ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 9(26), DOI: 10.17485/ijst/2016/v9i26/97308, July 2016* ISSN (Online) : 0974-5645

Industrial Network Analysis using Inter-Firm Transaction Data

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Abstract

Background/Objectives: Inter-firm transaction data can be used as basic information to grasp the effectiveness and robustness of country's economic activity. **Methods/Statistical Analysis:** In this paper, we constructed and analyzed an inter-firm network and inter-industry network using inter-firm transaction data from KED. From the result of analysis, we found that the distribution of transaction frequency between companies tends to follow the power-law distribution. This is because a large number of companies have trading connections few firms such as a conglomerate, implying that most transactions are concentrated in the major companies. And we analyzed the transaction type of each industry using the E-I index. According to the result, the companies which belong to the service-related industries tend to trade with the companies in other industries. Otherwise, the companies which belong to the motor manufacture-related industry and the electronic-related industry do a lot of trade with the companies in same industries. Especially, the network structure of these industries is hierarchized as a tree structure in comparison with other industries. **Findings:** From the inter-industry transaction network, we also found that the industries in Korea are largely divided into two groups: Domestic service industries and export manufacturing. These two sub-networks commonly form a tree structure representing the hierarchical flow of transactions where a transaction flows from leaf nodes to root node in the inter-industry network. Application/Improvements: The General Construction industry is the root node that is located at the top in the network of domestic service industries. And the electronic and computer-related industries are the root nodes in the network of export manufacturing.

Keywords: E-I Index, Hierarchical Network, Inter-Firm Transaction Network, Inter-Industry Transaction Network, Social Network Analysis, Tree Structure

1. Introduction

Generally, most industries form supply chains from a leading company like a conglomerate to sub-contracted firms. And inter-firm trade connections make a huge network of supply chain which represents transaction structure between companies. The structure of transaction relation does vary across the industries. The industries related to electronics, motors and metal show high hierarchy in comparison with those of service, textile and food.

A network is an effective method to representing objects and their relations of a group. It also provides explanations for various social phenomena and has been widely used various area including social science, politics and economics[1]. Mantegna analyzed a hierarchical arrangement of stocks traded in a financial market by investigating the daily time series of the logarithm of stock price[2]. He represents a stock market as MST (Minimum Spanning Tree) obtained starting from the matrix of correlation coefficient computed between all pairs of stocks of the portfolio by considering the synchronous time evolution of the difference of the logarithm of daily stock price. In many fields including physics and statistics, researchers try to reveal the characteristics of connection structure of stocks[3–6].

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Inter-firm transaction data can be used as basic information to understand the effectiveness and robustness of country's economic activity. Inter-firm transaction network can be made of purchase and sales transaction data between companies, which helps us to grasp the structural characteristics of the trading connection and the transaction flow in real economic activity. Jung and Hong investigated the inter-firm supplier network of representative five industries of Korea, which is composed of export manufacturing-related industries including motor, electronics and shipbuilding and domestic service-related industry including communication and software[7]. They analyzed the network characteristics of each industry using about 50,000 inter-firm transaction records obtained from KED (Korea Enterprise Data). According to the result, the network of motor-related industry has a vertical hierarchy.

There are some literature about the inter-firm transaction network based on the social network analysis method[8–11]. As the amount of inter-firm transaction data is too big for analysis of the scale of a country, most previous studies have been restricted within a province and an industry. But, in this paper, we build the general inter-industry transaction network of Korea using the inter-firm transaction big data and analysis the structural characteristics of the inter-firm and inter-industry transaction network based on the social network analysis method.

The remainder of this paper is organized as follows: We analyze the structure and the characteristics of inter-firm transaction and the inter-industry transaction in Sections 2 and 3, respectively. Finally, in Section 4, we draw conclusions and summarize our findings.

