Horizontal versus vertical structural holes in supply networks: Contrasting performance implications for focal firms

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Abstract

Our study investigates the relationship between structural characteristics of the supply network and firm financial performance. In particular, we introduce a novel approach to understanding structural holes in supply networks and examine the performance implications of the disconnections between the focal firm's suppliers and the disconnections between the focal firm's customers and suppliers. Our analysis based on the longitudinal supply network reveals contrasting effects of horizontal versus vertical structural holes on focal firms' financial performances. We also find that these contrasting influences of the two types of structural holes are more salient for the firms with high innovation capability.

Keywords: Structural hole theory, Supply network, Social network analysis

Introduction

The growing body of literature that applies social network theories to supply networks focuses on the connection between network structures and firm performances (e.g., Bellamy et al., 2014; Carnovale and Yeniyurt, 2015; Dong et al., 2015). The studies in this body of literature suggest that structural characteristics of supply networks are critically influential for firm performances as supply network structures are associated with firm innovation performance (Bellamy et al., 2014; Carnovale and Yeniyurt, 2015), supplier selection and management (Choi and Kim, 2008; Yan et al., 2015), supply risk (Simchi-Levi et al., 2015) and opportunism between supply chain partners (Dong et al., 2015).

The linkages between interfirm network structures and firm performances have been investigated frequently in the contexts of strategic alliance network, joint venture network, and joint research and development (R&D) network (e.g., Capaldo, 2007; Gulati, 1998; Zaheer and Bell, 2005). However, despite the increasing attention to the linkages between supply network structures and firm performances, there has been a lack of studies that empirically test the direct relationship between the structural characteristics of supply networks and firm financial performance. The performance implications of supply networks require special attention due to the unique characteristics of supply networks. Unlike strategic alliance or joint venture networks, supply networks are characterized with certain directions of materials, service, information, and monetary flows. Firms in a supply network have their unique production or service roles but their

roles as buyer or supplier are relative to the perspective of the focal firm (Carter et al., 2015).

We suggest a novel way of understanding structural holes (Burt, 1992) in supply networks and introduce two different types of structural holes: horizontal structural holes—the disconnections between a focal firm's suppliers—and vertical structural holes—the disconnections between the focal firm's customers and suppliers (see Figure 1). As a focal firm has multiple roles (e.g., customer, supplier, or middleman) in a supply network (Carter et al., 2015), structural holes can have very different influences on the focal firm depending on how we define the structural holes. Accordingly, we try to answer the following research question: *What are the effects of horizontal and vertical structural holes on the focal firm's financial performance?* Based on the panel data of the network of buyer-supplier relationships spanning an eleven-year period, we provide evidence for the contrasting impacts of horizontal versus vertical structural holes on focal firms' financial performances. We also show that these contrasting influences of the two types of structural holes are more salient for innovative firms.

