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An Empirical Study on Inter-Organisational Network Structures for Connected Car

Fumihiko Isada

Kansai University, Japan

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Introduction

- The aim of this study was to empirically clarify what kind of network structure of inter-organisational relations firms are growing with changes in industrial structure by creating a database of actual firm behaviour.
  - The traditional automobile industry has functioned under a network structure of closed and strong inter-organisational relationships with a specific group of firms.
  - However, the IT industry has opted for a relatively open, ad hoc, and weak network structure of inter-organisational relationships.
  - Iansiti and Lakhani (2017) foresee a shift in the industry structure of connected cars, with Google and Apple as platformers and automakers as complements.

Introduction

- For the organisation of this research, a database was constructed by extracting press releases and English-language newspaper articles to include as much information as possible from all over the world, including the latest information.
- The database then was analysed using the social network analysis method.
  - For the inter-organisational network structure analysis, each company was viewed as a node in the network.
  - Using social network analysis, various indicators that show the characteristics of the network's structure can be calculated (Borgatti et al. 2002).

Previous Research

- Social network analysis is a method of quantitatively analysing the impact of the structure of the networks in which people and organisations are embedded on their behaviour and performance (Granovetter, 2005).
  - Granovetter (1973) argued that for diffusion across a network, weak ties are the most valuable.
  - Bridging Ties‘ strength lies in the widespread dissemination of new, formal, and heterogeneous knowledge, and it is easily linked to radical innovation (Burt, 2004) .
  - Among the indicators of network structure, centrality is one of the most commonly used indicators in network analysis.
  - There are various ways of thinking about what constitutes a central position, and various indices of centrality have been proposed (e.g. Bonacich, 2007; Freeman et al., 1979).

Research Data

- This study used data from newspaper articles and corporate press releases, through which it is possible to collect comprehensive, integrated, and timely data on the relationships among many firms.
  - Specifically, the Lexis Advance database was used as the data source, which allows for full-text searches and browsing of newspaper articles from over 100 of the world's leading newspapers, including the New York Times, Los Angeles Times, Le Monde, and others.
  - Articles containing the search term 'connected car' and containing more than one company were extracted.
  - The extracted relationships between companies were narrowed to the relationships that correspond to the business ecosystem.
  - The period for evaluating the growth of companies was set at five years, and articles from 2019 and 2015 were extracted.

Analytical Method

- Data cleaning
  - All the words and compound words in the entire database were extracted using text-mining techniques, and the notations were unified or grouped.
- Social network Analysis
  - Each company's inter-organisational network structure was analysed according to each hypothesis based on the database for analysis.
  - An evaluation index for each firm's degree of growth was calculated.
- Multiple regression analysis
  - A multiple regression analysis was performed with the degree of growth as the dependent variable and the network indicators as the independent variables.
  - The components were exploratively classified into several types, and each type was tested for each of the above hypotheses.

Overview of the Research

- The number of articles extracted was 2,621 in 2015 and 1,861 in 2019, and the number of companies extracted was 1,784, with 18,424 combinations among these companies.
- The nouns in the articles were extracted by text mining methods and classified into four categories based on their content.

1. automotive hardware
   - vehicles and vehicle parts
   - 756 firms and 6,000 pairs
2. connected equipment
   - computer-related equipment, electronic equipment, and communication equipment
   - 765 firms and 6,067 pairs
3. software applications
   - applications, software, and systems
   - 416 firms and 3,648 pairs
4. Service
   - distribution, and transport
   - 678 firms and 5,430 pairs
     - The number of firms in each category and the number of inter-firm relationships overlap among the categories.

