

Betweenness Centrality and Supplier Performance: The Missing Link?

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Although researchers have paid increasing attention to network centrality in the literature of supply chain management, little is known about the role of betweenness centrality in enhancing supplier performance. This study reviews prior research that conceptualizes betweenness centrality. We take the social network perspective and investigate whether betweenness centrality can be a source of external information and competitive advantage. This study contributes to the literature of social network and supply chain management by synthesizing conceptual views of betweenness centrality and highlighting the way in which betweenness centrality can play a role as a knowledge broker between isolated firms.

Keywords: Centrality; Betweenness; Social network; Supplier; Performance

Introduction

Scholars in supply chain management have become increasingly interested in how the central position occupied by a firm in supply networks influences performance outcomes (Carnovale & Yenyurt, 2014; Gokpinar et al., 2010; Schilling, & Phelps, 2007). As firms' own knowledge base alone is not sufficient to obtain diversified knowledge, it is important for firms to capture, interpret, and implement knowledge resources from external networks (Gao et al., 2015). A firm's position is essential for achieving goals and succeeding in a competitive business environment (Hanneman & Riddle, 2005; Hallikas et al., 2008; Mazzola et al., 2015). Position influences a firm's decisions around investments, acquisition partners, and alliance formations (Ranganathan & Rosenkopf, 2014). Extant research on network positions has focused on how network configurations enable the channeling of scarce and valuable resources through various network connections. Researchers, for example, have discussed how to bridge ties in a web of relationships or how to build strong ties between network participants (Peng & Mu, 2011). However, establishing the network position also involves some costs to firms. Perry-Smith and Shalley (2003) argue, for example, that a firm's position is not always beneficial for creativity. It is also difficult for individual firms to identify appropriate partners and resources in a network because information about new market opportunities is dispersed in supply networks (Soh & Roberts, 2005).

Researchers have paid increasing attention to network centrality in the literature of supply chain management. Organizational collaboration in supply chains leads to the development of social ties and partner-specific knowledge that influence the variance in firms' performance (Kim & Zhu, 2018). However, the development of theories on network centrality is still at the early stages in the

field of operations and supply chain management (Borgatti & Li, 2009). Limited attention has been directed to betweenness centrality. Betweenness centrality indicates a firm's ability to manage direct and indirect ties and to potentially gain access to expertise (Cross & Cummings, 2004). We will begin by considering the insights of indirect ties, because the indirect ties are a critical source of information and innovation and serve as information intermediaries that enhance the information base of companies, and thus strengthen their ability to absorb and utilize external knowledge (Cross & Cummings, 2004; Lechner et al., 2010; Mehra et al., 2001; Sasovova et al., 2010). Few studies have explicitly accounted for the effect of this dimension on supply chain performance (e.g., Carnovale & Yenyurt, 2014; Fox et al., 2013; Schilling & Phelps, 2007). Researchers have therefore called for more research in order to better understand the nature of betweenness centrality (Carnovale & Yenyurt, 2014; Easton & Rosenzweig, 2015; Fox et al., 2013; Wincent et al., 2010).

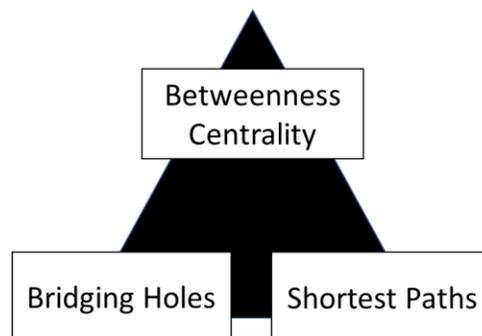
The purpose of this study is to review prior research that has proposed definitions of betweenness centrality. This study will also discuss how and why a supplier firm's betweenness centrality influences financial performance. We take the supplier perspective and explore whether betweenness centrality can be a source of external information and competitive advantage in supplier firms. Social network theory suggests that we examine the impacts of both direct and indirect ties on performance because firms are interconnected with one another and are embedded in various external social networks (Gao et al., 2015). Our argument is that although the number of a firm's direct ties indicates an opportunity to have access to external information, the firm also requires the capability to bridge unconnected ties and leverage the unique information that is available in supply chains. We draw on insights from social network theory to explain why betweenness centrality can lead to access to diverse information and knowledge.

