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Conceptual Development of Supply Chain Digitalization Framework

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Abstract: This paper presents a conceptual development on the use of novel digital technologies in the core supply chain management processes of plan, source, make and deliver Supply Chain Operations Reference (SCOR) model. We investigate the mechanisms by which supply chain digitalization influence supply chain capabilities which in effect impacts operational performance. We adopt the resource-based view of the firm to ascertain the transformational effect of supply chain digitalization. This study contributes to the literature toward understanding the conditions under which supply chain digitalization is more or less effective.

Keywords: Supply Chain Management, Industry 4.0, Digitalization, Smart manufacturing systems, Conceptual model

1. INTRODUCTION

The advent of the fourth industrial revolution (Industry 4.0) that is built on digital technologies is rapidly transforming the supply chain (Ridgway, Clegg, and Williams 2013; Siemieniuch, Sinclair, and Henshaw 2015; Ben-Daya, et al., 2017, Hofmann and Rusch, 2017; Ferdows, 2018, Ivanov et al., 2019). The traditional supply chain characterized by physical flows that move products and information from one end of the supply chain to the other (Mussomeli et al., 2016) is often visualized as a rigid arrangement of supply chain partners that handle different primary supply chain management processes. However, to take full advantage of it, companies need to break away from the traditional supply chain, with each step dependent on the one before it. Inefficiencies in one step can result in a cascade of similar inefficiencies in subsequent stages, which could result to a bullwhip effect (Lee et al., 1997). This results in waste and inefficient operation.

Digital technologies have fostered a new era of competitiveness. Digital technologies allow for the integration of data and information from disparate sources and locations to drive the production and distribution of goods and services (Mussomeli et al., 2016). They are categorized under three broad areas, namely digital technology enablers, digital systems integrators and application technologies. The digital technology enablers provide the backbone that allows for the digital transformation of the industrial production (Gurria, 2017). These enablers include big data (Nguyen et al., 2017; Gunasekaran et al., 2017), Internet of Things (Atzori, et al., 2010; Moeuf, et al., 2017), and cloud computing (Aviles, 2015; Gantzia and Sklatinioti, 2014). Under the digital systems integrators are simulations, artificial intelligence and cyber-physical systems (Khaitan and McCalley 2015, Wang, et al, 2015, Monostori, et al, 2016). The application technologies are the applications through which the main productivity effects in industry are likely to unfold which include additive manufacturing/3D printing (Mellor, et al., 2014, Durach et al., 2017), autonomous machines and systems, and human-machine integration (Gurria, 2017). Giving these layers of the digital technologies we argue that companies should first establish the digital enablers, followed by digital systems integrators and then finally the application technologies.

The use of novel digital technologies allows companies to generate new forms of revenue and business value for organizations (Buyukozkan and Gocer, 2018). The quest for these novel technologies is not necessarily about the technology itself but their use to provide transformational effects on supply chain processes (Rai, et al., 2006; Xue, et al., 2013).

Building on this concept, we define supply chain digitalization (hereafter, SC digitalization) as the extent to which a focal plant implements novel digital technologies in their supply chain processes to conduct business with its suppliers and customers and the degree to which these technologies transform supply chain capabilities and operational performance of the plant.

In this paper we intend to develop a conceptual framework that describes the relationship amongst supply chain digitalization, supply chain capabilities and operational performance.

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2. THEORETICAL BACKGROUND

The Supply Chain Operations Reference (SCOR) model was developed by the Supply Chain Council with the help of the top leading manufacturing companies. The SCOR model is a diagnostic tool for supply chain (Ntabe, et al., 2015) and a major framework that features supply chain management practices and business process reengineering (Lockamy III and McCormack, 2004; Wang, et al, 2010; Zhou, et al., 2011). It is used to address, improve, and communicate supply chain management decisions within a company, its suppliers and customers (SC Council, 2004). It provides a methodology for managing supply chain activities and processes, which can be used as a set of practical guidelines for analyzing supply chain management practices (Li, et al., 2011). In this study, we offer an approach to operationalize the SCOR concept under the guides of digital technologies (DT) and seek to determine how DT can transform supply chain practices.

Several Studies (Gurria, 2017, Laaper, 2017, and Dall'Omo, 2016) have shown that digital technologies play a critical role in managing supply chain processes that generate performance gains for the respective firms. The foundation of digital transformation requires a complete understanding and holistic analysis of the internal and external capabilities (Uhl, et al., 2014). However, there have been limited academic research that investigate how and why digital technologies can create performance gains by improving and transforming supply chain capabilities.

