Understanding the role of digital technologies in supply chain risks management

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Abstract. Supply chain risks have been regarded as one of the most significant threats to business continuity. Digital technology is considered to reform human production and manufacturing methods. In the recent wake of COVID-19, disruptive digital technologies have emerged as a key tool to manage supply chain risks. Therefore, exploring the impact of digital technology on supply chain risks is considered an important topic in the supply chain management domain. The paper reviews different digital technologies such as 3D printing, IoT, Blockchains, RFID and Big Data Analytics used in supply chains. This exploratory study is based on a survey response from 176 supply chain professionals in China. The findings show the role that digital technologies in managing supply chain risks. The study highlights the current level of implementation of digital technologies in supply chain functions and also highlights the importance of training. Moreover, the study highlights the importance of supply chain data analysis capabilities for supply chain risk management. Our study adds to the limited literature exploring the importance of digital technologies in supply chain risk management.

Keywords: Digital technologies, Supply Chain Risk Management, Industry 4.0.

1 Introduction

The world is currently going through a very difficult phase due to the ongoing Coronavirus (COVID-19) pandemic. COVID-19 pandemic has disrupted the global value chains as a result of the lockdown measures adopted by several countries to stop the spread of the disease (Kumar, 2020). Aksoy & Ozturk (2011) believes that the process of globalization has brought advantages to businesses and at the same time it has also brought several challenges. Global procurement, the strategies, outsourcing, and production have made the supply chain more geographically dispersed and increased the difficulty level of management. The ongoing COVID-19 pandemic has highlighted the

vulnerabilities of the global supply chains. Traditionally organisations have relied on operating models such as lean, just-in-time production and Toyota Production System (TPS) to reduce costs and improve competitiveness. However, these operating models reduce the company's inventory and increase the risk of supply chain disruption due to shortage of raw materials. According to Berger *et al.* (2004), interruptions caused by supply chain risks have increased costs, reduced revenues and decreased market share for businesses. Therefore, supply chain risks have been regarded as one of the most significant threats to business continuity. A 2011 report by the World Economic Forum (WEF) points out that in the past five years, more than 90% of companies believe that supply chain and transportation risk management has become more and more important in organizational management (Park *et al.*, 2013).

As the whole world is now transitioning towards the fourth industrial revolution, i.e. industry 4.0, many organisations are now relying on disruptive digital technologies to manage the supply chain risks. Park *et al.* (2013) suggest that among the many tools used to prevent and mitigate supply chain risks, digital technology plays a key role. Blockchain, 3D printing, Internet of Things, Cloud Computing, Robotics, Artificial Intelligence, Big Data Analytics and other digital technologies can not only shorten the relationship between enterprises and upstream and downstream partners in the supply chain, improve the efficiency of supply chain operations, but also help enterprises to share information and control responses in a timely and effective manner to deal with risks (Birge *et al.*, 2011). The term "Supply Chain 4.0" emphasises the relationships between Industry 4.0 and supply chains (Frederico *et al.*, 2019). Supply Chain 4.0 has the potential to disruptively transform traditional supply chains (Tjabjono *et al.*, 2017; Frederico *et al.*, 2019). Truong Quang & Hara (2018) highlight that digital technology in the supply chain is different from comprehensive management information systems such as MRP II or ERP. Its scope is not limited to the enterprise, but also extends to partners in the supply chain network. The digital technologies in the supply chain have gradually developed and matured with the advancement of supply chain precision, complexity, flexibility and supply chain management theory (Truong Quang & Hara 2018). Although most enterprises have realized the use of digital technology to strengthen supply chain information sharing and cooperation, to achieve the purpose of preventing and mitigating supply chain risks, the reality shows that enterprises with digital technology resources may not be able to effectively manage and control supply chain risks (Truong Quang & Hara 2018). Therefore, the main aim of this study is to explore the impact of digital technology on supply chain risk management.

2 Literature review

This section provides an overview of the existing literature around supply chain risk management and the application of digital technologies in supply chains. The study mainly explores five emerging technologies namely 3D printing, blockchain, Internet of Things (IoT), Radio-frequency identification (RFID) and Big Data Analytics (BDA).

