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Supply Chain Complexity and Supply Chain Resilience: a Literature Review

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: A Literature Review

1. Introduction

The increasing globalization of economy and advancements in technology are forcing fierce competition in the market. It leads to the fact the complexity of the supply chain has increased in the recent years, such that supply chains are becoming more complex than ever because of the increasing uncertainties of the business environment. Increased complexity in products, processes, and relationships has also been contributing to the managerial crisis from the complexity of supply chain (Marriotti, 2007). To this end, global supply chains present complex relationships and interactions between entities, raising new challenges for both researchers and practitioners.

There have been early studies on product-level complexities (Hobday, 1998; Novak & Eppinger, 2001; Closs et al., 2008; Closs et al., 2010). However, there has not been much done on at the supply chain level, which has recently gained the attention from the industry experts as well as academic researchers. Increasing attention to supply chain complexity also reflects the advancements in supply chain research. Instead of focusing on merely dyadic relationships, more scholars are investigating triads (Choi & Wu, 2009) and networks (Borgatti & Li, 2009; Galaskiewicz, 2011; Hearnshaw & Wilson, 2013) to better reflect the complex nature of the real-world supply chains.

In general, higher complexity in a supply chain is known to generate adverse outcomes on supply chains such as higher operational costs, poorer customer satisfaction, delayed delivery, and

lack of information sharing and integration among supply chain partners. However, mixed findings exist regarding its potential effect on supply chain resilience under disruption risks. There are literature review papers on either supply chain complexity or supply chain resilience. However, to the best of our knowledge, there is no literature review that connects these two topics simultaneously. Specifically, this research focuses on the interplays between supply chain complexity and supply chain resilience. There is a vast amount of research for supply chain resilience or supply chain complexity separately[1], but we only have a few papers in the joint area of academic research.

2. Understanding Supply Chain Complexity

In the management literature, complexity was initially studied regarding product or process level complexity in manufacturing systems. For example, Calinescu et al. (1998) suggest two scientific methods considering costs, feasibility, types of information required to measure manufacturing process complexity. Whereas Hobday (1998) highlights the impact of product complexity on the innovation in industrial organizations, and Novak & Eppinger (2001) test the relationship between product complexity and vertical integration using empirical evidence from the automotive industry.

From the supply chain perspective, various definitions of supply chain complexity have been suggested, and the literature on supply chain complexity has expanded over the past years. The earliest research on supply chain complexity, Wilding (1998) proposes a conceptual model called “supply chain complexity triangle” as a structure that explains the uncertainties in a supply chain. He claims that the combination of three factors (Amplification, Deterministic Chaos, and

[1] In Google Scholar, there are 311 articles intitled with *supply chain resilience* and 1,740 articles intitled with *supply chain complexity*, as of February 2023.

Parallel Interactions) can significantly increase the degree of uncertainty and complexity of the supply chain. However, the study does not provide a strong argument without any analytical model or empirical analysis. Milgate (2001) empirically investigated the relationship between supply chain complexity and deliver performance using survey data, suggesting uncertainty, technological intricacy and organizational system as three dimensions of supply chain complexity to enhance the understanding of the concept.

Later, Bozarth et al. (2009) suggest another explanation. Hereby supply chain complexity is defined as "the level of detail complexity and dynamic complexity exhibited by the products, processes, and relationships that make up a supply chain" based on the various literature on complexity, where detail complexity refers to the number of components or parts that make up the system, and dynamic complexity refers to the unpredictability of a system's response to a given set of inputs, driven in part by the interconnectedness of the parts that make up the system (Bozarth et al., 2009). This perspective is later expanded by Aitken et al. (2016) who have presented a conceptual model of how an individual business unit should respond to supply chain complexity.

Other early attempts to explain supply chain complexity rely much on the established literature from the systems perspective (Choi et al., 2001; Vachon & Klassen, 2002; Surana et al., 2005). They view supply chains as integrated systems of physical flows, information flows and relationships in line with the definition of a complex system by Simon (1991). To be specific, Choi et al. (2001) propose an idea of "complex adaptive system" to describe the complex nature of supply chain. Complex adaptive systems (CAS) view of supply chain well represents the complex nature of supply chain. CAS are defined as open systems compounded by various elements interacting with each other, which form a dynamic entity that adapt itself to the external environment, without any singular entity deliberately managing or controlling the system. Scholars

who have adopted this perspective considers supply chain complexity from a holistic, systems-level perspective in their empirical models (Choi & Krause, 2006; Gerschberger et al., 2012). They explain that supply networks could be considered as CAS because supply chains interact with various entities and adjust themselves to satisfy the needs of the customers and the environment.

