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Impact of supply base structural complexity on financial performance: Roles of visible and not-so-visible characteristics

Guanyi Lu[a,*], Guangzhi Shang[b]

[a] Oregon State University, USA
[b] Florida State University, USA

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ABSTRACT

Supply chains have become increasingly complex in the last decade, which makes their structural characteristics important determinants of firm performance. Prior studies on supply chain structure have largely emphasized *network-level* attributes but ignored *supply-base level* characteristics. However, in many cases it is the 1st tier suppliers, not those "deep in the network," that have most immediate influence on the buyer. In addition, some structural characteristics, such as direct links between the buyer's suppliers and its customers, are not-so-visible to the buyer, yet can impact its financial performance dramatically. The existing literature has overlooked these not-so-visible structural links. Using objective supply chain data collected from *Mergent Online* and *Compustat*, we map the supply base structure of 867 public firms. We construct three visible (horizontal, vertical and spatial) and two not-so-visible (eliminative and cooperative) structural complexity metrics, and examine their impacts on buyer firms' financial performance as measured by Return on Assets and Tobin's Q. Our empirical analysis shows that the five dimensions have differential effects: some have negligible impacts while others appear to strongly affect financial performance. Contrary to the common belief that complexity hurts performance, we find that an individual complexity dimension may have both positive and negative effects, and the overall effect may be non-linear.

1. Introduction

> "Supply chains are growing increasingly complex, making them harder to manage, operate, and change in response to customer, competitive, and financial shifts." – Wilson Perumal and Company, 2015.

Steinhilper et al. (2012) find that costs caused by supply chain complexity account for up to 25% of manufacturing firms' total expenditure. Supply chain complexity impedes decision-making (Manuj and Sahin, 2011), fertilizes disruptions (Chopra and Sodhi, 2014) and erodes plant level operational efficiency (Bozarth et al., 2009). Despite these disadvantages, a general consensus among practitioners and academics is that supply chains have become increasingly complex over the last decades—with little relief in sight—owing to increasingly sophisticated customer requirements (Bode and Wagner, 2015; KPMG, 2011). As a result, the structural complexity characteristics of supply chains have become important determinants of firm performance (Kim, 2014). A study by A.T. Kearney (2007) indicates that firms can increase earnings by 3%–5% if they can make improvements based on supply chain structure. Supplier management now involves more than just building mutually beneficial, long-term relationships. It also requires an in-depth understanding of the structural complexity of globally interconnected supply chains (Kim et al., 2015).

Supply chain structure has garnered much interest from Operations Management (OM) scholars. Prior studies have largely adopted a social network perspective to understand the *network-level* attributes of interconnected firms and their influences (Bellamy et al., 2014; Kim et al., 2011). While overall supply network structure is important (Kim et al., 2015), a more nuanced understanding of the *supply base* structure is also imperative. A supply base largely consists of 1st tier suppliers directly connected to the focal buyer. Overall network structure emerges with no single firm deliberately orchestrating its exact shape (Choi and Hong, 2002). But while a supplier "deep in the network" may affect the buyer, in many cases it is the supply base that more directly and strongly influences performance (Wilhelm et al., 2016). As Sivadasan et al. (2002, p.80) observed, "in a dynamic environment such as a supply chain, even basic supplier-customer systems, with structurally simple information and material flow formation, have a tendency to exhibit operational complexity" and eventually impact buyers' financial performance (Manuj and Sahin, 2011). A central challenge for

* Corresponding author.
E-mail address: guanyi.lu@oregonstate.edu (G. Lu).

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advancing supply chain structure research, therefore, is to show how and why supply base structural characteristics influence buyers' financial performance.

In addition, some structural links are not-so-visible to the buyer, yet impact its financial performance dramatically. For example, a supplier can sell directly to the buyer's customers, with the potential to replace it (Rossetti and Choi, 2005). Prior empirical studies have investigated the visible structural links (i.e., the links that connect to the buyer). Yet the neglect of not-so-visible structural links masks information critical to supply chain management decisions. Furthermore, the visible and not-so-visible links may be related. For instance, the potential elimination threat posed by supplier-customer links (a not-so-visible factor) is likely to be minimized when suppliers reside in geographically dispersed locations (a visible complexity measure). Thus, our motivation is to construct a comprehensive set of supply base structural metrics and answer the research question: how do the characteristics of supply base structural complexity affect the buyer's financial performance?

Utilizing a proprietary objective dataset compiled from two data sources—*Mergent Online* and *Compustat*, we map the supply base structure of 867 public firms and construct two sets of structural complexity metrics (specifically, visible and not-so-visible, see details in Section 2). We empirically examine the individual effects of these complexity dimensions on the buyer's financial performance. Contrary to the literature, which states that supply chain complexity hurts firm performance (Bozarth et al., 2009; Bode and Wagner, 2015), we propose that the effects of complexity dimensions at the supply base level are complicated and mixed. An individual dimension may have both positive and negative effects and the overall effect is contingent on the magnitude of the complexity dimension itself. We find that some complexity dimensions reveal a nonlinear (U-shaped or inverted-U) relation with the buyer's financial performance. In addition, these complexity dimensions exhibit differential effects; some wield considerably stronger impacts than others.

