Journal of Information Systems and Technology Management – Jistem USP
Vol. 19, 2022, e202219019
ISSN online: 1807-1775
DOI: 10.4301/S1807-1775202219019
Original Article

IMPACTS AND IMPLICATIONS OF DIGITAL TECHNOLOGY USE IN SUPPLY CHAIN PREPAREDNESS AND RESPONSE DURING THE COVID-19 PANDEMIC

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ABSTRACT

In this study, we examined the effect of digital technologies during COVID-19 pandemic. 104 supply chain managers responded to our survey. Based on their responses we were able to conclude that those firms who invested more in their digital technologies performed better in reducing the severity of COVID-19 pandemic related challenges, felt better prepared in general for the pandemic compared to the competitors, and considers their digital technology investments helped them during COVID-19 on their success which led them to invest further in Technology. We believe our findings will help businesses to consider investing in their digital technologies for better management of uncertainties in their supply chains.

Keywords: Digital Technology Capacity; COVID-19 Pandemic; Supply Chain Management

Manuscript first received: 2022-07-29. Manuscript accepted: 2022-10-04

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INTRODUCTION

"Supply Chain Disruption" has become a common term across the world during the COVID-19 pandemic. Prior to the pandemic, businesses opted for lean supply chain structures that saved operational and storage costs and implemented mostly a "Just-In-Time" ordering structure where inventory levels are kept at minimum (Abdallah, 2021; Riezebos et al., 2009). While extreme leanness in supply chains saves money in the short-run, it has proved to be catastrophic in the wake of the pandemic, and it seems that the difficult situation may remain well into the near future (Cuvero et al., 2021). Toyota and VW closed certain production lines in China because of a shortage of computer chips that are essential to the electronic control of their cars (Wu et al., 2021). Supply chain issues are expected to continue globally in 2022 and beyond, as 60-70% of manufacturing and shipping deals between America and Asia are made as short-term agreements (Wang & Curran, 2021), meaning that a majority of American importers do not have guaranteed supplies of their components for the upcoming months. In Germany, over 50% of the 3,000 firms surveyed in the Association of German Chambers of Industry and Commerce expected supply chain issues to continue into 2022 (Wang & Curran, 2021). In the UK, major retailer stock levels are at their lowest since 1983 (Partington & Partridge, 2021). In China, the government shut down the third busiest container port in the world for two weeks after a single dock worker tested positive for COVID-19 (Wang & Curran, 2021). In the ever volatile world that we live in, disruptions on supply chains will continue to evolve. For example, in March 2021, the Suez Canal was blocked for six days when a shipping vessel became stuck in the canal (Jungen et al., 2021). To make matters worse, experts predict that climate change will disrupt supply chains far more than COVID-19 has as we start to see dramatic increases in wildfires, droughts, floods, and other extreme weather (Sodhi & Tang, 2021). Given this information, it is *critical* that we improve our understanding of supply chain disruption risks, learn how to mitigate them, and learn how to properly respond to disruptions in order to minimize the long-term damage. Future disruptions are inevitable and will likely occur on a greater scale than we have ever seen; so, we must better be prepared.

Firms are lacking in many ways when it comes to supply chain risk management. Very few multi-objective supply chain networks include supply chain risk as an objective (Bilici et al., 2017). Authors propose a multi-objective optimization model and illustrate that controlling and lowering supply chain risk through supply chain nodes is very important for the success. Firms often do not have access to proper visibility in their supply chains (Messina et al., 2020), where visibility is defined as the ability of a supply chain to provide accurate and timely information to its supply chain partners in order to make better decisions (Goh et al., 2009). These companies often employ risk minimization strategies that do not reduce the actual risk faced by the firm (Gouda & Saranga, 2018). In the long run, it is more profitable to invest in risk containment strategies despite the initial cost involved (Chopra & Sodhi, 2014; McMaster et al., 2020; Shukla et al., 2011). Moreover, most of the previous research only focuses on post-disruption strategy, what is done *after* a disruption has occurred, rather than preparation/risk-mitigation (Chen et al., 2019).