2. Analysis on the Inter-Firm Transaction

2.1 Inter-Firm Transaction Data

In this paper we focus on understanding the inter-industry transaction from the inter-firm transaction data. We build the transaction database about the company information and the transaction data of them in 2011, which are obtained from KED (Korea Enterprise Data). Our company dataset contains 80,451 companies which are identified by own KED code. The dataset is summarized in Table 1.

Table 1. The valid company and transaction data from KED in 2011

Item	Valid	Invalid	Total
Company	38,988	41,463	80,451
Transaction	61,441	731	62,172

In Table 1, the 'valid' company indicates that it has one or more sales records to other companies in our inter-firm transaction data. The number of 'valid' company is 38,988, which covers about 48.46% of the company dataset. The number of 'invalid' company is 41,463, which represents to no sales records in our transaction data. Because the 'invalid' companies are isolated in inter-firm transaction network, we rule out them in trading relation analysis.

An inter-firm transaction record consists of a selling company, a client company, and transaction ratio. Our transaction dataset is summarized in Table 2.

Table 2. The State of inter-firm transaction data

Transaction type		Count	Rate (%)
Valid		61,441	98.92
	Transaction which a buyer is same to a seller	23	0.04
Invalid	Duplicated transaction	349	0.56
	Transaction involving without company information data	359	0.58
Total		**62,172**	**100.00**

The 'valid' transaction records indicate sales records between 'valid' companies, which are 61,441 of total 62,172 transaction data covering about 98.82%. The 731 'invalid' transaction records can be divided into three types. The first 'invalid' transaction is that a seller is same to a buyer. In this paper, we consider only inter-firm transaction. The next case is multiple transaction data with same company. Our transaction records indicate annual sales between companies. Because we only focus on the period of 2011, the transaction record between two companies contains only one record. The last type is a transaction involving a company which is not contained in our company dataset. Such 731 'invalid' transaction records are excluded in our analysis. In the paper, we construct and analyze on the inter-firm transaction network for 38,988 companies and the 61,441 transaction records between them.

Our transaction record is composed of a selling company, a client company and trade rate. Table 3 summarizes basic statistics of trade rate. According to

the analysis result, the average of total transaction rate is about 17.76%. In other words, a company may have about five to six client companies on average.

Table 3. The basic statistics of trade rate

	Avg.	St. Dev.	Min.	Max.
Trade rate (%)	17.76%	20.28%	0.01%	100.00%

Figure 1 shows the distribution of transaction rate between companies. As shown in Figure 1, many of trading records have transaction rate less than 20%. The number of transaction records which its transaction rate is above the average are 18,941, which cover about 30.8% of valid transaction records.

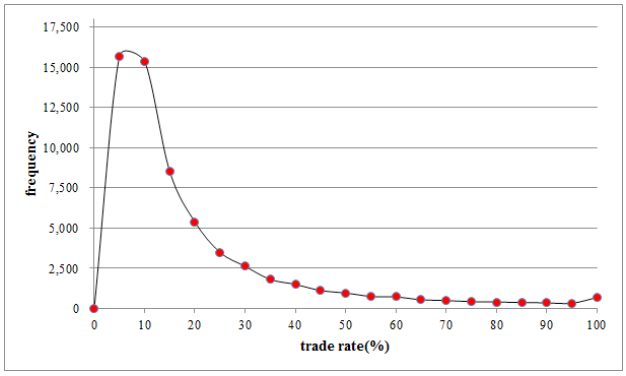


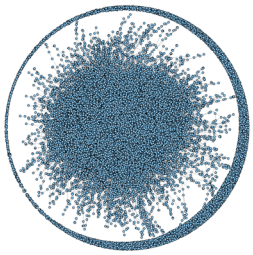
Figure 1. The distribution of transaction rate between companies.