This study makes two major theoretical contributions. First, it expands our understanding of supply chain structure by channeling focus from the broad network level to the more nuanced supply base level. The supply base has stronger and more immediate performance impacts than the rest of the supply network due to its "proximity" to the buyer (Wilhelm et al., 2016). Second, by also emphasizing the not-so-visible structural links where the buyer is generally not directly involved, our study extends the conceptualization of supply base complexity and provides a more comprehensive set of structural dimensions. Understanding the impacts of these dimensions is critical because the buyer is likely to influence only its direct links (Bode and Wagner, 2015). As a result, this study addresses a resonant theme within the supply chain structure research: showing how a firm should manage structural characteristics separately, with the potential to mitigate the negative impacts of complexity dimensions it cannot directly control. Our study also carries a methodological implication. Almost all studies on supply chain structure rely on information from the buyer—primarily survey and qualitative data—to measure structural complexity. However, the use of data solely from the buyer risks overlooking the impact of structural links of which the focal firm is unaware. We overcome this problem by constructing objective measures from buyer-supplier links identified by independent third parties.

The rest of this article is organized as follows: Section 2 reviews the related literature. Section 3 proposes the theoretical framework and develops research hypotheses. Section 4 discusses data source and variable construction. Section 5 depicts methods and reports results. Section 6 concludes the paper with a discussion on contributions and limitations.

2. Literature review

2.1. Complexity in supply chains

The concept of complexity has triggered research in multiple academic disciplines. It generally pertains to system-level attributes about connections among system constituents. In social science, Simon (1962, p.468) offers an influential definition that a system is complex if it is "made up of a large number of parts that interact in a non-simple way." This definition highlights two critical traits of complexity: structure and behavior (Perrow, 1984; Senge, 2006). According to Bode and Wagner (2015, p.216), the former "is often termed structural complexity (also static or detail complexity) and refers to the number and variety of elements defining the system." The latter is often labeled "dynamic complexity," referring to the interactions of those elements. The two traits are usually interrelated in practice. A large number of elements implies a great number of possible interactions, which is especially true when connected firms jointly assemble a final product (Bozarth et al., 2009; Manuj and Sahin, 2011).

Prior studies on supply chain complexity have capitalized on both traits and viewed complexity as a multi-dimensional concept. For instance, Vachon and Klassen (2002) propose two dimensions: uncertainty (which is associated with structure, i.e., the number of constituents), and complicatedness (associated with behavior, i.e., interaction among constituents). Choi and Krause (2006) identify three dimensions: the number of direct suppliers (structure), differentiation among direct suppliers (structure), and the relationships among the suppliers (behavior). Bozarth et al. (2009) also propose three: internal manufacturing complexity, downstream complexity and upstream complexity. They explicitly state that each of their complexity dimensions can be characterized as both structural and behavioral. While early studies provide insights into supply chain complexity, researchers have failed to achieve a consensus about which dimensions best describe supply chain complexity, partly due to their different foci (Jacobs and Swink, 2011; Manuj and Sahin, 2011). Our study focuses on structural complexity, because it is explicitly measured by buyer-supplier relationships. These relationships also reflect the interactions between firms. However, we note that interactions are difficult, if not impossible, to capture fully and objectively. The scope of this study is thus decidedly restricted to the *structural complexity* of a firm's *supply base* with a particular focus on *1st tier suppliers*.

Table 1 summarizes the most relevant studies. As we noted earlier, the small number of studies examining supply chain structural attributes largely emphasize network-level measures that link relational ties to performance metrics such as firm innovation, social capital and resource access. For example, Bellamy et al. (2014) demonstrate that supply network accessibility is significantly associated with innovation. Kim et al. (2011) investigate the supply networks of three automobile product lines (Honda Accord, Acura CL/TL and DaimlerChrysler Grand Cherokee) and show how network centrality and density affect material flow and contractual relationships. In network studies, the network "position" matters. According to the social network theory, firms occupying a "central" network position (as manifested by measures such as in-bound centrality, out-bound centrality, and network accessibility) will outperform competitors due to superior access to resources. Note that in a network, a buyer does not necessarily have "position" advantage over its suppliers because a supplier can have the same or even higher level of centrality (or other network measures) than its buyer. In contrast, at the supply base level, the buyer naturally occupies the central position. In a supply network, position is a firm attribute such that a number of firms may share similar position advantages. In a supply base, what matters more is the link attribute, i.e., which parties (e.g., two suppliers, or a supplier and a customer) are linked. Thus, how the focal firm connects to its suppliers and customers and how they connect with each other have strong performance implications. Compared with existing network measures which reflect a firm's position relative to others, our supply base measures capture how links are "distributed" within a supply base. While the kernels of social network theory can still be used in supply base research, its measures likely cannot. Among the studies we reviewed, only Bode and Wagner (2015) use "lower-than-network" level measures to study upstream supply chain disruptions. The lack of research on complexity at the supply base