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Determinants of Data Analytics Capability for Resilient Supply Chain in Manufacturing Companies: A Conceptual Model

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Abstract. The COVID-19 epidemic has made manufacturers more susceptible to supply chain disruptions due to unforeseen changes in demand, material shortages, and a shortage of labor. Prior studies have examined supply chain resilience as an organization's capacity to respond to unanticipated interruptions and provide solutions to ensure operational continuity. However, there is a limited attempt at exploring the significance of integrating shared information with other resources to increase data processing capacity for a reliant supply chain. In addressing this issue, this study combines the resource-based view (RBV) with organizational information processing theory (OIPT) to clarify the antecedents of big data analytics capability for resilient supply chains. Following the two-stage mixed-methods explanatory approach, the proposed model will be tested using data gathered from surveys and interviews with supply chain managers in Malaysian manufacturing companies. The expected findings will provide insights into how manufacturers can leverage big data analytics to build a resilient supply chain. Specifically, managers will better understand how to maximize data processing capacity for a resilient supply chain by fusing shared information with other organizational resources. This study's importance comes primarily from its contribution to theory and practice. It examines how firms build resilient supply chains by combining shared information with other organizational resources. Additionally, it adds to the growing body of literature on the foundations of big data analytics for a resilient supply chain. This subject is becoming increasingly crucial in the era of post COVID-19 pandemic.

Keywords: Data analytics capability, Resources, Supply chain resilient, Information processing, Supply chain visibility

1. Introduction

Despite the rapid rollout of COVID-19 vaccination across the globe, the severe disruptions in the economy and social life seem likely to remain a trend for the foreseeable future, subjecting top executives to constant pressure. A survey of manufacturers in Asia reported that 45% of the respondents are vulnerable to sudden materials shortages, 41% to unanticipated changes in demand and 30% to employees' unavailability (Agrawal et al., 2020). Besides natural disasters and pandemics, disruption may occur due to human interference, like political instability and terrorism, which could negatively impact revenue and cost (Dubey et al. 2019a). These disruptions have created significant shocks among supply chain partners. One of the primary outcomes of demand shock is the bullwhip effect, which occurs when supply chain partners either undercompensate or overcompensate for a sudden change in demand (Kaviani et al., 2020). For example, in response to resource shortage induced by the COVID-19 pandemic related lockdown, the downstream partner could overcompensate by artificially inflating their supply needs to gain a higher share of scarce resources. Although uncertainty and risk in the supply and demand end of operations predate COVID-19, the question of how to mitigate these issues has remained open (Kaviani et al.,2020).

Given the potential adverse impact of disruption, considerable scholarly and practitioner interests have been directed at supply chain risk management and resilience (Srinivasan and Swink 2018; Kaviani et al., 2020; Čerkauskienė, & Meidute-Kavaliauskiene, 2023). By building a resilient supply chain, organizations are enabled to swiftly adjust and recover from sudden disruptions to support operations continuity. A resilient supply chain can promptly reconfigure its structure in response to disruptions, thereby maintaining the previous state or achieving a better state of operations (Kaviani et al., 2020). Supply chain resilience has been described in terms of vulnerability and capability (Brandon-Jones et al., 2014). The former entails the potential causes of disruptions in the supply network, i.e., delays in information processing or procurement. The latter is the organizational capability for managing unexpected events caused by disruption, i.e., information sharing and collaboration (Kaviani et al., 2020). Previous studies have investigated supply chain resilience by focusing on the interplay between vulnerability and capability factors (Pettit et al., 2010; Kaviani et al., 2020). Other researchers have examined the factors of supply chain disruptions (Orlando et al., 2022) and implications on performance (Hendricks & Singhal, 2005), as well as risk management in the supply chain (Berger et al., 2023).

Brandon-Jones et al. (2014) focused on specific capabilities by investigating the impact of supply chain visibility on supply chain resilience. Studies have also adopted the organizational information processing theory (OIPT) in examining the effect of supply chain visibility in facilitating data analytics capability for a resilient supply chain (Srinivasan & Swink 2018; Dubey et al., 2019a). Data analytics capability has been considered as a technological ability to process and derive valuable insights from big data, thereby minimizing uncertainty amid market volatility and highly interdependent tasks environment (Srinivasan & Swink, 2018). Furthermore, Dubey et al. (2019a) examined how data from supply chain partners could be leveraged through firms' analytics capability to facilitate a resilient supply chain and performance contingent on organizational flexibility.