2.2 Inter-Firm Transaction Network

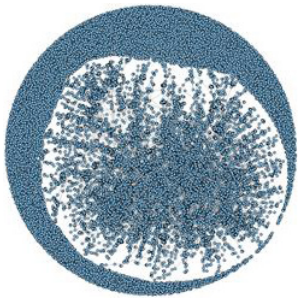
A network is an efficient tool for visualizing and understanding a system consisting of many components and the relation among them. An inter-firm transaction network which is a directed graph can be made of companies and transaction relation between them. A node represents a company and an edge represents a transaction between two companies. If the company 'A' supplies its product to the 'B' company, an edge is from the node 'A' to the node 'B' as shown in Figure 2. From inter-firm transaction network, we can find an overall topological structure of the transaction relation between companies.

Figure 2. The prototype network of inter-firm transaction.

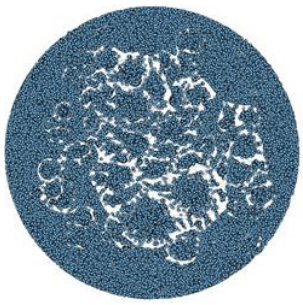
Figure 3 shows the inter-firm transaction network representing our dataset as mentioned Table 2. In Figure 3, a network is represented by weighted graph that a node represents a firm and an edge represents a transaction between linked two firms. The edge weight indicates the trading rate between two firms.



(a) Full graph containing all edges (node #: 38, 988, edge #; 61,441).



(b) The simplified network contains only edges with more than average trading rate (node #: 38, 988, edge #; 18,941).



(c) The simplified network contains only one edge per a node with max trading rate (node #: 38,988, edge #: 31,074).

Figure 3. Inter-firm transaction network which consists of 38,988 firms and 61,441 transaction records.

Figure 3(a) shows the full network graph containing 38,988 nodes and 61,441 edges. In this graph, most

Table 4. Top 10 companies with high in-degree centrality

Ranking	Company abbreviation	Company name	In-degree	In-degree centrality
1	HHI	Hyundai Heavy Industries	1,241	0.0318
2	SE	Samsung Electronics	763	0.0196
3	HE&C	Hyundai E&C	624	0.0160
4	DHI&C	Doosan Heavy Industries & Construction	551	0.0141
5	LGE	LG Electronics	494	0.0127
6	LDS	Lotte Department Store	483	0.0124
7	HMC	Hyundai Motor Company	459	0.0118
8	KEPCO	KEPCO	442	0.0113
9	GSE&C	GS E&C	431	0.0111
10	SC&TC	Samsung C&T Corporation	426	0.0109

nodes are linked each other forming large component containing 34,170 nodes, which cover about 89% of all nodes. The 1,790 rest of nodes are isolated in the graph. Figure 3(b) shows the simplified network graph applied with a threshold. Threshold value is defined as 17.6% that is an average of trading rate of all inter-firm transaction records. Figure 3(c) also shows the simplified graph by remaining only maximum weighted edges of a node. This graph consists of 38,988 nodes and 31,074 edges which form some subgroups.

Several indicators such as degree, density and centrality are used to represent the characteristics of a network in graph theory[12]. Degree centrality represents how many nodes are linked, which identifies the most influential nodes within a graph. As a transaction network between companies is a directed graph, degree centrality is calculated according to an edge direction. We consider a node with high in-degree centralities as more influence company because the company has many other subcontractors. This means that a node with high degree centrality is located in upper on hierarchical trading structure. We summarize the top 10 companies with high in-degree centrality and theirs in-degree in the transaction network in Table 4.

The average in-degree of the nodes in the inter-firm transaction network is about 1.58 which means a company is supplied products one or two other companies on average. From the result, the company with the highest in-degree is 'HHI' (Hyundai Heavy Industries) which gets 1,241 edges connected to other companies. 'SE' (Samsung Electronics) and 'HE&C' (Hyundai E&C) have 763 edges and 624 edges, respectively. As shown in Table 4, most leading conglomerates in Korea tend to have many edges.