2.1 Supply Chain Risk Management

Supply chain risks are "anything that presents a risk (i.e. an impediment or hazard) to information, material and product flow from original suppliers to the delivery of the final product to the ultimate end-user" (Peck, 2006). There are numerous causes for supply chain risks to occur that varies concerning complexity and completeness (Xanthopoulos and Pejicic, 2015). To analyse the effect of modern digital approaches on supply chain mitigations, there is a need to understand these risks in depth. Many authors have grouped these risks in different ways. According to Chopra and Sodhi (2004), there are nine specific categories of supply chain risks comprising of forecast, delays, disruptions, systems, inventory, capacity, procurement, receivables, and intellectual property. Christopher and Peck (2004) suggested two broad classifications of risks: Internal risk involving process and control and External risks involving demand, supply, and environment. Therefore, supply chain risk includes both its own operational risks and the risks arising from the information transmission process.

Supply chain risk has both the general characteristics of risk and the special nature of the supply chain. The supply chain risk is also dynamic and changes with changes in external factors. The result of supply chain risk comes from the combined effect of internal and external factors. The smooth operation of the supply chain requires each node to cooperate and work together (Cruz 2013). To achieve the final goal, each enterprise must depend on each other. The complexity of the supply chain also increases the probability of risk. Supply chain risk is directly affected by the company's operating level. The operating level of an enterprise includes budget input, technical level, strategic planning, and information sharing. Therefore, when controlling supply chain risks, we must start from the aspects of enterprise composition and construction principles. Supply chain risks are also transitive (Cruz 2013). Enterprises in the supply chain depend on each other, which means that the supply chain itself is a whole, and no matter which enterprise node in the chain has a problem, it will affect everyone connected in the chain. Therefore due to the structural characteristics of the supply chain if there is a problem with any node it will affect the entire chain. The supply chain risks also interact with each other. For example, the reduction of one risk may lead to the birth of another risk. Enterprises therefore should pay close attention to the relationship between various risks (Golicic & Smith 2013; Ivanov et.al 2017). One way to solve the complementarity of risks is to keep proper control over the inventory. When inventory is insufficient, the possibility of supply chain interruption is likely to occur, and larger inventory will take up too much liquidity, resulting in problems such as increased costs.

Risk mitigation is a vital part of supply chain management. According to Alonini *et al.* (2012), risk mitigation is a selection of methods and strategies in order to manage risks in a supply chain. Hallikas *et al.* (2004) provide strategies for risk mitigation such as transfer, take, eliminate, reduce, share or assess individual risks, focusing on probability and impact. Similarly, Aqlan and Lam (2015) established their mitigation strategies and they are risk avoidance, risk reduction, risk transfer, risk acceptance, ignoring risks, risk exploit. Ho *et al.* (2015) claim that risk mitigation process should be conducted on the same aspects which are relevant to supply chain, i.e., supply chain risk mitigation should include macro and micro risk mitigation, demand, process, supply,

finance, manufacturing, information and general risk mitigations. Behzadi *et al.* (2018) highlight that nowadays firms are increasingly global and less vertically integrated, increasing the complexity of supply chains and exposing them to much more risks.

2.2 Digital Technologies for Supply Chains

The digital transformation in supply chains has resulted in several benefits such as cost reduction, improved transparency, improved delivery speed, increased efficiency and improved profitability. The modern disruptive technologies are slowly transforming the supply chains and making them more intelligent and efficient. This section will explore the potential some of these industry 4.0 technologies for supply chains.

As one of the iconic technologies in the context of the new industrial revolution, 3D printing will have a wide-ranging impact on human production and manufacturing methods, life consumption methods and organizational management methods in the future (Truong Quang & Hara 2018). With the increasing flexibility and capabilities of 3D printing technology, 3D printing has become more and more beneficial to the manufacturing industry and is widely used in materials, automobiles, food and healthcare industries. Scheibe et.al (2017) reviewed the social impact of 3D printing from a technical perspective, including: first, 3D printing can customize healthcare products to improve population health and quality of life; second, 3D printing can reduce the sustainability of manufacturing Environmental impact; (3) 3D printing can simplify the supply chain and improve the efficiency and responsiveness of demand fulfilment. Xanthopoulos et.al (2012) and Aqlan & Lam (2015) studied the advantages of 3D printing over traditional subtractive manufacturing, including printing parts in a short time and improving the manufacturability of highly complex products, shortening production cycles, reducing manufacturing processes to save materials, reduce the need for moulds, increase the density of the final parts and manufacture free-form closed structures. Chen, Sohal & Prajogo (2013) find that 3D printing like industrial manufacturing technology can significantly reduce resource and energy demand and process-related CO2 emissions per unit of GDP. Basole et.al (2014) conducted a sensitivity analysis around supply chain cost changes by establishing a model, indicating that 3D printing technology will reduce sales losses due to product mismatches, as well as increase customer satisfaction due to the full availability of products and increase the market demand. El-Shahat (2017) believe that 3D printing technology can reduce costs by maximizing the use of products and equipment. Gladwin & Floyd (2015) also analyzed the costs and benefits of a 3D printing technology-based supply chain through case studies to provide technology investment advice. Whereas Bhasin *et al.* (2014) quantitatively estimated the potential impact of 3D printing technology on the global supply chain. Studies have shown that 3D printing technology will significantly change the future supply chain, as manufacturing will move from low-cost regions to closer to end customers, which can help companies reduce transportation and inventory costs. It can be seen that the investment in manufacturing technology affects the operation of the entire supply chain by affecting the decisions of the members of the supply chain.

