and (3) data processing. Besides, semiconductor & other electronic parts manufacturing and electricity/gas & steam play a significant role in the medium of knowledge.

Industries that have no or little impact on the structure of UAV technology spillover are forestry and wood manufacturing, fishery, and mining that are mainly primary industry. This kind of industry group decreased from coke/refining oil & nuclear fuel manufacturing industries in the early 1980s to fishery industries in the late 1990s. This shows that the impact of UAV technology on the overall industries increases, as time goes by.

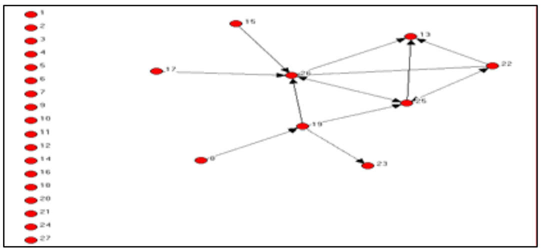
When the number of citations of UAV technology by other industries is analyzed, the average number is 87 and the total count of citations is 2,349 in the early 1980s. After its subsequent steady increase, the average number is 248 and the total count of citations is 6,699 in the late 1990s, demonstrating that the number of citations of UAV technology throughout industries persistently increased. When the number of citations in the same industry is included, the total citation counts increase by 30-45%, which indicates that as UAV technology becomes mature, the number of self citations also increases. The increase in the number of self citation means that as UAV technology matures, spillover occurs not only onto other industries but also in the same industry.

4.4. Structural Hole of Technology Spillover

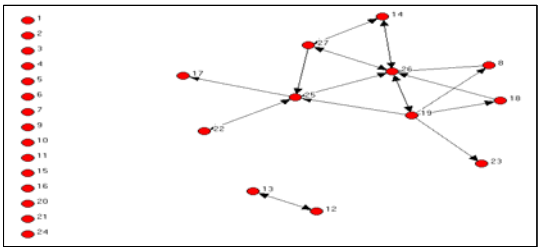
For an analysis of structural hole industry that performs a role of core industry for each period, a reasonable cutoff value was applied for analysis. Because technology flow exists between most industries, inter-industry connections with relatively little technology flow should be ignored to make it easy to understand the characteristics of the structure of technology spillover. This was done by setting a cutoff value.

<Figure 2> shows the findings of analysis performed with a cutoff value of 50. It clearly shows that as time goes by, the structure of technology spillover onto other industries becomes more and more complicated. The number of core industries where outflow and inflow of technological knowledge occur increases as well.

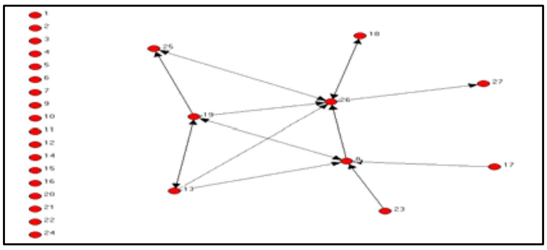
The industries that function as structure holes in the 1980s are communication machinery/broadcasting equipment manufacturing, communication, and transportation. In the 1990s, they are communication and chemistry products & sewing/shoes pulp manufacturing. Communication machinery/broadcasting equipment manufacturing continues to function as a role of knowledge outflow, but as industrial structure becomes complex, the identification of structural hole industry is not clear. Thus, the cutoff value in the 1990s was set to be 100. As a result, the industry of communication machinery/broadcasting equipment manufacturing was found to be the one that played a central role in knowledge outflow in the 1990s.



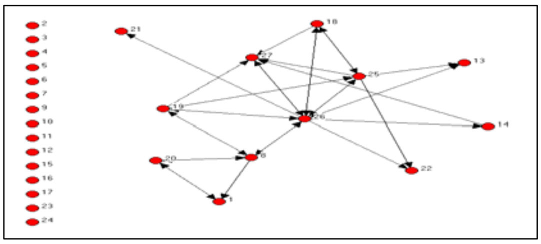
(a) 1981-1985년



(b) 1986-1990년



(c) 1991-1995년



(d) 1996-2000년

<Figure 2> Structural Hole (cutoff 50)

5. Conclusion

By using the patents that compose an aggregate of advanced technology such as UAV and the patent citation information on patents cited in other industries, this study examines the structure of technology spillover on other industries. Patent information was used as the indexes to measure the volume of technological knowledge and, the structure of UAV technology spillover on other industries was analyzed through CPP.

When density was estimated for the analysis of systematic connection of network, it was found systematic connection in the structure of UAV technology spillover increased over time. Regarding UAV technology, the industry that outflows knowledge is communication machinery/broadcasting equipment manufacturing; in the 1990s, UAV technology began to be absorbed to agriculture; throughout analysis period, the industries that received the largest benefits from UAV research and development were communication and transportation.

This study has laid a research foundation to estimate spillover effects on industry in future research and development of weapons system including UAV. Also, through the classification of industries by knowledge flow and the analysis of structural hole industry, the findings can be used in selecting core technological areas with large spillover effects in future research and development of weapons system.

Nonetheless, the research has limitations: by limiting the structure of technology spillover to disembodied knowledge flow, namely patent citation in this study, its understanding of the general structure of knowledge connection related to research personnel and product purchase might be insufficient. Since the analysis of the structure of UAV technology spillover is based on the data limited to the USPC-registered patents, it could be possible to have partiality in the data. In future research, it is necessary to examine the general structure of knowledge connection including embodied and disembodied knowledge flow.

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