Table 1. Results of multiple regression analysis for Automotive hardware

	Model 1	Model 2
Degree Centrality	.926**	.979**
nEgoBetweeness	.519**	.531**
Constraint	-.067	
Eigenvector centrality	-.298**	-.320**
Density	.723**	.721**
Closeness centrality	.002	
Adjusted R-square	.330	.330
Significance probability	<.001	<.001

Note: ** p < .01, * p < .05

- Model 1 is the result of forced imputation of all independent variables and Model 2 is the result of stepwise imputation of independent variables.
- Constraint and Closeness centrality were removed from the analysis due to multicollinearity problems. Constraint and Closeness centrality are considered to be similar to nEgoBetweeness and Density, respectively. In the following discussion, these two indices are excluded.

Table2. Results of the multiple regression analysis for Connected equipment

	Model 1	Model 2
Degree Centrality	.869**	.923**
nEgoBetweeness	.472**	.476**
Constraint	-.059	
Eigenvector centrality	-.287**	-.311**
Density	.688**	.679**
Closeness centrality	-.007	
Adjusted R-square	.280	.280
Significance probability	<.001	<.001

Note: ** p < .01, * p < .05

- Model 1 is the result of forced imputation of all independent variables and Model 2 is the result of stepwise imputation of independent variables.
- Constraint and Closeness centrality were removed from the analysis because of multicollinearity problems, as in the case of automotive hardware.

Table 3. Results of the multiple regression analysis for software applications

	Model 1	Model 2
Degree Centrality	.905**	.951**
nEgoBetweeness	1.099**	1.145**
Constraint	-.054	
Eigenvector centrality	-.267**	-.280**
Density	1.402**	1.441**
Closeness centrality	.021	
Adjusted R-square	.261	.264
Significance probability	<.001	<.001

Note: ** p < .01, * p < .05

- Model 1 is the result of forced imputation of all independent variables and Model 2 is the result of stepwise imputation of independent variables.
- As in the previous two analyses, Constraint and Closeness centrality were removed from the analysis due to multicollinearity problems.

Table 4. Results of the multiple regression analysis for Service

	Model 1	Model 2
Degree Centrality	.822**	.919**
nEgoBetweeness	.645**	.698**
Constraint	-.107	
Eigenvector centrality	-.259**	-.299**
Density	.837**	.867**
Closeness centrality	.021	
Adjusted R-square	.293	.291
Significance probability	<.001	<.001

Note: ** p < .01, * p < .05

- Model 1 is the result of forced imputation of all independent variables and Model 2 is the result of stepwise imputation of independent variables.
- As in the previous three analyses, Constraint and Closeness centrality were removed from the analysis due to multicollinearity problems.

Discussion

- No difference in the relationship between each network index and the degree of growth was observed among components such as hardware and software.
- Network size is positively related to the degree of growth.
  - Existing major companies are trying to continue their traditional business while adapting to new technological changes.
  - Such a growth pattern can be named as the growth pattern of existing large firms.
- The mediation index is positively related to the level of growth.
  - There is a possibility that platform leader firms are growing in the area of connected cars.
  - Such a growth pattern could be named the platform leader type.

Discussion

- Regarding eigenvector centrality, the results of the analysis show a negative relationship with the degree of growth
  - Firms far from the network centre may be growing.
  - Such a growth pattern can be called a peripheral growth pattern.
- The index of density may be positively related to growth.
  - Each is not necessarily a platformer for the entire automotive industry, and their activities may be rather regional, such as the US or Europe, with each regional group of companies providing connected car-related services.
  - Such a growth pattern could be termed a clustered growth pattern.
- The connected car space may be growing with a mix of inter-organisational networks with different characteristics.

Conclusion

- The results of the analysis of a large number of real databases show
  - The whole of Connected Car does not have the same characteristics of inter-organisational relations, but that growth companies with an inter-organisational network structure of various different characteristics coexist.
  - Possibly, the changes caused by connected cars are driving a change towards a horizontal division of labour in inter-organisational relations, such as the emergence of so-called platform leader firms in the automotive industry.
- As the limitations of this research,
  - The industrial structure in this area remains in flux and is expected to change in the future.
  - It cannot be denied that the analysis, based on newspaper article data, may differ from reality.
- As a future research,
  - It is necessary to conduct a continuous analysis while supplementing data with other methods.

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