The main purpose of blockchain technology is to achieve the use of technologies such as cryptography, consensus algorithms and reward mechanisms without the

intervention of third-party trust institutions so that each node does not need to trust any other nodes, nor does it require the central certification authority (Khrais, 2020). In a narrow sense, a blockchain is a shared database that connects blocks into a chain in a chronological order to ensure that data is not tampered with (Khrais, 2020). Broadly speaking, blockchain technology is a set of decentralized infrastructure models that combine multiple existing technologies. Zhou Liqun (2016) discussed the impact of blockchain technology on the factoring business development model and described the possibility of blockchain technology breaking the supply chain financial bottleneck. Hua (2016) highlighted the role of blockchain in the future supply chain financial innovation application and described the whole process of asset ownership traceability and logistics information. Wang *et al.* (2017) expounded the economic value of blockchain technology on the influence or role of different participants in supply chain finance. Yao *et al.* (2019) combine blockchain technology with supply chain finance, taking reverse factoring products as an example, and integrating supply chain partners into a completely effective and transparent ecosystem for everyone through blockchain. The transparency is used to reduce disputes and transaction costs, maximize the value of financial flows, and help smooth the flow of funds in the supply chain (Yao et.al 2019). Blockchains has already shown its potential not only in the financial sector but also in food safety monitoring and food traceability in the supply chains (Tian, 2016).

The Internet of Things (IoT) refers to a network that connects items to the network through technology, infrared sensors, readers and other devices to exchange information to achieve intelligent identification, location tracking, monitoring and management (Zanella *et al.* 2014). The IoT can collect terminal information through sensors and radio frequency identification. The collected information is quickly and stably transmitted to the control system through middleware technology and network so that the operator can analyze the entire system environmental data and items for real-time monitoring of data to discover and solve problems in a timely manner. However, the digital supply chains expose new types of cyber risk in the digital economy from shared infrastructure.

RFID, as one of the important technologies in the New World, has a wide range of applications in many fields, especially industries and fields that have great significance in real life, such as transportation, medical machinery, data statistical management, logistics management, and product anti-counterfeiting (Truong Quang & Hara, 2017). Its working principle is to use radio frequency signals to automatically identify the objects to be identified and visually present it as intuitive data, and the relevant conclusions can be obtained through the analysis (Sawik, 2017). RFID-technologies has been successfully implemented in the supply chains to deliver real-time information about the current status of logistics activities. Geis-berger and Broy (2012) showed that using REFID the truck-delivery of specific products could be optimized. For example, the delivery information of trans-ported products could be changed in real-time and whenever needed (Whang, 2010). This way, a product that is already on its way to the initially targeted customer could be routed to another nearby customer if the delivery was aborted. Hence, with the digitalization of all logistics processes through RFID-technologies, even problem management can be carried out centrally and online. Tian (2016) highlighted that in the USA and Japan, RFID system had been used for tracking

agri-food in the entire supply chain from planting to the distributor and retailer as RFID systems provide management information and safety data of agri-food for the producer, wholesaler, retailer and consumer.

Big Data Analytics (BDA) consists of refined data analysis means that simplifies decision-making procedures by the retrieval of essential and relevant data from an extensive data source within a reasonable time interval (Tsai *et al.*, 2015). Big Data has been characterized by 5Vs: volume, variety, velocity, veracity, and value (Wamba *et al.*, 2015). BDA is becoming increasingly popular among manufacturing companies as it helps gain insights and make decisions based on Big Data. It is also becoming an inevitable technology in SCM since it can be used for the smooth functioning of important SC components like barcodes, RFID, and sensors. Its quick and easy data handling capabilities are helping companies to compete well in the fluctuating markets. BDA is enabling better SC agility, enhanced customer delights as well as minimum running expenses (Nguyen *et al.*, 2018). Empirical evidence demonstrates that BDA has multiple advantages in SCM as it helps to reduce operational costs, improve SC agility, and increase customer satisfaction (Ramanathan *et al.*, 2017).

