A Structure Analysis of Keiretsu of Toyota

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INTRODUCTION

The keiretsu, a system of organizations with integrated and interlocking business relationships and joint shareholdings, is a form of networked organization. As an affiliation of enterprises, the keiretsu plays an important role in the growth of automotive manufacturing in Japan. For example, Asanuma and Kikutani (1997) conducted an empirical study of supply chain relationships in the automotive parts industry and electric machine manufacturing and found the longstanding transactional relationships among the keiretsu as a crucial factor for acquiring economic rationality. From a managerial standpoint, Imai and Kaneko (1988) pointed out that organizational structures evolved from the traditional vertical hierarchy to modern horizontal structures through the support and development of information technology in the keiretsu. They also predicted that the "network organization" form will be a most important type of enterprise in the future. According to Lincoln and Gerlach (2004), "the most distinctive form of network organization in Japan—and the most critical to understanding its economy—is the clusters of industrial, commercial, and financial corporations known as the keiretsu "(p. 15).

In this article, the authors present a brief overview of network analysis studies and methods, with a particular focus on the Japanese keiretsu system represented by firms such as Toyota and the auxiliary and ancillary companies that rotate around Toyota's network. The authors first describe relevant studies of the keiretsu system; then focus on a theoretical discussion of measurements and data collection methods that are generally used in network analyses. After presenting a brief example of a preliminary analysis of data on networks of firms related to Toyota through transactions and cross-shareholdings, the authors discuss limitations and future research.

BACKGROUND

A network is generally defined as a set of nodes or actors interrelated and connected by lines or channels. The "network organization" is an organizational form that is based on a network structure. All organizations can be considered as networks. Nohria (1992) stated that: "The term 'network' has become the vogue in describing contemporary organizations. From large multinationals to small entrepreneurial firms, from manufacturing to service firms, from emerging industries such as biotechnology to traditional industries such as automobiles, from regional districts such as those Silicon Valley and Italy's Prato district to national economics such as those of Japan and Korea, more and more organizations are being described as networks" (p. 1). The roots of network research lie in the sociometry of small groups (Moreno, 1934), and informal networks of relations (Roethlisberger & Dickson, 1939). Network researchers have identified that the key elements of value creation of network organizations are: 1) reduction in time and costs of operations; 2) increase in product service capabilities; and 3) increase in relationships and achievable partnerships.

Both historical and qualitative analyses of the keiretsu have been recently undertaken (Moloney, 2005; Lincoln & Gerlach, 2004). The quantitative research approach presented in this article focuses on relationships among the firms in the keiretsu using input-output analysis and graph theory. This work is based on a number of earlier studies, such as, for example, Brass & Burkhardt (1992), an empirical study of centrality and

power in the organization of a newspaper publishing company. Recent studies focus on the analysis of the relationships among the firms in the keiretsu of Toyota and other organizations (Ito, 2002; Wakabayashi, 2003). The correlation coefficient between the centrality index of a network and corporate performance, such as sales and ordinary profit, has been measured (Ito, 2004). Furthermore, the importance of individual firms was displayed in the keiretsu of Toyota using a model called "strengthening, neutral and weakening (SNW) analysis" (Ito & Sakamoto, 2005). SNW analysis is an analytical tool used to determine the importance of each individual actor in a network, based upon comparative assessment of the entire network and its sub-networks. In this approach, the individual actor p_k is called strengthening (s) if the centrality of its sub-network is less than that of the entire network. If the opposite holds true, the actor is called weakening (w). Actor p_k is defined as neutral (n) if the centrality of its sub-network is equivalent to that of the entire network

KEY MEASURES OF NETWORK INTERACTIONS

Graph theory supports the study of networks. A graph consists of a set of points and a set of lines connecting pairs of points. The point, which composes a network, is called a "node," and the line, which connects any two nodes directly, is called an "edge" in graph theory. The shortest path linking a given pair of nodes is called "geodesic."

Key Measures of Centrality

Freeman (1978/79) identified key measures of network interactions based on the centrality of each node within the entire network from three points of view: a) degree, b) betweenness, and c) closeness.

a) Degree

Degree of a node is defined as the number of nodes that connect with it directly. Freeman calculated it based on Nieminen (1974).

$$C_D(p_k) = \sum_{i=1}^{n} a(p_i, p_k) \qquad (1)$$

where

$a(p_i,p_k)=1$ if and only if p_i and p_k are connected by a line

$a(p_i,p_k)=0$ otherwise

A given node p_k can at most be adjacent to other (n-1) nodes in a network. The ratio with the C_D (p_k) is defined as:

$$C_D'(p_k) = \frac{\sum_{i=1}^{n} a(p_i, p_k)}{n-1} = \frac{C_D(p_k)}{n-1} \qquad (2)$$

Freeman called equation (2) *absolute degree*, and the equation (1) *relative degree*. The degree of an entire network is defined as follows (Freeman, 1978/79).

$$C_D = \frac{\sum_{i=1}^{n} [C_D(p^*) - C_D(p_i)]}{n^2 - 3n + 2} \qquad (3)$$

where

$$C_D(p^*) = \max C_D(p_i)$$

The number of nodes adjacent to a given node in a *symmetric network* is represented by the degree of that node. For *asymmetric networks*, the *in-degree* of a node p_k is the number of ties received by p_k and the *out-degree* is the number of ties initiated from p_k. The degree of a node means the proportion of other nodes that are adjacent to p_k and is viewed as an important index of its potential communication activity. In transaction networks, "in-degree" means the number or percentage of automotive parts received; and "out-degree" means the number or percentage of automotive parts supplied. And, in the network of cross-shareholdings, "in-degree" means the number or percentage of a firm's stock owned by other firms, and "out-degree" means the number or percentage of a firm's investment into other firms.

b) Betweenness

The index of *betweenness* is calculated as a probability that node p_k falls on a randomly selected geodesic linking p_i with p_j. Freeman (1977) defines the index