The digital technologies improve capabilities by allowing companies to trim operating cost, improve product quality while increasing sales revenue through expanding market shares, developing new products that meet customer needs, and creating strategic advantage that improve all business operations (Gurria, 2017). Researchers have recognized capabilities as an important source of an organization's operational strengths and competitive performance (Flynn and Flynn, 2004; Peng et al., 2008). In the proposed framework, supply chain digitalization (SCD) serves to transform supply chain capabilities to improve operational performance of the firm.

Supply chain capability is defined as the ability of a company to identify, utilize, and assimilate both internal and external resources and information to facilitate the overall supply chain activities (Bharadwaj, 2000; Wu et al., 2006). Capability studies have been used in recent supply chain research (Ferdows and De Meyer, 1990; Noble, 1995; Boyer and Lewis, 2002; Flynn and Flynn, 2004; Singh, et al., 2015) to reframe the conversation into how and why capabilities create performance gains for the firm. Capabilities studies in general are informed by resource-based view (RBV) of competitive advantage that focuses on a firm's ability to consciously and systematically create distinctive capabilities which enable the firm to gain competitive advantage in the marketplace (Penrose, 1959; Wernerfelt, 1984; Hulsman et al., 2008; Yusuf et al., 2014). A company's resources provide the firm with unique capabilities that allow it to manage change and identify new opportunities (Barney, 1991).

Specifically, we use the resource-based view (RBV) of the firm to ascertain how digital technologies can be explored and exploited to obtain a distinctive SC advantage. This theoretical perspective, while positing that a firm's resources span across boundaries and are imbedded in inter-firm processes has changed the focus of competitive advantage from single organization to inter-organizational resources, thereby shifting from single organization to the entire supply chain network.

It is confirmed that supply chain capabilities can improve the competitive advantage of the supply chain by integrating key business processes from the suppliers, through the manufacturing processes to the customers thereby improve business performance (Kristal et al., 2010). Zacharia, et al. (2011) found that collaborative process competence mediates the relationship between the absorptive capacity and collaborative engagement capabilities which subsequently have a positive influence on operations performance. Liao, et al. (2017) used supply chain capability as a mediator in establishing relationships among supply chain collaboration and value innovation, supply chain capacity, and competitive advantage. Wu, et al., (2006) conceptualized supply chain capabilities as a second-order construct that comprises of four dimensions: information exchange, collaboration, interfirm activity integration, and responsiveness. Rai et al. (2006) identified IT infrastructure integration for supply chain as a lower-order capability that can be leveraged to a higher-order supply chain process integration capability. These dimensions serve as the source of significant and sustained performance gains in a supply chain.

Mckone-Sweet and Lee (2009) consider six supply chain capabilities, assessing both organizational and information technology (IT) dimensions. Mckone-Sweet and Lee's definition of SC capabilities, corroborates Wu et al (2006)'s work on the impact of information technology on supply chain capabilities. Based on the foregoing we adopt Mckone-Sweet and Lee's definition of SC capabilities, which attempts to integrate both the organizational and IT capabilities, that emphasizes the involvement of the customer and supplier. Therefore, the digital supply chain capabilities are presented as comprising of six dimensions: coordination, planning, customer involvement, supplier involvement, IT exploitation and IT exploration. To that extent, we propose the following two research questions to guide the study:

RQ 1 – Does the use of digital technologies in the core supply chain management processes of SCOR model influence supply chain capabilities?

RQ 2 –To what extend does use of digital technologies enhance operational performance through their impact on supply chain capabilities.

3. RESEARCH FRAMEWORK

In this paper we present a three-stage model that describes the relationship amongst supply chain digitalization, supply chain capabilities and operational performance. We draw on the SCOR framework to investigate the role of supply chain

digitalization on improving supply chain capabilities and its overall effect on operational performance (see Figure 1).

In assessing the supply chain digitalization, we investigate the level of investment of digital technologies, current level of use and future directions of implementation of digital technologies (see Figure 2). Based on current use and future direction of digital technologies implementation, our goal is to unveil the transformational effect of supply chain digitalization on supply chain capabilities which will impact the overall operational performance.

The research framework is presented in Figure 1.