Sequel to the above, existing studies have clarified the role of information sharing in enabling a resilient supply chain, with limited insights on how organizations combine shared information with other internal resources to maximize data processing capability for a resilient supply chain. In addition to the shared information, organizations need other resources like data infrastructure and intangible elements of cultural norms and flexibility to create value-generating capabilities through big data analytics. Thus, this study aims to integrate the resource-based view (RBV) with OIPT to clarify the antecedents of big data capability for a resilient supply chain in smart manufacturing operations. Smart manufacturing relies on digital technologies like big data analytics to facilitate rapid information sharing and accurate decision-making to address supply chain disruptions. Through smart manufacturing, an organization can develop the integrative and collaborative capability for responding to customer demands in real time and adjusting to disruptions in the supply chain (Zheng et al., 2018). Accordingly, this study examines how organizations can leverage data analytics capability in smart manufacturing operations to support a resilient supply chain.

2. Literature Review and Hypotheses Development

2.1. Supply Chain Resilient

Supply chain uncertainty and risk are inherent in every supply network involving partners from across the globe. However, the COVID-19 pandemic and its containment strategies, such as lockdowns and physical distancing, have intensified firms' vulnerability to risks and disruptions. A recent publication by Mckinsey found that more than one-third of manufacturers in Asia are vulnerable to COVID-19 induced disruptions in the supply chain (Agrawal et al., 2020). Many interventions (i.e., lower inventory and geographical dispersion) at reducing supply cost come with the untended consequence of heightened vulnerabilities, negatively impacting profit margin through increasing disruptions in the network (Brandon-Jones et al., 2014). Thus, organizational performance can be enhanced by initiating quick recovery after a disruption. The recovery time decreases as the organization develops resiliency capacity in the supply chain, improving performance (Pettit et al., 2019).

Supply chain resilience is a multidimensional and multidisciplinary concept that has received increasing interest among academic and practitioner communities yet lacks a generally accepted definition. According to Brandon-Jones et al. (2014, p. 55), supply chain resilience is the "ability of a supply chain to return operating performance, within an acceptable period of time, after being disrupted." Market leaders like Nike and Lafarge Holcim have considered deepening collaboration with supply chain partners essential to building resilience. Hence, there has been a surge in research focused on supply chain resilience to enhance the organizational ability to adapt to unexpected disruptions and support operations continuity.

The popular management press has suggested several initiatives for improving resilience and recovery; these include collaborating with suppliers, multi-sourcing and deploying digital technologies (Remko, 2020). Digital technologies like big data analytics can offer insights into huge volumes and varieties of data to support accurate decision-making. Zheng et al. (2018) acknowledged that smart manufacturing could deploy the fourth industrial revolution (IR 4.0) technologies like big data analytics in facilitating rapid information sharing and accurate decision-making to address supply chain disruptions.

2.2. Big Data Analytics Capability

There has been a significant surge in academic and industry discourses on the implications of big data analytics and other digital technologies (i.e., internet-of-things, cloud computing) in the modern economy. Some have characterized these technologies as the IR4.0 or the "next frontier for innovation, competition, and productivity" (Manyika et al., 2011, p.1). The increasing deployment of big data analytics in social media, mobile devices and other infrastructures has enabled firms to harness the internet of things and cloud-based platforms to transform their processes and operations. Firms can make data-driven decisions through big data analytics and find better ways to organize, learn and innovate across functional activities like marketing, operations and finance (Wamba et al., 2017). Big data analytics has emerged as one of the most salient drives of competitive advantage in the modern economy (Dubey et al., 2019b). The rapid digitalization of business processes, products, and services has resulted in the accumulation and availability of large data sets for analysis. Big data analytics offer a holistic method for structuring, managing, processing, and analyzing the 5 Vs data-related dimensions (i.e., volume, variety, velocity, veracity and value) to support decision making and business growth (Wamba et al., 2015). Aral and Weill (2007: 763) noted, "investments into different IT assets are guided by firms' strategies and deliver value along performance dimensions consistent with their strategic purpose." In line with this, an organization can achieve strategic integration by deploying IT capability to shape and facilitate its business strategy.

Consistent with the literature (Mikalef et al., 2018), this study considers big data analytics a value-generating capability that depends on the organizational resources and visibility across the supply chain.

2.3. Supply Chain Visibility

Supply chain visibility is defined as the "extent to which all the actors along the supply chains have a shared understanding of, and access to, the product-related information that they request, without loss, noise, delay and distortion" (Dubey et al. 2021, p. 119). Consistent with the OITP, supply chain visibility is essential to meeting information processing capability needs. Visibility is created through connected information systems and coordinated decision-making, facilitating the exchange of available and quality information across the supply network. Through demand visibility, the firm is enabled to detect changes in customer needs and demands and market conditions of pricing and promotional activities. Such visibility is enhanced through access to customers' systems and processes like the point of sale (POS) data, stock levels, demand forecasts and marketing plans. Likewise, through connections with suppliers, the firm gains visibility into suppliers' costs, capacities utilizations, inventory levels, purchase orders outstanding, and distribution networks (Srinivasan & Swink, 2018).