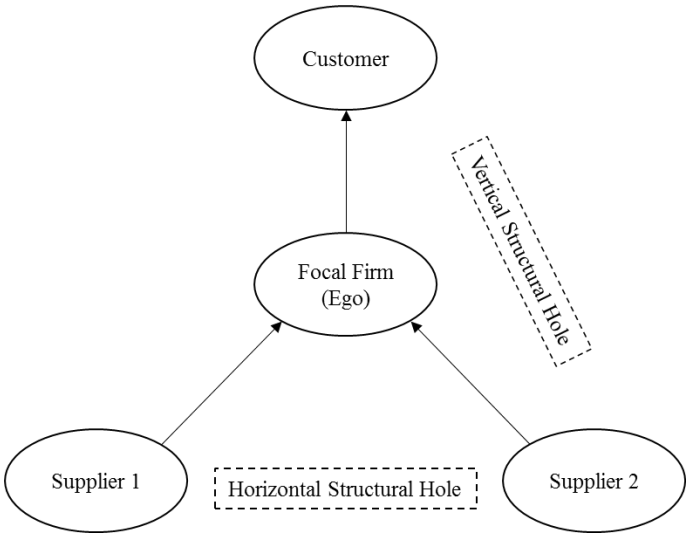

Figure 1 – Horizontal and vertical structural holes

We contribute to the supply network literature by introducing the concepts of horizontal and vertical structural holes and providing empirical evidence for the linkage between structural characteristics of supply networks and firm financial performance. Especially, the relationship between structural holes in supply networks and firm financial performance has remained unclear possibly because the conflicting roles of horizontal and vertical structural holes were not distinguished. Our study also contributes to the social network literature by suggesting an avenue for resolving the ongoing debate regarding the benefits of dense networks with less structural holes versus sparse networks rich in structural holes (Reagans and Zuckerman, 2008). The conceptual distinction between horizontal and vertical structural holes in supply networks clarifies the conditions where a focal firm can benefit from dense or sparse networks. In addition, our study provides practical implications for managers regarding how innovative firms can utilize and develop supply network structures strategically.

Theoretical development and hypotheses

Structural hole theory

Structural hole theory (Burt, 1992) emphasizes the benefits of having non-redundant ties with other network members who are not connected with one another. Structural hole

refers to the disconnection between the focal player's contacts (Burt, 1992). If two actors in a network are not directly connected to each other but indirectly connected through a focal player, it is located on a structural hole. Burt (1992) argues that the players who are bridging structural holes have diverse contacts and therefore have wider access to information and can capture opportunities earlier than their peers. He adds that the players sitting on structural holes are also in a better position to know when it would be valuable to bring two disconnected people together and control the relationship between them. Simmel (1922) terms these players who benefit from bridging structural holes the *tertius gaudens* (the third who benefits). In the supply chain literature, structural hole theory has been applied to examine the influence of structural characteristics of supply networks on focal firms' innovation output (Bellamy et al., 2014; Carnovale and Yeniyurt, 2015), opportunism (Dong et al., 2015), and services outsourcing (Li and Choi, 2009). Yet, the evidence for the direct connection between structural holes and firm financial performance has remained elusive.

We argue that in the supply network context, structural holes can involve very different types of structural holes. Due to the unique conditions in supply networks involving directionality of materials, service, information, and monetary flows (Carter et al., 2015), the effects of structural holes on firm performance are relative to different types of structural holes. In our study, we distinguish two different types of structural holes—horizontal structural hole and vertical structural hole (see Figure 1). We expand the terms "horizontal" and "vertical" ties among buyers and suppliers (Lazzarini et al., 2008) and apply them to describe the "lack" of ties or disconnection. A horizontal structural hole in our study refers to the structural hole between two suppliers of a focal firm. In contrast, a vertical structural hole is defined as the structural hole between a customer and a supplier of a focal firm. If multiple customers and suppliers are not connected through buyer-supplier relationships among themselves, the focal firm can have multiple horizontal and vertical structural holes in its ego network.

Horizontal structural holes

We argue that in the supply network context, more ties between a focal buying firm's suppliers (less horizontal structural holes) do not necessarily limit its information and control benefits as *tertius gaudens*. Since the focal buying firm procures materials or services from suppliers, it plays the role as an integrator rather than a broker or middleman between the suppliers. In this context, existing buyer-supplier ties between suppliers can allow the focal firm to facilitate cooperation in its upstream supply network (Wu and Choi, 2005).

Contrasting with structural hole theory, Obstfeld (2005) introduces the concept of *tertius iungens* (the third who connects) and proposes the advantages of dense social networks with less structural holes. Obstfeld (2005) argues that individuals in dense social networks are in advantageous positions to facilitate collaborative interactions and promote innovations. Dense social networks provide conditions for clarifying expectations about effective roles of the network members (Podolny and Baron, 1997) and therefore, reduce risks in exchange relationships (Moran, 2005). Coleman (1988) also argues that a dense network creates social norms and trustworthiness by allowing the network members to use reputation effectively as a collective sanctioning mechanism. Bizzi (2013) observes that structural holes in group relationships create frictions and problems among the members.

Since suppliers play critical roles in the process of creating and delivering products, connections among suppliers (i.e., lack of horizontal structural holes) can make it easier for a focal buying firm to combine resources across the supply network and create

innovation. Buying firms can proactively create relationships among their suppliers to achieve collaborative synergy and market efficiency (Wu and Choi, 2005). In this context, a buying firm can better encourage suppliers to engage in collaborate activities such as quality improvement, cost reduction, new product development, and capacity sharing.