Figure 4 shows a chart depicting the in-degree distribution of the nodes in log-log scale. In this figure, x-axis indicates in-degree of each node and y-axis indicates the node counts of that in-degree.

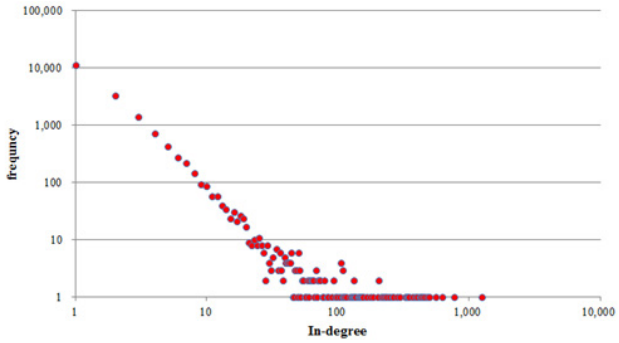


Figure 4. In-degree distribution of inter-firm transaction network.

It can be easily identified that the population distribution follows the power-law distribution. When a quantified data follows the power-law distribution, the graph of log-log scale of the data shows a straight line. The meaning of the power-law model is that the frequencies of events and the sizes of them can be inversely proportional in a severe manner[13]. It may be inferred from this result that most transaction connection are concentrated in a small number of companies. In other words, it means that these companies are very influential in Korean economy.

Most companies of an industry have transaction with other companies belong to other industry. We construct transaction network of each industry to investigate dependence on other type of business. And the transaction dependence of other industries is measured by E-I (External-Internal) index. The E-I index is calculated as follows.

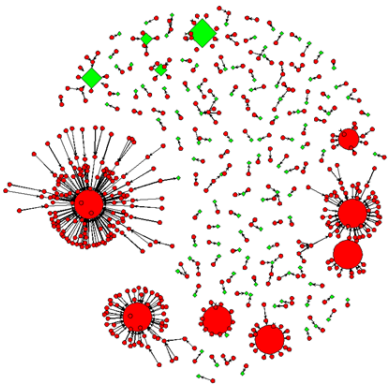
Table 5. THE E-I Index of the industry with a high frequency of transaction

Industry	E-I index	Industry	E-I index
Manufacture of Other Transport Equipment	-0.38	Manufacture of Basic Metal Products	0.65
Manufacture of Motor Vehicles, Trailers and Semitrailers	-0.35	Manufacture of Rubber and Plastic Products	0.67
Manufacture of Electronic Components, Computer, Radio, Television and Communication Equipment and Apparatuses	0.09	Land Transport; Transport Via Pipelines	0.69
Sale of Motor Vehicles and Parts	0.21	Storage and Support Activities for Transportation	0.70
General Construction	0.28	Waste Collection, Disposal and Materials Recovery	0.70
Manufacture of Wearing Apparel, Clothing Accessories and Fur Articles	0.29	Computer Programming, Consultancy and Related Activities	0.73
Manufacture of Food Products	0.35	Manufacture of Wood Products of Wood and Cork, except Furniture	0.73
Tanning and Dressing of Leather, Manufacture of Luggage and Footwear	0.37	Manufacture of Other Non-metallic Mineral Products	0.73
Manufacture of Textiles, Except Apparel	0.38	Special Trade Construction	0.75
Manufacture of Chemicals and Chemical Products except Pharmaceuticals, Medicinal Chemicals	0.43	Wholesale of Medical, Precision and Scientific Instruments and Equipment	0.76
Manufacture of Other Machinery and Equipment	0.44	Manufacture of Fabricated Metal Products, except Machinery and Furniture	0.78
Publishing Activities	0.47	Other Manufacturing	0.79
Wholesale Trade and Commission Trade, except Motor Vehicles and Motorcycles	0.49	Manufacture of Pulp, Paper and Paper Products	0.79
Manufacture of Furniture	0.50	Business Facilities Management and Landscape Services	0.81
Retail Trade, except Motor Vehicles and Motorcycles	0.61	Professional Services	0.82
Architectural, Engineering and Other Scientific Technical Services	0.63	Printing and Reproduction of Recorded Media	0.82
Manufacture of Electrical Equipment	0.64	Business Support Services	0.91