Some researchers adopt the entropic view from information theory as an alternative explanation of operational complexity (Sivadasan et al., 2002) and supply chain complexity (Isik, 2010), which is introduced by Pincus (1991). Frizelle & Woodcock (1995) is one of the early studies that adopted this view in the domain of operations management. From this perspective, supply chain complexity can be understood as the quantitative variations from the uncertainty and variety in a supply chain measured by entropy-based mathematical formula.

Scholars also have attempted to classify and understand the subcomponents of complexity sources. One approach is to define two different sources of the complexity to comprehend the relationship between the system and the surrounding environment (Jost, 2004). In managerial context, internal complexity is the complexity originates from structures, elements, and processes of the manufacturing area. Contrary to this, external complexity comes from the sources except for internal factors, such as demand fluctuations, innovative activities, or macroeconomic changes. Therefore, internal complexity is generally assumed to be managed by the company, while external complexity is considered fixed given conditions. Another classification which is useful for managing complexity is structural complexity versus dynamic complexity (Blecker & Kersten, 2006; Brady & Davies, 2014; Bode & Wagner, 2015). In this context, structural complexity refers to the complexity factors from the fixed nature of products, structures, and processes, while dynamic complexity originates from the operational variances such as shortages, breakdowns, and fluctuations.

3. Supply Chain Complexity and Resilience

Resilience is considered as the ability to recover and return to the original state after a disruptive event. Christopher and Peck (2004) defined supply chain resilience as "*the ability of a supply chain to return to normal operating performance after being disrupted.*" Another common definition of supply chain resilience is "*the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function*" (Ponomarov and Holcomb 2009). Hence, in a resilient supply chain, the supply chain entities exhibit stability in their performance under disruptions (Blackhurst et al., 2011).

A vast amount of academic research has been conducted in the domain of supply chain resilience. However, literature provides limited and mixed support for the relationship between supply chain complexity and supply chain resilience under disruptions. For example, Käki et al. (2015) suggested that network complexity could either increase or decrease the severity of a disruption. They concluded that complex networks tend to be riskier and have a greater number of possible disruption sources through which the disruption could be propagated. However, they also argued that a supply network might recover better in a dense and complex supply chain, which is less dependent on individual suppliers.

On the positive side, complexity is related to diversification in supply networks, which is an important risk management strategy for companies in dealing with external changes (Taleb et al. 2009). In a complex supply chain, the focal company may suffer less from supply chain disruptions, as the focal firm in such a network will probably have enough alternative options to mitigate or hedge the risk.

In contrast, Craighead et al. (2007) suggested that higher network complexity increase the severity of network disruption. They argued that disruption would be more likely to propagate in the network when there were more interdependencies and connectedness within the network. Because of the mixed results associated with complexity and resilience found from above selected literature, we conduct an extensive literature review to fill the gap regarding this research question.

4. Methodology

Structured literature review has been perceived as a rigorous and efficient research method to overview a specific research topic. We follow the guidelines suggested by Tranfield et al. (2003) and extend it to be applicable in this context when the research interest exists within the joint area between two different domains of research. This study follows a literature review process protocol described as below:

1. This study focuses on the articles published in international academic journals for the reliability and quality of the literature review. Only papers published in peer-reviewed and internationally recognized academic journals in the field of OSCM were selected, whereas conference proceedings, doctoral dissertations, and working papers were excluded in the review process. Lastly, the attention of the study is limited to the papers written in English to achieve the highest level of relevance.
2. We cannot easily identify the article of our interest by applying both "supply chain complexity" and "supply chain resilience" at the same time. Therefore, we will take a twofold approach for each keyword, respectively.[2]

[2] If one try to search articles by including both search keywords at the same time, it will only show <10 articles, which does not reflect the existing literature in the area of interest of this study.

3. In the first step, the initial search keyword identified is “supply chain complexity” OR “complex supply chain” and it will be applied in the subject field on the academic research databases. Then, the topical relevance whether the article found is related to the “supply chain resilience” is ensured by reviewing the abstract, introduction, and conclusion sections of the papers. Then, those with irrelevant focus were eliminated after a thorough review of the entire paper.
4. In the second step, the initial search keyword identified is “supply chain resilience” OR “resilient supply chain” and it will be applied in the subject field on the academic research databases. Then, the topical relevance whether the article found is related to the “supply chain complexity” will be checked, following the same process above.
5. Then, the collected articles are further analyzed and synthesized. The title, publication year, author(s), journal, and methodology will be collected as main information.
6. Additionally, an extensive array of background theories, research ideas, contextual settings, and research methods were coded to identify the differences among the studies.
7. Lastly, future research opportunities and suggestions are provided based on the identified gaps from the results of the analysis.

End of the working draft.

Preliminary Outcomes will be presented at the IPSERA 2023 conference.

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