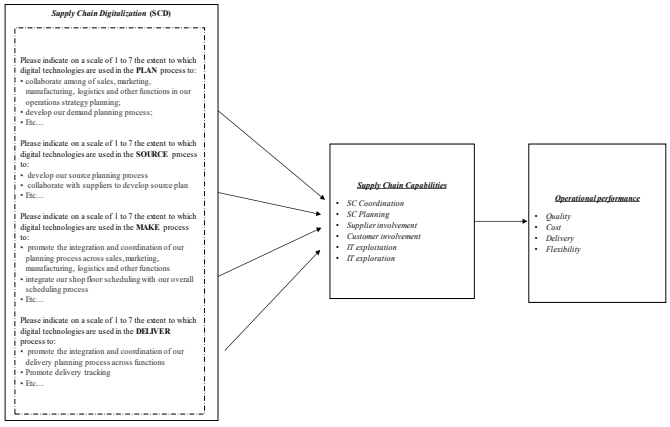

Fig. 1. Conceptual framework.

The SCOR model explains the processes along the entire supply chain and provides a basis for how to improve those processes. It has been described as a promising model for strategic decision making in supply chains (Turhan et al., 2011). The model has been widely adopted in many companies and anecdotal evidence and trade journals have reported significant improvements after firms adopt the score model (Zhou, et al., 2011). The basic building blocks of supply chain management processes in the SCOR Model are: plan, source, make and deliver. Within the context of this model, we investigate the extent to which the use of the novel digital technologies in the plan, source, make and deliver decision areas of the SCOR model influence supply chain capabilities which in effect enhance operational performance of the firm.

Digital Technologies[1]	Current level of investment of the following digital technologies in your supply chain	Current level of use of the following digital technologies in your supply chain	Future expectation of use of the following digital technologies in your supply chain
Digital Technology Enablers			
Big Data Analytics			
Internet of Things (IoT)			
Cloud Computing			
Digital Systems integrators			
Machine Learning/AI			
Simulation			
Blockchain			
Digital Applicators			
Additive Manufacturing/ 3D Printing			
Drone/Driverless vehicles			
Advanced/Collaborative Robotics			

Fig. 2. Adoption of digital technology.

We adopt the Mckone-Sweet and Lee's definition of SC capabilities. The authors consider two aspects of organizational capabilities for internal integration — coordination and planning. Coordination is an indicator of a firm's ability to integrate across business processes across the organization and planning is an indicator of a firm's ability to integrate their internal planning process with information from other members of the SC. They also consider two aspects of organizational capabilities for external integration — customer involvement and supplier involvement. Additionally, the authors also emphasize the importance of two aspects of supply chain IT capabilities — the use of IT for Exploitation and Exploration. Exploitation is an inward-looking tendency that focuses on operational efficiencies whereas exploration is outward-looking that seeks to gain better understanding of the environment and explore new ways to collaborate with customers and suppliers. Rosenkopf and Nerkar (2001) found empirical evidence that exploration beyond organizational boundaries had more impact than exploitation within organizations. Exploration typically involves innovations and risk taking while exploitation brings greater standardization and control to the supply chain (McKone-Sweet and Lee, 2009). Managing organizations for the simultaneous pursuit of exploitation and exploration may be a task of dynamic rather than static alignment (Siggelkow and Levinthal 2003, Westerman et al. 2006). Organizations need to continuously reconfigure their activities to meet changing demands in their internal and external environments. Maintaining an appropriate balance between exploration and exploitation, which promotes organizational ambidexterity, is a primary factor in system survival and prosperity (March, 1991). This supports adopting the IT capabilities through the lens of both exploitation and exploration.

The final stage of the framework is to measure operational performance. We employed four first-order constructs, following Ferdows and De Meyer's (1990) dimensions. Quality and cost performance were each measured using a single item, using the same items as Bozarth et al. (2009). Single-item perceptual measures are acceptable when the object of the construct is concrete, uniformly imagined (Bozarth et al., 2009) and when it is sufficiently narrow and unambiguous to the respondent (Wanous et al., 1997). Delivery and flexibility performance were each measured as two-item measures, using the measures validated by Liu et al. (2009) and McKone-Sweet and Lee (2009).

4. CONCLUSIONS

This paper presents the conceptual framework that leads to the development of a survey instrument that investigates the role of digital technologies on supply chain management practices. The supply chain module is one of three distinct modules that is being developed under the sixth round of the Global Manufacturing Research Group (GMRG VI) study.

GMRG (www.gmrg.org) is a multi-national community of researchers dedicated to the study and improvement of manufacturing supply chains world-wide. Through systematic study and research throughout the world, the

GMRG aims to improve manufacturing supply chains through the development of theory and dissemination of results. By sharing ideas, results, and concepts with research colleagues and manufacturing executives around the globe, the GMRG serves to strengthen the linkage between research and practice. The sixth round of the GMRG is currently being developed and will be deployed in first quarter of 2019.

Preliminary results of the global study on supply chain digitalization study will be presented at the conference.

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