As the world continues to move into the digital era, new technological tools have the potential to significantly enhance firms' supply chain operations by increasing the visibility and faster response in supply chains (Hou & Su, 2006; Lai et al., 2006). For example, the use of Artificial Intelligence (Baryannis et al., 2019), cyber-resilience strategies (Boyes, 2015), blockchain (Gao et al., 2018;

Manupati et al., 2020), and Big Data Analytics (BDA) can help better manage supply chain risks (Dubey et al., 2021; N.P. Singh & S. Singh, 2019). The Internet of things and BDA are predicted to have the most significant impact on supply chains (Hopkins, 2021). Appropriate adoption of Artificial Intelligence (AI)/Machine Learning (ML) will support formation of new generation of intelligent manufacturing (Cioffi et al., 2020). The most significant benefits of AI and ML in supply chain management comprise greater innovation, process and resource optimization, and improved quality. The integration of operational objectives with key performance indicators like resilience, stability, and robustness can help ensure that a company's long-term goals are aligned with performance indicators that go beyond short-term profit and extend to a supply chain's ability to withstand disruptions (Ivanov et al., 2017). Gorecki et al., 2020 developed a simulation model of whole job shop production process flow to mitigate potential errors that may occur in real-life process. Though the main objective of the simulated system is to test operational performance based on key performance indicators the model manages hazards, risks during the simulation process in order to modify processing time of a certain task.

Research Questions

In this paper, we examined if technology use helped companies overcome some of the supply chain difficulties during the COVID-19 pandemic. We are particularly interested in what extend Digital Technology capacities build prior to COVID-19 helped supply chain firms:

- In managing the severity of the COVID-19 pandemic effects;
- In keep their stability in their operations and costs related to COVID-19 pandemic;
- In overall preparedness for the disruptions related to COVID-19 pandemic.

We also test the perceived help vs the factors above. As an example, we all can justify buying a new laptop for our productivity, but is it really going to make a change in productivity? Lastly we test if the pre-COVID-19 digital technology investments led to post COVID-19 technology investments.

Research Agenda

We define the beginning of 2020 and beyond as the COVID-19 pandemic period. This is the period, major lockdowns across the world occurred. In case of countries like China, local lockdowns continued well into 2022. In our study, we sent 205 surveys to mid to upper level supply chain managers in the US to assess the impact of technology use during COVID-19. We received 104 complete responses. Our study is unique as our focus is on the front line supply chain managers, we examine severity and stability effects of the Digital technology investments and we separate perceived help from the reality. Additionally, we examined the survey results using structural equations modeling to have sufficient empirical support Our study is timely and important since technology will continue to evolve, and it is imperative for supply chain managers to know if technology use is helpful in unexpected situations such as the COVID-19 pandemic.

We explain the supporting theory in section 2, our survey and research model in section 3, our hypotheses in section 4 , and the results and analysis are given in section 5. Conclusions and future directions for potential research are discussed in the last section.

LITERATURE REVIEW

The **resource-based view** analyzes a firm's position from the perspective of having access to critical resources to create a competitive advantage (Wernerfelt, 1984). In other words, instead of focusing on developing unique products, this theory emphasizes developing access to superior resources in order to create a sustained competitive advantage (Lockett et al., 2009; Peteraf, 1993). Moreover, firms must understand that the resources they have today and how they use them will significantly influence their ability to compete tomorrow; it is critical that firms fully understand both how their resources can be used and that resource value is subject to change according to large-scale shifts in global technology and market resource value (Lockett et al., 2009). A competitive advantage can be internally developed through the acquisition of asymmetric information or specialized resources (Lockett et al., 2009). From the perspective of digital technologies in the supply chain as the development of internal resources (data), we can apply the resource-based view theory to hypothesize that firms who correctly implement digital technologies into their supply chains will be at a competitive advantage since they are developing the superior resource of cutting-edge data processing and automation.

Similar to the resource-based view, the concept of **dynamic capabilities** refers to the organizational structure that causes resources to develop and change. Firms must possess dynamic capabilities in order to continually transmute their resources and remain competitive in the long-run (Ambrosini & Bowman, 2009). Furthermore, managers should track the development of their dynamic capabilities and recognize that such actions require long-term commitment; managers should not give up and believe their efforts are not worth the investment simply because of a lack of short-term results or performance (Wang & Ahmed, 2007). This highlights the importance of the earlier discussion on the need for management that embraces adaptation and change. A supply chain that has dynamic capabilities and is structured in a way that allows it to change resources and how they are used may help mitigate disruptions, and therefore increase a firm's sustained competitive advantage.