2.4. Organizational Flexibility

Flexibility reflects the organization's ability to adapt to tasks with high levels of uncertainty. It stems from the adaptability of a firm's structure and managerial capabilities to match customers' changing needs (Srinivasan & Swink, 2018). It entails both organizational design and managerial tasks (Kalogiannidis et al., 2022). From the supply chain perspective, organizational flexibility is the supply chain managers' ability to rapidly and efficiently adapt their internal supply chains to the changing market demand and supply conditions (Srinivasan & Swink, 2018).

2.5. Organizational Information Processing Theory (OIPT)

According to Srinivasan and Swink (2018), firms depend on information to coordinate and execute tasks in high-uncertainty situations effectively. In managing tasks, firms can either minimize their dependency on information by enabling mechanistic structure or building capability for information processing. The former entails coordinating tasks through division of labor and information flow through a rule-based hierarchical system; the team members refer to their managers to resolve unexpected situations (Srinivasan & Swink, 2018). OIPT emphasizes how an organization designs and arranges its capabilities for managing information processing to gain a competitive advantage. Information processing capability becomes inevitable in handling uncertainty to sustain a higher performance level (Dubey et al., 2019a). Galbraith (1973, p. 5) defined "uncertainty as the difference between the amount of information required to execute a task and the level of information already available with the organization." Hence, organizational performance is enhanced when a proper alignment is achieved between the need for information processing and processing capabilities (Fan et al., 2017; Dubey et al., 2019a). The availability of timely and accurate information enhances visibility, meeting the need for information processing. The relevant data analytics capability can enable the organization to maximize the generated insights for performance improvement.

2.6. Resource Based View (RBV)

In addition to information sharing, an organization can develop capability through the resources it possesses. The RBV conceptualizes organization as a bundle of resources which can be integrated to create a competitive advantage. Resources are the rare and unique assets that enable an organization to execute value and create a strategy to generate rent (Barney, 1991). Thus, this concept delineates resource-picking activities from the capability-building processes to harness the firm's competitive advantage resources (Mikalef et al., 2018). Through resource picking, an organization recognizes the resources, i.e., tangible, human, and intangible, essential to attaining high performance. These are mainly non-specific and tradable assets, unlike capabilities that are specific and non-tradable abilities that emerged from integrating recognized resources with other processes to enhance the firm's performance (Makadok, 2001).

Information systems literature has extensively employed the interplay between resources and capabilities in explaining organizational outcomes like performance and competitive advantage (Mikalef et al., 2018). Capabilities are developed through the complex interactions between organizational resources and competencies, making it difficult for others to imitate easily. Therefore, converting resources to capabilities involves managerial interventions at identifying the appropriate resources, structure, and actions needed to maximize value from the organization's assets. For example, organizations with the right culture, structure, competent personnel, and IT infrastructure possess the IT capabilities to support competitive advantage.

Studies from the big data analytics context also demonstrated the impact of tangible and intangible resources in developing big data analytics capabilities (Mikalef et al., 2018; Dubey et al., 2019b). Further to the focus on supply chain visibility, the proposed study draws on the RBV to posit the tangible and intangible resources underlying big data analytics capability in the supply chain. The tangible resource reflects the data, which from the OIPT perspective is the supply chain visibility, i.e., access to timely and accurate supply and demand ends data (Mikalef et al., 2018). One of the critical resources in an organization is the quality of its data, which entails completeness, accuracy, format, timeliness, reliability, and perceived value. Thus, the variety and diversity of data shared across the supply chain network enables visibility. Nevertheless, an organization needs to possess the complementary infrastructure for storing, sharing, and analyzing the data resources to create value generating capability through analytics. Accordingly, studies have examined the role of data infrastructure and associated features in enabling data analytics capability (Wamba et al., 2015; Gupta & George, 2016).

Besides the tangible resources, the cultural values underlying organizational practices are essential in developing and exploiting capability. Previous studies have identified cultural norms as the main barrier to successfully implementing big data projects (Mikalef et al., 2018). Many organizations overlook the results of data analysis by making decisions based on managerial intuition or gut feeling (Gupta & George, 2016). Thus, data-driven culture is essential to maximizing the insights from supply chain partners. Moreover, capability building entails the integration of resources and other organizational processes to create value generating outcomes. Salient to value creation through data analytics capability is the organizational ability to respond to changes. Organizational flexibility captures the design and managerial tasks underlying the ability to adapt quickly to changing market conditions. Thus, organizational flexibility is essential for firms to act on the supply insights generated from analytics to support a resilient supply chain.