Moreover, in a supply network structure without ties between suppliers (i.e., more horizontal structural holes), a buying firm must rely on each supplier for relevant upstream supply information. In this setting, the suppliers may develop less sense of interdependence and tend to behave more opportunistically, as it becomes more difficult for the focal buying firm to verify supply information from multiple routes and use reputation as collective sanctions against opportunism. By the same mechanism that benefits *tertius gaudens*, a focal buying firm's upstream supply network rich in horizontal structural holes concedes information and control benefits to its suppliers, as the other members of the network are more likely to be located on structural holes in an open network structure (Reagans and Zuckerman, 2008).

H1: The extent of horizontal structural holes in the focal firm's supply network is negatively associated with its financial performance.

Vertical structural holes

In contrast to horizontal structural holes, vertical structural holes can enhance the competitive position of a focal firm. When the focal firm is located on many structural holes between its customers and suppliers, it can actively play the role of the broker or middleman that controls the flows of materials and information. As materials or services flow from the supplier to the customer *through* the focal firm, it can take advantage of the *tertius gaudens* (Simmel, 1922) position by selectively transferring critical supply-side and demand-side information between its customers and suppliers (Li and Choi, 2009). As the information coming from the focal firm's upstream supply chains is likely to be very different from the information from its downstream supply chains, the focal firm can enjoy information benefits by having many customers that are disconnected with many of its and suppliers (i.e., many vertical structural holes). This unique position in the network creates opportunities for the focal firm to combine and create new ideas (Burt, 2004).

In addition to information benefits, if the focal firm sits on multiple structural holes between several suppliers and customers, it can leverage its position as a broker and control material/service flows from certain suppliers to certain customers. Overall, a focal firm located in a network rich in vertical structural holes is in a unique position to collect and integrate information from both supply and demand sides and control the information and material flows for its own benefit.

H2: The extent of vertical structural holes in the focal firm's supply network is positively associated with its financial performance.

Innovation capability and structural holes

Horizontal structural holes can be more damaging for innovative buying firms under fast-changing technological environment. The risk related to having horizontal structural holes becomes more salient for innovative buying firms because they rely more heavily on technological developments of their products (Hargadon and Sutton, 1997; Henderson and Clark, 1990). For a focal buying firm, allowing the direct suppliers to occupy structural hole positions between the focal firm and other suppliers can limit its access to critical technological developments at the component level, gradually eroding the firm's core capability and in turn, financial performance (Brusoni et al., 2001; Weigelt, 2009). An upstream supply network with many horizontal structural holes makes it more difficult

for a buying firm with high innovation capability to transfer tacit technological knowledge (Reagans and Zuckerman, 2008) and induce collaborations among suppliers to facilitate developments of innovative products (Dyer and Hatch, 2006). Furthermore, the innovative buying firm with many horizontal structural holes can face more difficulties in monitoring technological advancements and cost reduction efforts of the suppliers (Camuffo et al., 2007) due to the lack of redundant information sources in the upstream supply network.

H3: The focal firm's innovation capability moderates the relationship between the extent of horizontal structural holes and its financial performance such that the negative relationship is strengthened when innovation capability is high.

On the contrary, the positive relationship between vertical structural holes and firm performance can be stronger when a focal firm already has high innovation capability. Existing stocks of knowledge are critical to the process of combining and creating new knowledge (Obstfeld, 2005). Additionally, Burt (2004) argues that structural holes provide more opportunities for generating good ideas though access to diverse information. With readily advanced innovation capability, the focal firm can better detect, interpret, assimilate, and apply new information regarding technological developments and market changes from both supply-side and demand-side and apply it for its own product or process innovation (Cohen and Levinthal, 1990). Rowley et al. (2000) observe that in environments with fast technological developments, structural holes are positively associated with firm performance. Zaheer and Bell (2005) also find that innovative mutual fund firms that also bridge structural holes are better at improving their performance. The disconnections between the focal firm's customers and suppliers allow it to play the role as a broker of technological and market information and provide a unique position to match market opportunities with technological developments from upstream supply chains.