The remainder of the paper is organized as follows. First, definitions of betweenness centrality in the literature are reviewed. Second, we discuss the measures of betweenness centrality. Third, we introduce a proposition for how betweenness centrality influences supplier performance. Finally, we summarize the key findings and contributions of this study.

Definition

Given the broad definitions of betweenness centrality that have been proposed, researchers have underlined one of the two dimensions: bridging structural holes and the number of shortest paths (see Figure 1).

Figure 1: Classification of Definitions



In terms of the bridging structural holes, researchers highlight that a firm's position encourages them to bridge structural holes among unconnected partners (Davis & Mizruchi, 1999; Fox et al., 2013; Mehra et al., 2001; Sasovova et al., 2010; Van Wijk et al., 2013; Wincent et al., 2010; Yan et al., 2015).

The structural hole refers to an absence of ties between a firm’s partners, that provides non-redundant information from various disconnected network clusters (Andrevski et al., 2016). The structural hole also represents missing relationships that inhibit information flow between business partners (Burt, 2007). In this dimension, betweenness centrality indicates the amount of brokerage each firm has between all other firms in a network (Borgatti et al., 2013). High betweenness indicates that a central firm has the power to threaten a network with operational disruption (Borgatti et al., 2013). For example, a firm (A) serves as a gatekeeper when the firm lies between two firms (B and C) that are not directly connected. The central firm (A) controls the flow of information and products by serving as a liaison between the isolated firms (Wincent et al, 2010; Carter et al., 2007).

Van Wijk et al. (2013) and Wincent et al. (2010) define betweenness centrality as the extent to which a firm is bridging structural holes by connecting two or more partners that are not directly connected with one another (Wincent et al., 2010). Sasovova et al. (2010) view a firm with betweenness centrality as a broker in a network where the broker directly connects other firms that are not directly connected. Firms spanning many structural holes tend to be exposed to diverse information, which motivates the firms to discover new productive resource combinations and manage the pool of unused combinations of productive resources (Andrevski et al., 2016). Fox et al. (2013) describe betweenness centrality as the extent to which strategic suppliers or customers communicate with each other outside of a focal firm. Mehra et al. (2001) suggest that betweenness centrality is the extent to which a firm occupies a structurally advantageous position, connecting otherwise unconnected others in networks (Mehra et al., 2001). Davis and Mizruchi (1999) and Yan et al. (2015) argue that a firm with betweenness centrality plays the role of a gatekeeper who evaluates and imports external information and resources.

The second dimension of betweenness centrality is the number of shortest paths that a firm occupies in a network. According to this dimension, a central firm should manage the shortest paths in a network in a way that enables it to gain the benefits of its network position. Researchers have attempted to quantify how a firm is positioned on the geodesic path connecting two other firms. Easton and Rosenzweig (2015), for instance, argue that betweenness centrality refers to the number of shortest paths that go through the node. Carter et al. (2007) describe betweenness centrality as the number of paths that pass through a central firm on the shortest paths connecting two other firms. Borgatti and Li (2009) define betweenness centrality as the extent to which a firm lies along many of the shortest paths between pairs of others. Carnovale and Yenyurt (2014) and Schilling and Phelps (2007) suggest that betweenness centrality describes the extent to which a firm is located on the shortest path between any two other firms in its supply networks. These definitions highlight the position of a firm on the geodesic path that may explain why and how firms interact with one another and facilitate or constrain interactions (Cannella & McFadyen, 2016). Table 1 shows example definitions of betweenness centrality.