The evidence presented so far provides a good overview of the application of the industry 4.0 technologies in the supply chains. It also shows that these digital technologies provide numerous benefit to supply chains and hence has seen greater adoption in all facets in recent years. As their ability to provide real-time visualization of the data, improve transparency, better demand forecast, etc. helps supply chains to better deal with the risks and disruptions. As we are currently facing significant disruptions due to the ongoing pandemic, it would be interesting to explore how these digital technologies can assist in supply chain risk management. Next section provides the methodology adopted in this study.

3 Methodology

This is an exploratory study aiming to understand the role that digital technologies play in supply chain risk management. Following the review of the extant literature, a number of digital technologies and their application in the supply chain domain were explored. A survey questionnaire was then designed. The questionnaire was designed to examine participants' understanding of digital technologies, its role in managing supply chain risks and understand challenges associated with the supply chain. The questionnaire designed in this study was divided into four parts:

1. the company's basic information;
2. the company's digital supply chain practices;
3. supply chain risk management;
4. supply chain capabilities.

The questionnaire includes various multiple-choice questions. The study targeted professionals working in the supply chain area and who are familiar with digital technologies. The survey was sent to more than 500+ professionals in China through a personal network and social media platforms such as LinkedIn and WeChat. The data was

collected between June-August 2020. The survey resulted in 176 valid responses, with a response rate of 44 percent. This included responses from 5 CEOs,12 senior/general managers and 159 general employees familiar with the supply chain domain.

4 Findings and Discussions

The first part of the survey was focused on the demographics of the companies. From the perspective of funding sources, 82 percent of the respondent's organisation belong to Joint Ventures, 11 percent were private enterprises, 3 percent state-owned and rest (4 percent) wholly owned by foreign enterprises. Nearly 81 percent of those enterprises employed more than 5000 employees, around 4 percent were SMEs (employing less than 500 employees) and rest 15 percent of the enterprises employed between 500-5000 employees (Figure 1).

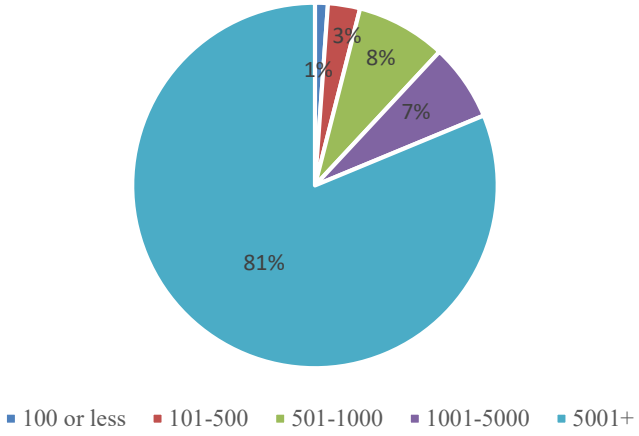

Fig. 1. The total number of employees in the company

The second part of the survey was focused on understanding the supply chain digital practices within the enterprises. When asked about emerging digital technologies that are being used in the supply chain practices of their company (see Figure 2), almost nearly 82 percent respondents highlighted the greater reliance on IoT, BDA, AI, robotics, cloud computing, mobile and social technologies, augmented reality/virtual reality, and 3D printing. However, only a small percentage (11 percent) of respondents mentioned the usage of unmanned/autonomous vehicles.

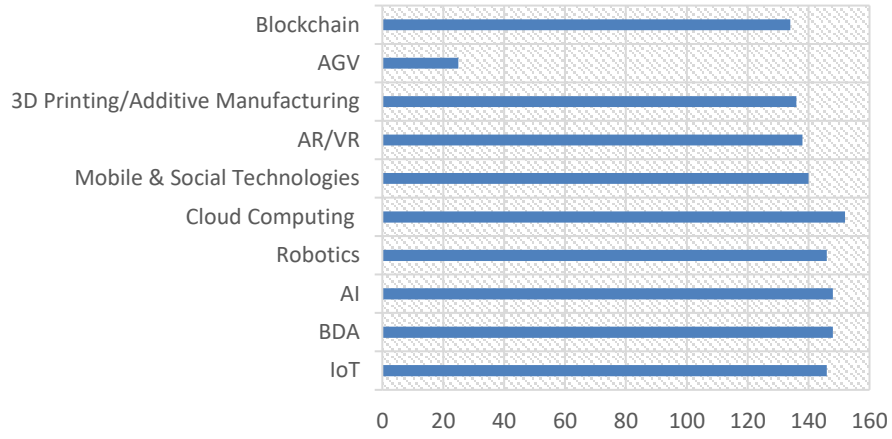

Fig. 2. Which of the following emerging digital technologies are used in your company's supply chain practices?