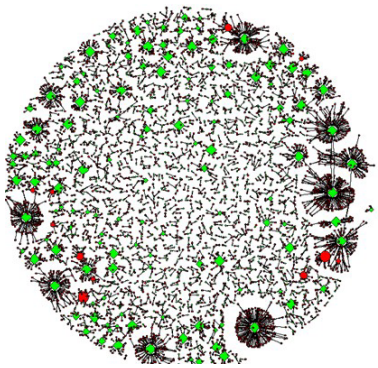
where EL and IL indicate the number of external links and internal links, respectively. The external link represents a link connected up to other group. And the internal link represents a link connected up to a node which belongs to the same group. The range of E-I index can be from -1 to 1. If the value of E-I index is 1, then all companies of an industry have transaction with the companies of other industries and vice versa. The E-I index values of the industry which have transaction records more than 100 are summarized in Table 5.

The E-I index varies from -0.38 to 0.91 depending on the industry. The result have shown that the dependence on other industries is lower in the motor manufacture-related industry such as manufacture of other transport equipment and manufacture of motor vehicles, trailers and semitrailers. That is, the companies in these industries tend to transact with other companies in the same industry. In contrast, the service-related industries such as business support services and professional services have higher dependence on other industry, which means the firms in these industries have transact with the companies which belong to other industries and they may be very affected by the other industries.

Figure 5 shows the network graph of representative industry including 'Manufacture of Other Transport Equipment' and 'Special Trade Construction'.



(a) The network of 'Manufacture of Other Transport Equipment' industry.



(b) The network of 'Special Trade Construction' industry.

Figure 5. The network graph of representative industries on the E-I index.

In the graph, a red circle represents a company in that industry and a green square represents that in other industries. And the node size indicates the amount of edges connected to it. The largest node represents a major company. Figure 5(a) shows the network graph of 'Manufacture of Other Transport Equipment' industry. The E-I index of this industry is -0.38, implying that there are many intra-industry transactions. We can see this fact from the graph. Figure 5(b) shows the graph of 'Special Trade Construction' industry having 0.75 E-I index. This industry has a high level of dependence on other industries in transaction. From the graph, we can see that most companies are connected to other companies in other industries.

3. Analysis on the Inter-Firm Transaction

3.1 Inter-Industry Transaction Data

The industrial sectors and companies are connected to each other in supply-chain. A company is classified to an industrial sector which is identified by SIC code which is defined by the KSIC (Korean Standard Industrial Classification). We classify the sample companies according to this SIC code and analyze the transaction relation between industrial sectors. KSIC consists of 21 categories assigned a code from 'A' to 'U' as shown in Table 6.

Each category is again classified to one or more detailed divisions assigned with two digits from '00' to '99.' The total number of divisions of KSIC is 77. In this paper the companies are classified to proper industrial sector by upper two digit of their SIC code.

To analyze the scale of each industrial sector we classify the companies in our data set according to the first two digits of their SIC code. The top 10 biggest industrial sectors are summarized in Table 7, where the size of each sector indicates the number of companies belonging to it.

Our dataset is classified 71 divisions, but six divisions including 'Mining and Quarrying (SCI code 05, 06, 08)', 'Activities of Households as Employers; Undifferentiated Goods - and Services - Producing Activities of Households for Own Use (SCI code 97, 98)' and 'Activities of Extraterritorial Organizations and Bodies (SCI code 99)' do not have any companies. The biggest industrial sector is 'Wholesale Trade and Commission Trade, except of Motor Vehicles and Motorcycles (SCI code 46)' which contains 9,796 companies. And the transaction rate of the companies belonging to this sector is 13.91% on average. 'Special Trade Construction (SCI code 42)' and 'Manufacture of Other Machinery and Equipment (SCI code 29)' follow with 4,779 companies and 3,071 companies, respectively.