Table 1: Example Definitions of Betweenness Centrality

Category	Definition
Bridging holes	<ul style="list-style-type: none"> • The extent to which partners partner and communicate with each other outside of a focal firm (Fox <i>et al.</i>, 2013) • The extent to which a firm is bridging structural holes by connecting two or more partners that are not directly connected with one another (Wincent et al., 2010). • The extent to which each firm occupies a structurally advantageous position, connecting other firms that are unconnected in a network (Mehra et al., 2001) • The extent to which a firm plays the role of a gatekeeper in a network (Yan et al., 2015)

Category	Definition
	<ul style="list-style-type: none"> • The extent to which a firm in a network is on the shortest path among many network partners (Davis and Mizruchi, 1999) • The extent to which a firm plays the role of a broker who bridges structural holes (Van Wijk et al., 2013) • A broker in a network that represents the frequency with which a node directly connects pairs of nodes that are not directly connected (Sasovova et al., 2010)
Shortest paths	<ul style="list-style-type: none"> • The number of these shortest paths that pass through the node (Easton and Rosenzweig, 2015). • The number of paths that go through a firm on the shortest paths connecting two other firms (Carter et al., 2007) • The extent to which a firm lies along many shortest paths between pairs of other firms (Borgatti and Li, 2009) • The metric's ability to assess the impact of ties beyond one remove from a person (Cross and Cummings, 2004) • The extent to which a firm is located on the shortest path between any two firms in its network (Schilling and Phelps, 2007) • The extent to which a network actor is located strictly between other actors (Carnovale and Yeniyurt, 2014)

Measurement

Betweenness centrality can be measured as the frequency with which company i is located along the shortest path between two other firms (Freeman, 1979) in the network. The measure was calculated as follows:

$$\text{Betweenness}_{it} = \sum_{j,k \neq i}^N \frac{g_{jikt}}{g_{jkt}}$$

where g_{jkt} is the shortest path between companies j and k in year t and g_{jikt} is the shortest path between companies j and k that contains company i in year t , and N , if the total number of firms in the network. The network analysis software UCINET 6 can be used to calculate the level of betweenness centrality.

Role of Betweenness Centrality in Improving Supplier Financial Performance

In this section, we draw on the social network theory to clarify the relationship between a supplier firm's betweenness centrality and its financial performance. Supplier financial performance refers to the extent to which a supplier firm improves financial performance, measured as return on investment and sales growth rate. Social network theory suggests that a comprehensive understanding of supply networks requires a more complete consideration of network structure, network content, and the surrounding conditions (Gao et al., 2015).

Betweenness centrality is likely to influence supplier financial performance for three reasons.

First, a supplier firm that acts as a bridge to new opportunities can connect other firms separated by structural holes, which may enable the firm to access novel information and improve firm performance (Tiwana, 2008). It is important to consider the extent to which a supplier firm engages in boundary stretching practices (Markóczy et al., 2013). This is because bridging a tie refers to a firm's ability to span a structural hole (Regans et al., 2004). The structural position serves as a basis for the exercise of power (Brass and Burkhardt, 1993). Obstfeld (2005) argue that a firm's effort to develop a relationship with disconnected partners is central to the combinative activity at the root of innovation. The structural characteristics are characterized by how the sources of information and knowledge are structurally connected in supply networks, and how effectively a firm can access the different sources of information and knowledge assets in the network (Bellamy et al., 2014; Brass and Burkhardt, 1993). Similarly, betweenness centrality as an intermediary role has been shown to enhance communication frequency in supply chains. Carnovale and Yenyurt (2014), in an empirical study, found that a high level of betweenness centrality signals a supplier firm's legitimacy and credibility, facilitating interaction and communication among network partners. Ahuja et al. (2003) suggest that centrality enables a firm to actively communicate social norms and expectations, which helps to align the interests of each partner with a mutual goal. Gokpinar et al. (2013) argue that the misalignment of communication patterns and product architecture is associated with a decrease in the quality of the final product. Cross and Cummings (2004) suggest that when a firm is positioned in the intermediary location, it can absorb knowledge and respond appropriately to a changing environment. Thus, a supplier firm with betweenness centrality is likely to have an opportunity to gain access to valuable knowledge and to enhance financial performance.