Figure 3 shows that only 3 percent enterprises does not understand the urgency of the digital supply chain reform, and has not yet started the digital supply chain practice; 5 percent of them understand the urgency of digital supply chain reform, but have not yet begun the practice of digital supply chain; whereas 20 percent have started either short-term (less than one year) or long term (more than one year) digital supply chain project. Interestingly nearly 72 percent of enterprises have already formulated a mid-to-long-term (more than one year) digital supply chain strategy and are constantly advancing. When asked about the senior leadership support to digital supply chain practices, nearly 74 percent of the respondents agreed that their leaders attach great importance to the company's digital supply chain practices. 78 percent of participants believe that the return on investment of digital supply chain practices is above 80 percent. Whereas, 73 percent believed that the company's digital supply chain practices closely match the company's current development and 76 percent enterprises regularly provide technical training to employees. Around 76 percent enterprises agreed that their functional departments collaborate in the digital supply chain practice process and 94 percent participants believed that external suppliers were very willing to cooperate in the digital supply chain projects.

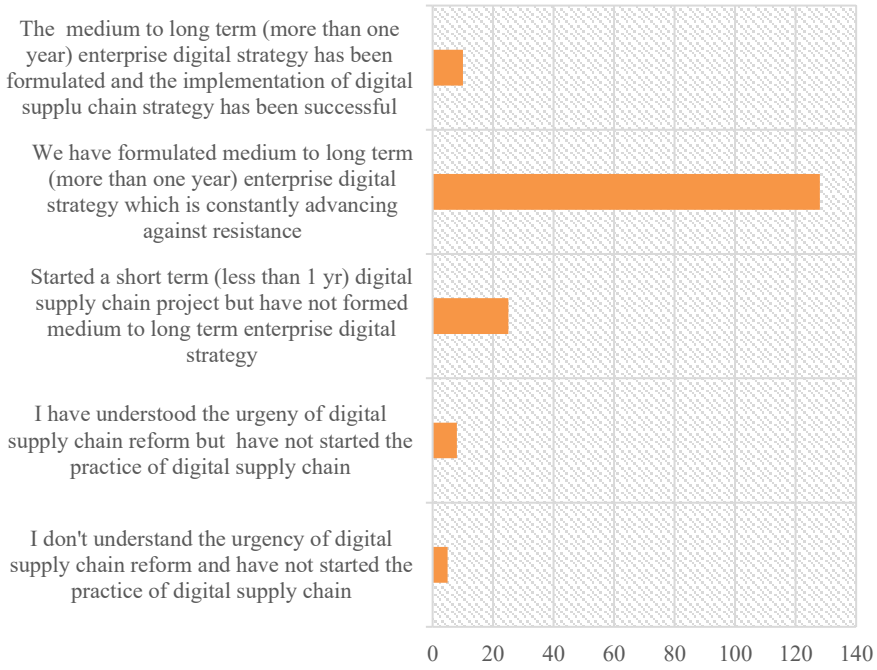

Fig. 3. Digital Supply Chain practice implementation by companies

The third part of the survey asked questions about supply chain risk management. Around 60 percent participants believed that the most likely risk in the supply chain was the risk of information dissemination, and the remaining 11 percent highlighted risks related to the production organization and procurement. In addition, they also highlighted the risk related to the selection of distributors (17 percent), and around 9 percent highlighted logistics operation risks and around 3 percent highlighted the corporate culture differences as the risk factor. Regarding the company's measures to deal with supply chain risks (see Table 1), respondents were asked to choose a number of potential options that enterprises would normally follow to mitigate supply chain risks. Table 1 shows the respondent's view of these potential measures. Nearly 17 percent participants chose to strengthen information exchange and sharing and improving the efficiency of information exchange whereas 20 percent suggested strengthening enterprise risk management and establishing emergency mechanisms to deal with risks. While nearly 71% suggested that all these measures are necessary to manage the supply chain risks.