We analyze the transaction frequencies of each industrial sector and the statistical results of top 10 industrial sectors with heavy transaction are summarized in Table 8.

The industrial sector with the highest transaction is 'Wholesale Trade and Commission Trade, except of Motor Vehicles and Motorcycles (SCI code 46)' which relates to 15,706 transactions covering about 25.56%. The average transaction rate of this sector is 13.91%. 'Special Trade Construction (SCI code 42)' and 'Manufacture of Other Machinery and Equipment (SCI code 29)' follow with 9,064 and 5,834 transactions, respectively.

From these results, we can conclude that an industrial sector containing many companies generally has a lot of transactions. However, although 'General Construction

Table 6. Large categories of Korean standard industrial classification

Category code	Related industry	SIC code
A	Agriculture, Forestry and Fishing	01 ~ 03
B	Mining and Quarrying	05 ~ 08
C	Manufacturing	10 ~ 33
D	Electricity, Gas, Steam and Water Supply	35 ~ 36
E	Sewerage, Waste Management, Materials Recovery and Remediation Activities	37 ~ 39
F	Construction	41 ~ 42
G	Wholesale and Retail Trade	45 ~ 47
H	Transportation	49 ~ 52
I	Accommodation and Food Service Activities	55 ~ 56
J	Information and Communications	58 ~ 63
K	Financial and Insurance Activities	64 ~ 66
L	Real Estate Activities and Renting and Leasing	68 ~ 69
M	Professional, Scientific and Technical Activities	70 ~ 73
N	Business Facilities Management and Business Suport Services	74 ~ 75
O	Public Administration and Defence; Compulsory Social Security	84
P	Education	85
Q	Human Health and Social Work Activities	86 ~ 87
R	Arts, Sports and Recreation Related Services	90 ~ 91
S	Membership Organizations, Repair and Other Personal Services	94 ~ 96
T	Activities of Households as Employers; Undifferentiated Goods- and Services- Producing Activities of Households for Own Use	97 ~ 98
U	Activities of Extraterritorial Organizations and Bodies	99

Table 7. Top 10 industries in inter-firm transaction network

Ranking	Related industry	SIC code	Number of company	Rate (%)
1	Wholesale Trade and Commission Trade, except Motor Vehicles and Motorcycles	46	9,796	25.12
2	Special Trade Construction	42	4,779	12.26
3	Manufacture of Other Machinery and Equipment	29	3,071	7.88
4	Manufacture of Fabricated Metal Products, except Machinery and Furniture	25	1,792	4.60
5	General Construction	41	1,569	4.02
6	Manufacture of Electronic Components, Computer, Radio, Television and Communication Equipment and Apparatuses	26	1,464	3.76
7	Manufacture of Electrical Equipment	28	1,263	3.24
8	Manufacture of Rubber and Plastic Products	22	1,028	2.64
9	Manufacture of Motor Vehicles, Trailers and Semitrailers	30	997	2.56
10	Retail Trade, except Motor Vehicles and Motorcycles	47	242	2.42

Table 8. Top 10 industrial sectors with heavy inter-industry transaction

Ranking	SIC code	Frequency of transaction	Rate (%)	Avg. of transaction rate (%)
1	46	15,706	25.56	13.91
2	42	9,064	14.75	19.89
3	29	5,834	9.50	19.30
4	25	3,453	5.62	17.49
5	26	2,369	3.86	20.46
6	28	2,277	3.71	20.02
7	30	1,779	2.90	24.52
8	22	1,721	2.80	17.95
9	24	1,550	2.52	14.74
10	20	1,391	2.26	15.96