Second, betweenness centrality offers a means of not only controlling opportunistic behaviors of supply partners but also collecting valuable knowledge (Fox et al., 2013). Management scholars have stressed the importance of network ties as a driver of a firm's behavior (Brass et al., 2004). Uzzi (1996) argues that social ties and network structures influence economic behavior. Acting as a knowledge broker allows a supplier firm to have decision-making authority and to identify non-redundant information concerning resources and opportunities (Mehra et al., 2001). Moreover, a supplier firm with a high betweenness centrality can determine who deserves to access valuable external knowledge resources (Liu et al., 2005), which may influence firm performance. Although a supplier firm needs to maintain a variety of ties and work closely with other firms, obtaining unique and non-redundant information is important to improving financial performance. Betweenness centrality concerns the extent to which a firm serves as a bridge between two or more actors that are indirectly connected (Burt, 1992). This kind of centrality indicates how effectively a supplier firm controls its unconnected firms and accesses a flow of non-redundant information (Wincent et al., 2010; Easton and Rosenzweig, 2015). The more a supplier firm acts as a knowledge broker between isolated firms in supply chains, the greater will be the likelihood of financial performance improvement.

Third, a supplier firm's structural hole position is the location of its brokerage between a firm and other disconnected firms in a network, representing an ability to monitor the flow of information and enhance performance (Burt, 1992; Lin et al., 2009). A broker that connects unknown partners can span distinct social circles where diverse information circulates (Wong and Boh, 2014). The structural position of a firm indicates different motivations for using knowledge and differential access to the knowledge circulated in a network (Paruchuri and Awate, 2017). This position functions as a signal of the prestige granted, indicating its prior performance and position in a social structure (Jensen, 2008). A firm's structural position in a network indicates that the firm can cooperate with other firms in transferring information and resources (Peng et al., 2010). Such a network structure is the pattern of connections between two firms and is associated with the impersonal configuration of linkages within supply networks (Villena et al., 2011). The network structure is also related to a firm's position relative to direct and indirect ties surrounding the firm (Lechner et al., 2010). Understanding the network structure is a process that requires identifying the position a supplier holds in an extended network, with the aim of evaluating the

informational values of that position (Kim, 2014). The structure of a supply network also represents channels of information and consists of mechanisms to search and monitor network partners' strategies and actions (Lin et al., 2009). These arguments suggest the following hypothesis:

Proposition: The network centrality of a supplier firm who acts as a bridge between unconnected partners influences its financial performance.

Conclusion

The goal of this study is to synthesize the definitions of betweenness centrality and discuss the effects of a supplier firm's betweenness centrality on performance. Drawing on social network theory, we develop a proposition as an interpretation of the key idea of the theory. According to social capital theory, firms whose network connections bridge across holes or gaps in supply chains tend to have a greater capacity for knowledge sharing and generate more innovations than other firms whose network relationships feed into dense networks (Tortoriello, 2015). We synthesize insights from prior studies that proposed different definitions. Our review shows that researchers have defined betweenness centrality from two perspectives: bridging structural holes and the number of shortest paths. We found that researchers argue that firms with betweenness centrality leverage their shortest paths in networks and bridge unconnected ties in order to leverage unique information available in supply chains.

This research makes three theoretical contributions to the literature on social network and supply chain management. First, this study advances our understanding of the role of a supplier firm's betweenness centrality in enhancing financial performance. We applied the insights of the supply chain theory to the network literature. Researchers have mainly discussed the relationship between a focal firm's degree centrality and performance (Arya and Lin, 2007; Carnovale and Yenyurt, 2014; Reinholt et al., 2011; Tsai et al., 2011). Second, this study highlights betweenness centrality as a way for supplier firms to act as knowledge brokers between isolated firms and thus improve their financial performance. From a theoretical perspective, this study suggests that a supplier firm that lies between other pairs of partners accrue advantages from their network position (Fox et al., 2013; Hanneman and Riddle, 2005; Yan et al., 2015). Third, this study attempts to synthesize the conceptual views of betweenness centrality. Although extant research has highlighted the importance of betweenness centrality, comparative analysis of existing definitions of centrality has rarely been provided in the literature. We hope our findings will stimulate new avenues of future research.

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