2.7. Theoretical Framework

From the IOTP perspective, access to data from the supply chain partners creates visibility for enabling big data analytics capability, which supports resilience. Based on the RBV, supply chain visibility can be considered an antecedent of the capability building process (Mikalef et al., 2018; Dubey et al., 2019a). The data shared across the supply network is a tangible resource that could be combined with other resources to create value generating capability, i.e., data analytics capability. Effective data exchange between supply chain partners depends on the availability of the data infrastructure and the quality of information sharing (Dubey et al., 2021). Thus, by integrating the RBV with OIPT, this study posits supply chain visibility, data infrastructure, and information sharing as antecedents of big data analytics capability.

Nevertheless, the firm's cultural norm could constrain other resources' impact on capability, thereby limiting supply chain resilience. For example, organizations that lack data-driven culture might not maximize the value of visibility on big data analytics capability. Thus, big data analytics capability's impact on supply chain resilience is expected to be contingent on organizational flexibility.

Drawing insights from the above, the following hypotheses are suggested, with the proposed research model depicted in Figure 1.

H1. Data infrastructure is positively associated with big data analytics capability in manufacturing operations supply chain.

H2. Information sharing is positively associated with big data analytics capability in manufacturing operations supply chain.

H3. Data driven culture is positively associated with big data analytics capability in manufacturing operations supply chain.

H4. Supply chain visibility is positively associated with big data analytics capability in manufacturing operations supply chain.

H5a. Supply chain visibility mediates the effect of data infrastructure on big data analytics capability in manufacturing operations supply chain.

H5b. Supply chain visibility mediates the effect of information sharing on big data analytics capability in manufacturing operations supply chain.

H6. Big data analytics capability is positively associated with resilient supply chain in manufacturing operations.

H7. Organizational flexibility moderates the effect of big data analytics on resilient supply chain in manufacturing operations.

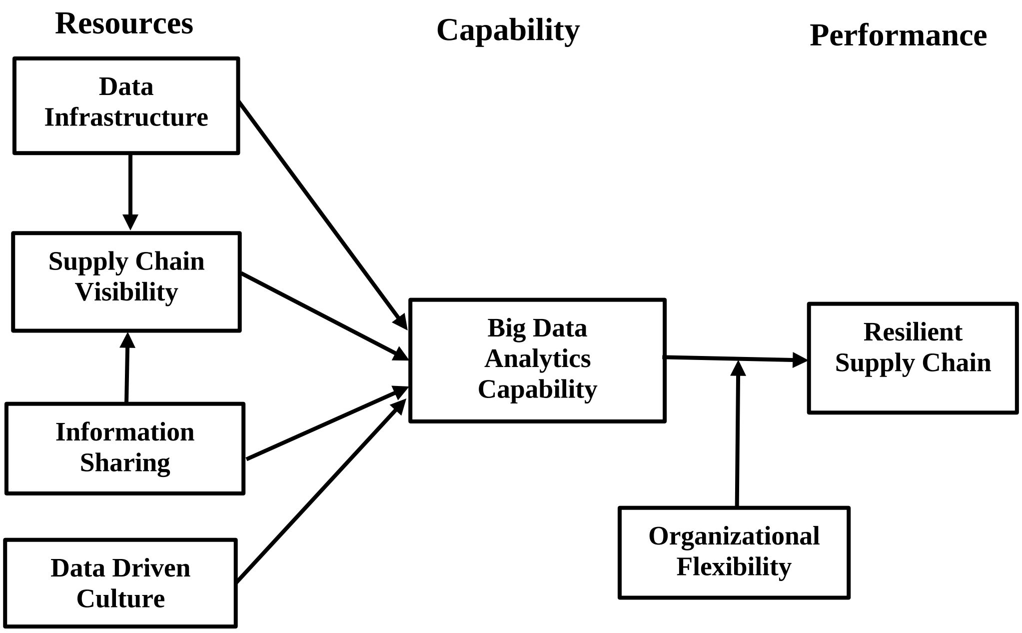

Fig. 1: Research Model

3. Research Methodology

3.1. Context of Study

The manufacturing sector is the most influential in Malaysia, attracting more than half of the foreign direct investment. This sector has immensely contributed to the country's foreign exchange earnings through exports, infrastructure modernization through construction, and advancement of the economy through skills enhancement and job creation (Yadegaridehkordi et al., 2018). Thus, Malaysia's national policy on science, technology, and innovation (DSTIN) 2021 – 2030 aims to intensify local technology development and application to support the transformation to a technology developer. Similarly, the Malaysian Science, Technology, Innovation, and Economic (MySTIE) framework has been designed to propel the manufacturing sector to smart operations based on IR4.0 to enhance the resilient utilization of resources. As a result, the manufacturing industry is pivotal to transitioning the Malaysian economy to knowledge-intensive operations, a key enabler of the shared prosperity vision 2050.