H4: The focal firm's innovation capability moderates the relationship between the extent of vertical structural holes and its financial performance such that the positive relationship is strengthened when innovation capability is high.

Methodology

Sample and data sources

The data is collected from three data sources—Compustat Fundamentals Annual, FactSet Supply Chain Relationships, and the United States Patent and Trademark Office (USPTO) patent database. Initial sample companies will be all publicly traded manufacturing companies listed in the semiconductor and other electronic component manufacturing (33441) industry. We selected this industry since the majority or the firms in this industry is publicly traded and they are both customers and suppliers to many other firms. This middle-tier supply network positions of the firms in the semiconductor and other electronic component manufacturing industry allow us to observe multiple horizontal and vertical structural holes. The initial sample companies are identified using Compustat, and then their supply chain relationships are collected from FactSet Supply Chain Relationships database. FactSet Supply Chain Relationship database provides the archival data of contractual buyer-supplier relationships from 2003 (FactSet, 2017). FactSet identifies contractual buyer-supplier relationships based on the companies' annual reports, regulatory disclosures, and other announcements. The companies that are not identified in FactSet Supply Chain Relationships or have less than three suppliers or two customers are excluded from the final sample. We used the USPTO patent database to collect the number of granted patent applications of the companies in the final sample.

The final sample includes 164 firms with 1,115 observations across the eleven-year period.

Since not all the firms in the initial sample from Compustat are selected as the final sample, sample selection bias can exist. To prevent endogeneity problems originating from sample selection, we used the Heckman selection model (Heckman, 1979) for analysis. Heckman models consist of two estimation stages. In the first stage, we used a probit model to predict the probability of being in the sample in a specific year with the sample focal firm's yearly news article search count and the firm size in terms of the natural log of the number of employees. News article search count was obtained by searching the focal firm using ProQuest. Then, based on the predicted values from the first stage estimation, we calculated inverse Mills ratios (Heckman, 1979) and included them as a control variable in the second stage estimations, which test our hypotheses.

Variables

Dependent Variables. Two dependent variables are used to measure the focal firm's financial performance. First, return on assets (ROA) measures the short-term financial performance. Second, Tobin's q (Tobin, 1969) is used to measure the focal firm's stock market performance that reflects investors' expectations of the firm's long-term financial performance. Within the economics and finance literature, long-term, future value of the firm is often measured using Tobin's q whereas ROA (net income/total assets) is typically used to measure backward-looking, short-term financial performance of the firm (Mittal et al., 2005).

Independent variables. The two independent variables of this study are horizontal and vertical structural holes. Both measures are adapted from Burt's (1992) aggregate constraint measure. Aggregate constraint measures the degree of having no access to structural holes (Burt, 1992: Chapter 2). The formulas for Burt's aggregate constraint are the following: $C_i = \Sigma_j(p_{ij} + \Sigma_q p_{iq} p_{qi})^2, i \neq q \neq j$, where C_i is network constraint on firm i and c_{ij} measures i's dependence on contact j and p_{ij} is the proportion of i's network time and energy directly spent on j and $\Sigma_q p_{iq} p_{qi}$ is the proportion of i's network time and energy indirectly spent on j.

Since Burt's (1992) aggregate constraint measures no access to structural holes and it ranges from 0 to 1, we use $1 - C_i$ as the measure of the extent of structural holes. To measure the extent of horizontal structural holes, we extracted the focal firm's ego network involving the buyer-supplier relationships between the focal firm and its direct suppliers, and the buyer-supplier relationships among the focal firm's direct suppliers. Then we calculated C_i for each focal firm. To measure access to vertical structural holes, the focal firm's ego network involving the focal firm, its direct customers and suppliers, and the buyer-supplier relationships between customers and suppliers are extracted. The same calculation of C_i is applied to these second type of networks to measure vertical structural holes.

Moderator variable. The focal firm's innovation capability is measured using the natural log of the number of the firm's patents obtained in the past five-year period. Patents are commonly used to measure innovation capability of a firm (Bellamy et al., 2014; Hall et al., 2005).

