Comparison between Korean Electronic and Metal Industries using Component-based Social Network Analysis

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Abstract

An increasing number of discussions has been ongoing regarding the supply network, primarily due to its contribution to firms' competitiveness, which extends beyond the traditional dyadic relationship between buyers and suppliers. Thus far, one of the most useful approaches to consider the supply network perspective is social network analysis. Accordingly, this study seeks to determine the structural configurations of the supply network, and its characteristics based on the components in these networks, using real industrial data, such as from the entire Korean electronic and metal industries. Specifically,
mainly by using network diameter, network density, and network centralization, our study provides some implications of how focal firms’ positions on the supply network, and the gap of technological change level are crucial to evaluate the structural configuration of the network. Our findings show that both these aspects are closely related to the structural configuration of the entire supply network, based on its components.

**Keywords:** supply network, social network analysis, components, network density, network centralization, metal industry, electronic industry.

**INTRODUCTION**

The importance of supply chain management for firms’ competitiveness has, in recent times, resulted in an increasing number of discussions on this subject. As the complexity and diversity of supply chains have increasingly intensified [1], the dyadic perspective of supply chains has changed into a network perspective to deepen the understanding of the architecture and its effects [2][3]. Until now, the most useful approach proposed to consider this network perspective of supply chains is the social network analysis (SNA).

Indeed, in order to understand the network architecture, supply-network–related studies using SNA have recently been discussed in the field of supply chain and logistics [2][4][5]. However, despite this attention and some theoretical and conceptual contributions, SNA applications in supply chains continue to face two difficulties. First, the challenges in obtaining data lead to a shortage in framing real-life supply networks [3]. Second, there is a need to elaborate on relevant explanations of SNA metrics in certain supply network settings.

To overcome these challenges, this study seeks to determine the structural configurations in supply networks, using real industrial data. By primarily using network diameter, network density, and network centralization, this study shows that some characteristics of supply networks could be explained by the differences in some SNA metrics.

As [3] pointed out, understanding the structural configurations of supply chains is critical to enhance fact-based decision making. The positions of individual firms regarding the supply network influence their strategies and behaviors relative to those of the other firms. For instance, [6][7] argue that a firm’s power and influence are derived from its structural position in the network, and [3] links the structural position in a network to issues that create innovation adoption, brokerage, and alliance. However, extant studies mostly focus on an egocentric network that concentrates on positional structures of individual firms in a network. In contrast, this study discusses structural configurations of the entire supply network, and not the individual firms. For this purpose, the data in this study are obtained from the Korean electronic and metal
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industries, and mainly compare these industries through network-level metrics. These industries were selected because both are considered to clearly show heterogeneity, from the perspective of focal firms, regarding the supply network and the gap of technological change.

The remainder of the paper is organized as follows. The next section presents a literature review covering previous studies on this subject. Next, the research methods section describes the methodology used, and the results and discussion section analyzes the results. The last section concludes the paper.

LITERATURE REVIEW

Traditional supply chain management has focused on the linear relationship between buyers and suppliers, but the current trends of outsourcing and global sourcing render supply chain more complex, being fragmented into a multi-tier structure [8]. Such a change in the supply chain structure and its resultant performance results in complex interactions between the structure and function of supply chains. Traditional studies were undertaken from the perspective of the dyad and linear logistics; however, with the growing importance of multi-tier supply chains, this perspective is not considered to relevantly reflect the supply network complexity [9]. Supply chains should be considered a network of various businesses and relationships, and not simply a linear chain that only links the relationships among individual businesses [10].

Accordingly, the notion of SNA is especially suitable for studying how the patterns of inter-firm relationships in supply networks are converted into a competitive advantage through material flow management and information diffusion [5]. For this reason, since a decade, increasing discussions have been ongoing regarding the benefits of applying the network perspective and methodology to supply chain studies.