3.2. Proposed Research Design

The proposed study will adopt an explanatory two-stage mixed methods (i.e., qualitative and quantitative) design in addressing the research question. Organizational response to supply chain disruption is a complex issue that requires consideration of several factors which could not be captured through the positivist paradigm alone. Further to providing answers to the relevant research questions, using mixed methods in this study will help draw on the strengths of both qualitative and quantitative research (Onwuegbuzie et al., 2010). Thus, this study will follow the abductive reasoning technique to investigate big data analytics capability and its influence on resilient supply chains. In doing this, the findings obtained from hypotheses testing will be integrated with the data collected from interviews of supply chain managers to provide in-depth insight into how organizations build data analytics capability for resilient supply chains. Appropriate research design entails the identification of the unit of analysis and level of investigation, which in this study is the manufacturing company. Please acknowledge collaborators or anyone who has helped with the paper at the end of the text.

4. Discussion and Implications

The significance of this study is primarily found in its contribution to theory and practice. Theoretical implications include combining RBV and OIPT to demonstrate the role of big data analytics capacity in enabling a resilient supply chain. It offers a novel perspective on how companies might build resilient supply chains by combining shared information with other organizational resources. Additionally, it contributes to the growing body of research on the fundamentals of big data analytics for a resilient supply chain, which has become increasingly important in the post COVID-19 epidemic. From the practice perspective, this study will provide insights into how manufacturers can leverage big data analytics to build a resilient supply chain. Managers will better understand how shared information could be integrated with other organizational resources to enhance data processing capacity for a resilient supply chain. As a result, firms can better predict and handle disruptions by leveraging their data analytics capabilities.

The conceptual model captures the value of flexibility in creating a resilient supply chain. The determinants of data analytics competence can help manufacturing organizations become more agile and react swiftly to changes in demand and supply. Consequently, managers can use the study's findings to guide their decisions on allocating resources and purchasing data processing equipment. Firms that can create robust supply chains using big data analytics will be better positioned to compete in a constantly changing and unpredictable market (Bahrami et al.,2022). By creating a robust supply chain, the suggested conceptual model gives manufacturing organizations a framework to increase their competitiveness.

5. Conclusion

The conceptual model draws on the OIPT and RBV in proposing the antecedents of big data capability for a resilient supply chain in smart manufacturing operations. Based on the OIPT, we conceptualize supply chain visibility as dependent on access to supply chain partners data, thereby enabling the firm's capability for big data analytics. From the RBV, supply chain visibility provides data on supply chain network, which could be combined with other resources to create value generating capability, i.e., data analytics capability. Thus, firms can better harness this capability in building resilient supply chain, with the provision of adequate data infrastructure and other intangible resources like information sharing and data driven culture as well as organizational flexibility. Accordingly, the proposed study will demonstrate how firms can leverage big data analytics capability in smart manufacturing operations to support a resilient supply chain.

The expected findings will enable manufacturers to prioritize the key resources in building big data analytics capability for driving resilient supply chains, thereby achieving MySTIE's framework objective of transitioning the Malaysian economy to the knowledge-intensive domain. Understanding the impact of big data analytics capability on resilient supply chains will enhance the manufacturers' global competitiveness, thereby contributing to increasing exports, better employment opportunities, and higher GDP to support the shared prosperity vision 2030. This study also aligns with the United Nations sustainable development goals #9 i.e., fostering resilient infrastructure, industry and innovation. The expected findings will offer insights to manufacturers on implementing smart operations by investing in key internal resources to leverage big data analytics capabilities in building a resilient supply chain. Relevant recommendations will also be provided on improving supply efficiency through the adaptability of the manufacturing companies in integrating analytics insights in driving strategic operations decision.

Notwithstanding the contributions, a few limitations have emerged from this study. First, the study is based on a conceptual model, lacking empirical validation of the proposed relationships. Thus, subsequent studies should collect appropriate data to demonstrate the relationships among the variables. Second, the study is limited to Malaysia's manufacturing sector; hence the expected findings might not apply to other industries or countries with different backgrounds and contextual conditions. Accordingly, future research could explore the relevance of the model in other industries and economies.

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