Control Variables. Control variables include global network centrality measures and other firm-level variables that can be correlated with both independent and dependent variables. Global network centrality measures include indegree and outdegree centralities and input and output closeness centralities (Freeman et al., 1979). Other firm-level variables that can be correlated with market valuation and short-term financial

performance are also included as control variables. They include firm size (log total assets), debt to equity ratio (liabilities/equity), R&D intensity (R&D expense/sales), capital intensity (capital expense/sales), and cost of goods sold to sales ratio (COGS/sales). Year dummy variables are also included to control for unobserved heterogeneity across time.

Analysis

We conducted the analysis with the sample firms in the semiconductor and other electronic component manufacturing industry (5-digit NAICS 33441) listed in Compustat for the eleven-year period from 2004 to 2014. After identifying initial sample firms from Compustat, we used the FactSet Supply Chain Relationships database to build an industry-wide network at the end of each year from 2003 to 2013. The network involves the sample focal firms and their direct customers and suppliers and the customers and suppliers of the direct customers and suppliers (i.e., indirect customers and suppliers). To analyze the panel data and control for unobserved heterogeneity across the firms in the sample, we used fixed effect models. To minimize multicollinearity problems when testing interaction effects, we grand-mean centered (Enders and Tofighi, 2007) horizontal and vertical structural holes and innovation capability variables.

Results

We conducted two separate fixed-effects regression analyses with ROA and Tobin's q as dependent variables. Table 1 shows the result of the fixed-effects regression models. Model 2 shows the result after controlling for sample selection bias. The coefficient for horizontal structural holes ($B = -0.41$, $p > 0.1$) is not significant at the $p < 0.05$ level. Therefore, H1 is not supported when the dependent variable is ROA. However, the coefficient for vertical structural holes ($B = 0.68$, $p < 0.05$) is significant, supporting H2. The interaction between innovation capability and horizontal structural holes ($B = -0.18$, $p < 0.01$) has a significant negative association with ROA, supporting H3. In addition, the interaction between innovation capability and vertical structural holes ($B = 0.21$, $p < 0.05$) has a significant positive association with ROA, supporting H4.

Model 4 shows the result of the fixed-effects regression with Tobin's q as the dependent variable. After controlling for sample selection bias, horizontal structural holes ($B = -4.64$, $p < 0.05$) show a significant negative association with Tobin's q, providing support for H1. In contrast, vertical structural holes ($B = 5.95$, $p < 0.5$) show a significant positive association with Tobin's q, supporting H2. The interaction between innovation capability and horizontal structural holes ($B = -1.76$, $p < 0.01$) has a significant negative association with Tobin's q, supporting H3. However, the interaction between vertical structural holes ($B = 1.48$, $p > 0.1$) does not have a significant association with Tobin's q, not supporting H4. Overall, H2 and H3 are fully supported, and H1 and H4 are partially supported. We interpret and discuss these results further in the following section.

Table 1 – Result of the fixed-effects regression models

Model	1	2	3	4
Dependent variable	ROA	ROA	Tobin's q	Tobin's q
Constant	−0.241*	−0.293*	6.709***	7.509***
	(0.115)	(0.122)	(1.497)	(1.586)
Firm fixed-effects	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
Inverse Mills ratio		0.029		−0.444
		(0.034)		(0.344)
Control variables	Yes	Yes	Yes	Yes

Horizontal structural holes (H1)	−0.402	−0.411	−4.789*	−4.644*
	(0.258)	(0.258)	(2.158)	(2.152)
Vertical structural holes (H2)	0.683*	0.683*	5.950†	5.954*
	(0.327)	(0.331)	(3.046)	(3.016)
Horizontal SH × Innov. capa. (H3)	−0.181**	−0.184**	−1.800**	−1.762**
	(0.069)	(0.069)	(0.669)	(0.678)
Vertical SH × Innov. capa. (H4)	0.205*	0.206*	1.481	1.478
	(0.093)	(0.094)	(0.953)	(0.952)
R^2 within	0.168	0.169	0.591	0.592
N observations	1115	1115	1115	1115
N groups	164	164	164	164