(SCI code 41)' is the fifth largest industrial sector containing 1,569 companies, its transaction count is 1,296 which is not much for its scale. The reason is that the companies belonging to 'General Construction' industry mainly put out the work to sub-contractors but our transaction data are based on the sales

3.2 Inter-Industry Transaction Network

As shown in Figure 3, each company is connected in business with other companies belonging to different industrial sector. We build and analyze the inter-industry transaction network to uncover how closely industrial sectors are connected to each other. In the inter-industry transaction network, a node means an industrial sector. If an edge between two nodes indicates the industrial sectors linked by the edge conduct transactions each other which is put weight according to the frequency of transactions.

As the general inter-industrial transaction network with our dataset is very complex, we simplify the network by removing edges except the edges with the highest weight of each node. Figure 6 shows the inter-industry transaction network constructed in this manner.

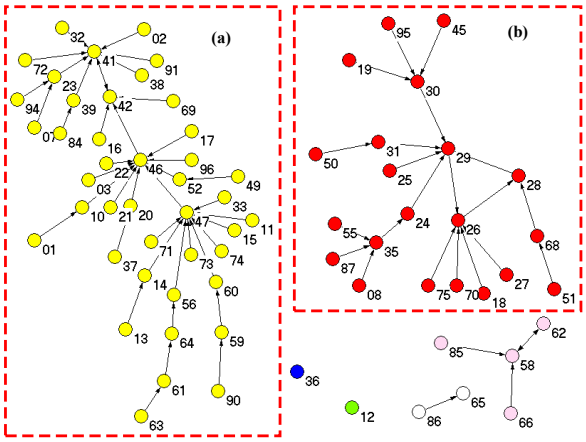


Figure 6. Innter-industry transaction network.

The label of a node represents the SCI code of each industrial sector with two digits in Figure 6. The simplified inter-industry transaction network consists of 71 nodes and 68 edges which comprises six components. The group A of Figure 6(a) represents the biggest component which centers round the industry of 'General Construction (SCI code 41)' and 44 industrial sectors are connected. The second biggest component is the group B in Figure 6(b). The sub-network B centers round the industries including 'Manufacture of Other Machinery and Equipment (SCI code 29)', 'Manufacture of Electronic Components, Computer, Radio, Television and Communication Equipment and Apparatuses (SCI code 26)', 'Manufacture of Electrical Equipment (SCI code 28)' which consists of 21 industrial sectors. From the topology of the sub-network A and B, these are likely to a tree structure in which any two nodes are connected by exactly one edge, implying thatthe structure of these sub-networks does not allow cycles. In both two sub-network A and B, the direction of all edges is the same from the leaf node to root node, implying that the sub-networks are hierarchized.

The longest path of the simplified inter-industry transaction network has 7 edge lengths from (63) to (41) as shown in Figure 7.

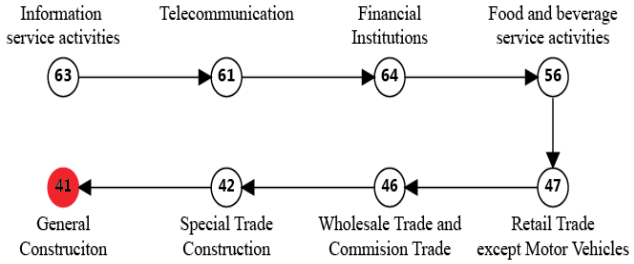


Figure 7. The longest path of the simplified inter-industry transaction network.

The path follows 'Information Service Activities (63)' > 'Telecommunications (61)' > 'Financial Institutions, except Insurance and Pension Funding (64)' > 'Food and Beverage Service Activities (56)' > 'Retail Trade, except Motor Vehicles and Motorcycles (47)' > 'Wholesale Trade and Commission Trade (46)' > 'Special Trade Construction (42)' > 'General Construction (41).'