Table 1. Company's measures to deal with supply chain risks

Measures	Volume
Strengthen the risk management of node enterprises	10%
Establish an emergency response mechanism	10%

Measures	Volume
Strengthen information exchange and sharing, improve information communication efficiency	17%
Strengthen incentives for supply chain stakeholders	10%
Optimize partner selection	11%
Pay attention to flexible design and maintain the flexibility of supply chains	12%
Improve the culture and create common values with supply chain partners	10%
Strengthen procurement and optimize logistics and distribution	11%
Establish a strategic partnership	10%
All of the above	71%

The final part of the survey focused on exploring the supply chain capabilities. Based on the data stored in the company's digital supply chain system, supply risk warning and automatic generation of flexible response plans, 60 percent participants believed that the company's supply chain data analysis capabilities can largely support supply chain risk management. Nearly all participant's agreed that when they face product quality-related problems, the digital technologies help trace the supplier, parts batches, and the root cause of the problem in time. Around 52 percent reported real-time monitoring of their inventory situation whereas only 2 percent reported that they do not have real-time monitoring of their inventory. In general, more than 80 percent participants agreed that the application of digital technology will reduce supply chain risks.

The findings from the survey show that many enterprises have already started adopting emerging digital technologies in their supply chains. The responses show that there is a greater level of awareness among respondents regarding the emerging disruptive technologies. Enterprises also see digital technologies as a great tool to deal with supply chain risks. The study identifies several risk factors such as information collection errors, information security risks, information infrastructure failures, information transmission timeliness, corporate reputation and logistics transportation and storage. The entry point in this regard puts forward suggestions and measures for risk management. Among the six risks, information collection errors, information infrastructure failures and information transmission timeliness are risks that occur at the perception layer, mainly the risks caused by the application of IoT. The implementation of the IoT system in the supply chain needs to be improved for better effectiveness. Information security risks include information asymmetry risks, information risks, information distortion risks, but the proportion of information security risks relative to other risks is relatively large. Corporate reputation risks are often brought about by information security risks. As a result of information security risks, false information cannot be effectively identified, affecting the corporate reputation in supply chain exchanges. Improving the level of the digital technology supply chain can effectively reduce transaction costs, improve the efficiency of information transmission and improve quality issues.

5 Conclusions

This study attempts to understand the role that digital technologies in managing supply chain risks. The study reviews the application of a number of emerging digital

technologies such as 3D printing technology, blockchain, Internet of Things (IoT), RFID technology and Big Data Analytics (BDA) in the supply chains and how these technologies are being used to manage the risks. A survey of the supply chain professionals was conducted that highlights the extent of the usage of emerging technologies in managing supply chain risks. Our findings show that supply chain risk has been regarded as one of the key threats to business continuity. Finding also shows that 3D printing technology not only makes the traditional subtractive manufacturing technology obsolete but also provides more choices for designers, manufacturers, sellers and maintenance technicians while bringing more production capacity closer to the end-user. The main purpose of blockchain technology is to realize encryption without the intervention of a third-party trust agency, thereby ensuring the security of supply chain transactions. The key technologies of the Internet of Things (IoT) include barcode technology, QR code, global positioning system, cloud computing and EPC information network. RFID technology can be applied to multiple industries to ensure that companies can trace their products back to each chain. BDA has shown to improve SC agility, reduce operational costs, and increase customer satisfaction. For large enterprises with multi-level organizational structures and larger scales, the use of digital technology has many benefits in improving procurement efficiency, cost, quality, and standardization, as well as some risks. By analyzing the risks that affect the target of centralized procurement, decomposing the risks, and identifying the influencing factors of the risks, the centralized procurement risks can be analyzed from multiple angles and in all directions, and the supply chain risk problems can be better solved through digital technologies. Our exploratory study thus adds to the limited literature exploring the role of digital technologies in managing supply chain risks.

This study has some limitations. The study is based on the 176 valid responses from China and hence future research should increase the sample size and collect data from other regions of the globe. Future studies can also perhaps use a combination of qualitative and quantitative methods for broader generalization and triangulation of the findings. Since this study only explores five digital technologies in detail, future studies should also look at the implication of other technologies such as AR/VR, automation and cloud computing to supply chains. Besides, future studies should develop a conceptual framework and empirically explore how these emerging technologies affect supply chain performance. The practical application of these digital technologies in different sectors can also be an interesting area to explore.

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