Discussion

The results of the analysis provide contrasting financial performance implications of horizontal versus vertical structural holes in supply networks for focal firms in the semiconductor and other electronic component manufacturing industry. These contrasting aspects of horizontal versus vertical structural holes seem to influence the focal firm's short-term and long-term financial performances differently. On the one hand, having more suppliers that are connected to each other through buyer-supplier relationships is associated with the focal firm's long-term (Tobin's q) rather than a short-term (ROA) financial performance. This finding may imply that although the focal firm with less horizontal structural holes cannot pursue short-term financial gains, it can benefit in the long-term from collaborations among the suppliers. On the other hand, more vertical structural holes between the focal firm's customers and suppliers are associated with better short-term (ROA) and long-term (Tobin's q) financial performances. This finding supports the classic arguments of structural hole theory (Burt, 1992).

We also found that for an innovative focal firm, more disconnections among its suppliers (i.e., more horizontal structural holes) can be harmful to both short-term and long-term financial performances. Reagans and Zuckerman (2008) argue that there are risks associated with relying on non-redundant ties with more structural holes, because ambiguous information or tacit knowledge may be better transferred through redundant ties in a dense network. Therefore, an innovative focal firm with rich tacit knowledge in new product or process development would find it more difficult to facilitate knowledge transfer among suppliers if they do not interact with each other through buyer-supplier relationships. On the contrary, the positive interaction between vertical structural holes and innovation capability on ROA suggest that innovative focal firms are better at improving short-term financial performance by utilizing their middleman positions between customers and suppliers. However, potentially due to the lack of innovation collaborations and cohesion between customers and suppliers, innovative focal firms with more vertical structural holes do not enjoy additional long-term financial gains compared to their less innovative counterparts.

Theoretical contribution

The findings of our study highlight the importance of considering directionality in supply networks and suggest the relativity of structural holes in such networks. Unlike other interfirm alliance or joint venture network research in strategic management where ego firms and alter firms are all "partners," the context of our study is the supply network where the nodes can be either buyers or suppliers relative to the perspective of the focal firm (Carter et al., 2015). Not considering these unique characteristics of supply network can provide inaccurate implications on the roles of structural holes in supply networks. As Borgatti and Li (2009) suggest, we avoid simplistic application of social network concepts into the supply network context. We intend to contribute to both structural hole

theory and the literature on supply network structures by providing theoretical and empirical evidence for how the mechanisms behind structural holes can function differently relative to the specific contexts in supply networks.

Our study also contributes to the ongoing debates regarding the performance implications of redundant ties or dense networks in the social network literature (Reagans & Zuckerman, 2008; Rowley et al., 2000). By considering the directions of the flows in supply networks and distinguishing horizontal and vertical structural holes, we provide the potential for resolving seemingly competing arguments about the benefits of dense networks (Coleman, 1988) versus structural holes (Burt, 1992). Based on the empirical evidence of our study, we call for further theoretical and methodological developments that incorporate directionality in conceptualizing structural holes.

Managerial implications

Our study provides several managerial implications. First, especially for a firm with high innovation capability, developing dense upstream supply networks with more buyer-supplier relationships among its suppliers can be beneficial for its overall financial performance. There are multiple ways of developing denser upstream supply networks. Buying firms can induce contractual relationships between suppliers (Wu and Choi, 2005), initiate direct contractual relationships with Tier-2 suppliers (Choi and Linton, 2011), or select suppliers with existing buyer-supplier relationships among themselves. Buying firms should consider these options to reduce horizontal structural holes in their upstream supply networks.

In addition, a firm in middleman positions between its multiple customers and suppliers can enjoy superior financial performances by actively sustaining vertical disconnections between the customers and suppliers. Supply chain scholars have emphasized the dangers of supply chain disintermediation in which a focal firm's customers make direct transactions with the focal firm's suppliers (Rossetti and Choi, 2008). Conceptually, the more supply chain disintermediation, the less vertical structural holes for a focal firm. By developing the concept of vertical structural holes and empirically testing their effects on firm financial performance, our study substantiates the arguments for the dangers of supply chain disintermediation. Managers should be aware of the financial disadvantages of supply chain disintermediation and engage actively in sustaining middleman positions of their firms between customers and suppliers.

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