As a starting point for applying SNA to supply networks, [11] depicted some supply chains for the final assembly stage of three models in three auto companies, and introduced some propositions related to their structural characteristics. Then, [5] noted the fundamental outlines of SNA and also the principles and characteristics of potential networks that could be utilized in supply chain management. However, because it is difficult to obtain real data to understand the entire supply chain, there is a shortage of empirical studies that apply SNA to real supply networks. Few studies that adopted the network perspective are yet to obtain theoretical and practical implications through a qualitative approach.

[3] recently proposed the research findings that quantitatively analyze the structural characteristics of supply networks through SNA. The authors present fundamental explanations on how various metrics could be applied by SNA methodology, and further apply such results to the supply chains investigated in the study of [11]. In addition, [12] offer a nexus supplier concept in contrast with the strategic supplier of the dyad relationship, as a critical partner that influences the performance of focal firms. However, this study is still in providing a theoretical foundation to utilize the improved supply network management by analyzing the structural and relational characteristics
of the supply network. Thus, the question on how SNA could be adopted to analyze real supply networks at the industry level remains unanswered.

RESEARCH METHOD

Data collection

The data used in this analysis are based on Korean firms’ purchasing and supply records provided by the credit report service of the Korea Enterprise Data (KED). Since this information includes the business and financial status, as well as the purchasing and supply records of individual firms, it is useful for analyzing supply networks and for further analysis. In this study, we follow some data collection procedures to effectively improve the accuracy of our analysis results.

First, we include the listed firms within the associated codes by industry, such as C24 (manufacture of basic metal products), C26 (manufacture of electronic components, computers, radio, televisions, and communication equipment and apparatuses), and their sub-codes, based on the Korean Standard Industrial Classification (KSIC). Next, some screening procedures are adopted to obtain more precise and reliable data. For instance, some data are excluded in the following cases: 1) when there is no information on purchasing and supply; 2) when a firm corresponds to individually owned business; and 3) when a firm has not conducted its business for three successive years (2012–2014). Consequently, the number of sample firms considered in the study is 662 in the metal industry and 985 in the electronic industry. Thus, 1,647 firms are included in the analysis. This is further extended to 7,771 firms when considering all firms in the network analysis. Lastly, we configure the network boundary to appropriately serve the purpose of this study. That is, to reveal the difference between the electronic and metal industries from the supply network perspective, we finally select the main components—that is, excluded isolated nodes (firms)—as the units of analysis. Including these isolated nodes may distort the results such that most characteristics of networks emerge from the number of direct or indirect ties among the nodes. Because our data for each firm have a maximum limit of five firms for showing the flow of materials and parts, the supply networks could lead to quite a few isolated nodes.

Data Analysis and Validity

In this study, the asymmetric matrix needed for the abovementioned network data is based on the directed matrix (that is, from source to target firms), which is conditioned by materials and parts flow. Additionally, only the binary matrix is built for this study because the simple rate of trade volume for each firm could vary by its total sales volume. For analysis tools, we mainly use UCINET (ver.6) in combination with R.

Regarding the validity of the data, the records provided by KED are indeed highly reliable because of their frequent revision and utilization by several institutions and companies in Korea. Even if a firm has less than five trading firms, or no trade information in the input data, its additional link information from its trading partners
could help establish a quasi-network, akin to the original network to an extent. For instance, while only four purchasing firms and two supply firms are listed for Samsung Electronics, our analysis result shows that the company has 212 in-degree and 24 out-degree connections. Thus, it might be conjectured that most important trading relationships are included in supply networks.

**ANALYSIS RESULTS AND DISCUSSION**

The overall supply networks of each industry are displayed in Figure 1. The center of the supply network is constituted by several focal firms (e.g., large leading buyers in the upper tiers), with isolated firms outside the network (mainly small and medium suppliers in the lower tiers).