From the inter-industry transaction network, we found that the Korean industries are largely divided into the domestic service industries centering on the construction-retail and the export manufacturing centering on the electricity-electronic-machine.

4. Conclusions

The inter-firm transaction data provides us basic information to grasp the effectiveness and robustness of country's economic activity. Unfortunately, most previous works focused on the supply-chain and the sales network of one industry, so they do not have been used for understanding the flow of the inter-industry transaction and information in a national economy.

In this paper, we constructed the inter-industry

transaction network using inter-firm transaction data obtained from KED. And we analyzed the transaction structure and characteristics between industrial sectors of Korea based on the social network analysis method. From the analysis results, we found that the distribution of transaction frequency between companies tends to follow the power-law distribution. This is because a large number of companies have transaction connections with few firms such as a conglomerate, implying that most transactions are concentrated on the major companies.

Also, we analyzed the industrial dependence of each industry using the E-I index. From the results, we found that the service-related industries tend to transact with the companies in other industries. Otherwise, the motor manufacture-related industry and the electronic-related industry do a lot of intra-industry transaction. Especially, the network structure of these industries is hierarchized as a tree structure in comparison with other industries.

From the inter-industry transaction network, we also found that the Korean industries are largely divided into two groups: Domestic service industries and export manufacturing. These two sub-networks commonly form a tree structure representing the hierarchical flow of transactions, where a transaction flows from leaf nodes to root node in the inter-industry network. The General Construction industry is the root node that is located at the top in the network of domestic service industries. And the electronic and computer-related industry is the root node in the network of exportation manufacturing.

5. Acknowledgment

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2013S1A3A2042747).

6. References

1. Hong JP. The effect of buyer's opportunistic behavior on the supplier's R&D expenditure in the supplier relations. Korean Journal of Political Economy. 2011; 37(1):311–44.
2. Park JG. Impact of subcontracting on performance in Korean manufacturing: The difference between assemblers and component suppliers. Journal of Korean Economic Development. 2004; 17(1):1–17.
3. Borgatti SP, Mehra A, Brass DJ, Labianca G. Network analysis in the social sciences. *Science*. 2009; 323(5916):892–5.
4. Mantegna RN. Hierarchical structure in financial markets. The European Physical Journal B-Condensed Matter and Complex Systems. 1999; 11(1):193–7.
5. Onnela JP, Chakraborti A, Kaski K, Kertesz J, Kanto A. Dynamics of market correlations: Taxonomy and portfolio analysis. Physical Review E. 2003; 68(5):1–13.
6. Kim JW, Park KN. A study on methodologies to develop an e-Industrial cluster hub system using social networks. Indian Journal of Science and Technology. 2015; 8(21):1–9.
7. Jung JH, Hong JP. A study on the network structure of the supplier-customer relations between flagship small companies. The Korean Small Business Review. 2015; 37(4):77–103.
8. Lee YJ, Kim EK, Cho HG, Woo G. Detecting and visualizing online dispute dynamics in replying comments. Software: Practice and Experience. 2013; 43(12):1395–413.
9. Lee YJ, Cho HG, Woo G. Analysis on stock market volatility with collective human behaviors in online message board. Proceedings of IEEE CIT2014; China. 2014. p. 482–9.
10. Kim SD, Hong SH, Lee MH. Business network characteristics among Chungcheongbukdo-based top 300 enterprises: Focused on sales relationship. Journal of the Korea Contents Association. 2014; 14(9):437–49.
11. Ho HS, Kim KM, Baek WS, Lee MH. Knowledge networking analysis of Chungnam automobile parts industry based on Social Network Analysis (SNA) methods. Journal of Korea Planning Association. 2010; 45(4):183–96.
12. Freeman LC. The development of social network analysis: With an emphasis on recent events. UK: The Sage Handbook of Social Network Analysis; 2012. p. 26–39.
13. Barabasi A. The origin of bursts and heavy tails in human dynamics. Nature. 2005 May; 435(1):207–11.