(a) Supply chain for the electronic industry

(b) Supply chain for the metal industry

*Figure 1: Overall supply network diagram*
Additionally, the basic network characteristics using the entire data set are outlined in Table 1. The total number of firms and links considered in the network is 7,771 and 10,756, respectively. Regarding the average path distance, which represents the distance between firms in a network, the electronic industry (8.33) has more path length than the metal industry has (7.44). Likewise, the network diameter, which reflects the size of the network, is slightly higher in the electronic industry (22). Thus, the supply network of the electronic industry could be classified as a longer and more complex high technology, than that of the metal industry with low and medium technology. Considering that a high technology industry commonly has more complex product structures and parts or modules, it follows that the network complexity of the electronic industry is higher than that of the metal industry.

Table 1: Basic SNA metrics of entire supply networks

<table>
<thead>
<tr>
<th></th>
<th>Electronic industry</th>
<th>Metal industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of firms</td>
<td>985</td>
<td>662</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>4,676</td>
<td>3,095</td>
</tr>
<tr>
<td>Number of links</td>
<td>6,390</td>
<td>4,366</td>
</tr>
<tr>
<td>Average path distance</td>
<td>8.33</td>
<td>7.44</td>
</tr>
<tr>
<td>Network diameter</td>
<td>22</td>
<td>19</td>
</tr>
</tbody>
</table>

As noted earlier, various SNA metrics for network characteristics largely depend on the number of nodes and linkages. Thus, additional effort to exclude several isolated firms is required for parsimony and clear insight. Components, as sub-networks within networks, are sets of links among the nodes connected directly and indirectly, and yet continuously. There can be several components in a network, and the largest among them is called the main component.

The component analysis for the two industries results in the derivation of 44 components in the electronic industry and 21 in the metal industry. The components occupy 93.54% and 96.35% of all nodes, and 95.84% and 97.76% of the links of each complete supply network, in the electronic and metal industries, respectively. Network diagrams based on the components of the two industries are illustrated in Figure 2.
Comparison between Korean Electronic and Metal Industries using Component-based supply chain for the electronic industry

(a) Component-based supply chain for the electronic industry

(b) Component-based supply chain for the metal industry

Figure 2: Supply network diagram based on components

Considering the components, the profile of the component-based supply network is summarized in Table 2. It reveals that both the average path distance and network diameter in a component-based supply network do not differ in values in the entire supply network, indicating that network analysis based on components is valid.
Table 2: Basic SNA metrics of supply networks based on components

<table>
<thead>
<tr>
<th></th>
<th>Electronic industry</th>
<th>Metal industry</th>
</tr>
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<tbody>
<tr>
<td>Number of components</td>
<td>44</td>
<td>21</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>4,374 (93.54%)</td>
<td>2,982 (96.35%)</td>
</tr>
<tr>
<td>Number of links</td>
<td>6,124 (95.84%)</td>
<td>4,268 (97.76%)</td>
</tr>
<tr>
<td>Average path distance</td>
<td>8.300</td>
<td>7.475</td>
</tr>
<tr>
<td>Network diameter</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>Network density</td>
<td>0.032%</td>
<td>0.048%</td>
</tr>
</tbody>
</table>

※Numbers in parentheses represent the ratio of the values of component-based supply networks to the corresponding values in the complete supply networks.

Further, the electronic industry (0.032%) has lower network density than that of the metal industry (0.048%). The electronic industry in Korea includes leading focal firms such as Samsung and LG. The competitive landscape among these firms is quite intense due to rapid product life cycles and protection of cutting-edge technologies. Thus, since the focal firms’ suppliers compete with other focal firms and their suppliers, the trade among the suppliers in the competing supply chain can only continue to be quite limited. The opposite is true for the network density of the metal industry. As compared to the electronic industry, the number of leading focal firms in the Korean metal industry is relatively few (i.e., POSCO and Hyundai Steel). The competitive intensity as a low and medium technology industry is also low. This renders the metal industry to be more likely to have a more intense supply network structure than that of the electronic industry. In terms of network diameter, the electronic industry appears to have a longer supply chain compared to the metal industry, implying that the processing and assembly process in a high technology industry is relatively complex and lengthy than that in others. However, it could be a burden for focal firms because it impedes rapid decision making and increases the efforts and cost of operations in supply network management.

Meanwhile, the concept of centrality in SNA represents the central position an actor occupies, and reflects the power of the actor in the network. Network centralization derived from centrality represents the degree to which the centralities of actors differ [13], showing that the value of network centralization ranges between zero and one. As network centralization approaches one, the centrality of the actors in the network shows uneven dispersion. The result of network centralization for the two industries is summarized in Table 3. In this study, we show two basic network centralization metrics—degree and closeness—since such centralities have different meanings according to the ways to measure centrality. In general, degree centrality focuses on the number of direct ties, while closeness centrality reflects the distance that considers both
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direct and direct ties. Since our supply network is based on directional matrix, out-
degree/in-degree and out-closeness/in-closeness network centralization metrics are
calculated.

| Table 3: Network centralization of supply networks based on components |
|---------------------------------------------------|-------------------|-------------------|
| Network centralization                          | Electronic industry | Metal industry |
|                                                   | (%)               | (%)              |
| Degree                                            |                   |                  |
| Out                                               | 0.517             | 4.214            |
| In                                                | 4.588             | 1.663            |
| Closeness                                         |                   |                  |
| Out                                               | 0.009             | 0.061            |
| In                                                | 0.044             | 0.017            |

In directional supply networks, in-centralization evaluates the trading relationship from
the standpoint of buyers, while out-centralization is based on the perspective of
suppliers. In terms of out-degree and out-closeness network centralization, our results
show that the centralization metrics of the metal industry are higher than those of the
electronic industry. The main reason is that component-based metal supply network
comprises leading focal firms with high market share, such as POSCO and Hyundai
steel. These few core suppliers play the central role in providing steel materials to
numerous small and medium buying firms. In contrast, the electronic industry has
relatively high in-degree and in-closeness network centralizations, since trade proceeds
from several small and medium suppliers to leading focal firms, such as Samsung, LGE,
LGD, etc. Considered together, the metal industry, in which the materials and parts flow
from focal firms to lower-tier buyers (mainly small and medium processing and
distribution firms), is much likely to have uneven distribution in the centralities of firms,
while the steel industry, in which the materials and parts flow from lower-tier suppliers
to upper-tier focal firms is much likely to show uneven distribution. Since uneven
distribution alludes to concentration of power in the network, these findings appear to
reflect network configuration adequately.

CONCLUSIONS
In this study, we analyze and provide the implications of the differences in the supply
network in the Korean electronic and metal industries at the level of the entire network.
Using some metrics frequently discussed in SNA, our research findings provide some
implications of how the focal firms’ positions on supply networks and the gap of
technological change level are crucial to evaluate the structural configuration of the
supply network.
Comparatively, when materials and parts flow downstream in supply chains, the average path distance and network diameter of the electronic industry is higher than that of the metal industry. This reveals that the entire supply network in the electronic industry constitutes a more complex and long supply chain. Regarding network density, for which the metal industry shows higher value than the electronic industry, the former has a relatively lower competitive environment than the latter, so that suppliers in the metal industry have more unconstrained trading opportunities. Lastly, both out-centralization of the metal industry and in-centralization of the electronic industry are higher than others are, implying that the central power of the metal industry is concentrated on the upstream part of the supply chain, while the central power of the electronic industry is focused on the downstream part.

Despite of above interesting results, there are some limitations of the study in that it places restrictions on network data by considering only binary matrix and a maximum of five firms in it. It is worth noting that more extended metric data can be built on trade volume for each firm and full supplier lists.

To conclude, based on component-based SNA, our study suggests that both the focal firms’ positions on supply networks and the gap of technological change level are closely related to the configuration of the entire supply network. Evidently, this study contributes to the literature by seeking empirical study through real industry data. Thus, this subject could be considered a potential avenue for future research.

REFERENCES