Organizational information processing theory proposes that an organization's response to a stimulus will be determined by the way it interprets, processes, and chooses relevant information (Smith et al., 1991). Bode et al. found that firms will respond differently to situations based on how they process information, which is based on the *imperative postures* they hold. In other words, the beliefs of company managers are the product of past experiences (Bode et al., 2011). In another study done with 151 CEOs, researchers found that information processing structure has a causal relationship with how executives make assessments and decisions about strategic issues. Moreover, they found that the executives' information processing structure influenced which pieces of information the CEOs even chose to consider as relevant (Thomas & McDaniel, 1990). The pattern here is clear; firm's actions are determined by their information processing structure, and their information processing structure is built on beliefs that are a result of past experiences (Sinkula, 1994).

It is essential to restructure organizations based on the information an organization requires and the capabilities it needs to attain, process, and communicate that information (Daft & Lengel, 1986; Premkumar et al., 2005; Sinkula, 1994; Tushman & Nadler, 1978). Again, organizational information processing theory connects to the earlier discussion about past experiences and beliefs informing future decisions. The theory further demonstrates the extent to which firms and managers make decisions based on the way they view a situation, which is determined by their past experiences. As such, it is critical that we design firms with this in mind. We can hypothesize that the introduction of digital technologies into the supply chain will increase the information processing capabilities of firms, which will allow them to view situations and make objective judgments that are unclouded by likely irrelevant past beliefs. This will, in turn, improve a firm's competitive advantage since they will be acting in accordance to situations as they actually are, rather than how they simply *believe* situations are because they are processing information better.

The introduction highlighted various examples of how supply chain disruptions have and continue to impact supply chain performance. The COVID-19 pandemic has been a particularly striking example of the fragility of global supply chains. We propose that firms are missing out on an opportunity to use digital technologies to mitigate the effect of supply chain disruptions on performance. According to the resource-based view, we can begin to understand digital technologies as a resource available to firms that increases their competitive advantage. Rather than focusing entirely on the product-side of the business, developing their resource capacity and capabilities may be more beneficial for firms. Digital technologies are a promising way to accomplish this. For example, a substantial investment into a firm's digital technology capabilities may produce an information processing and automation system that becomes a unique, asymmetrical resource held by a particular firm, thereby creating a competitive advantage. Additionally, digital technologies like artificial intelligence can increase a firm's dynamic capabilities by automatically identifying and creating processes for the firm to change its resources or create new ones. This kind of an automated decision-making system makes it easier for firms to quickly and effectively adapt to an ever-changing external environment.

Organizational information processing theory tells us that firms largely make decisions based on past beliefs, experiences, and collective memory. That is, how a firm chooses to respond to a disruption situation is directly moderated by its past experience. This can pose a problem because managers are making decisions based on unconscious bias. Many may refuse to even consider digital technologies as an option worth investing in, as they believe that their past experiences properly equip them to handle future disruptions. COVID-19 has demonstrated that this is largely not the case. Digital technologies can serve as an effective tool for managers to move towards eliminating the bias of their decision-making that the organizational information processing theory tells us they possess. By collecting, processing, and analyzing huge amounts of data that are otherwise inaccessible to ordinary individuals, digital technologies provide managers with an unbiased portfolio of information that can be used to prevent, detect, and resolve disruptions. At the more advanced stages, digital technology can even use the data to make intelligent, automated decisions for managers. This solves the problem of managers acting in accordance with their beliefs, rather than with the reality of a situation.

In this way, we can see that both the theories of resource-based view and organizational information processing support the model that digital technology can serve as a positively moderating variable between supply chain disruption and performance.

MATERIALS AND METHODS

A descriptive online survey was chosen as the most appropriate method for this research. In this section we will delineate the demographics of the sample, the respondent's digital technology use in their supply chains and the measurement of the key factors of our research. The survey targets were supply chain managers at companies across the Midwest United States. Supply chains in general, and particularly the ones in the US are strongly connected to global economies due to the strong trade relations of the US and the rest of the world. Researchers of this paper are working in the Midwest United States, our many connections are working in the Midwest for global companies.

Demographics

We used LinkedIn as the primary method of reaching out the supply chain managers. Survey links to the questionnaire were sent in four waves across multiple months in 2021 to 2022 to 205 managers, and we received 107 responses. Three of the questionnaires were excluded from data analysis because of missing data leading to a final sample of 104 valid questionnaires (50.73% usable response rate). Following Table 1 shows the demographics summary of the survey data out of 104 valid questionnaires.

Table 1. Demographics of Survey Data

Survey Demographics	
Firm Size of Respondents (Revenue)	
$100 Million and Above	88%
$10 Million to $100 Million	10%
Less than $10 Million	2%
Firm Size of Respondents (Number of Employees)	
More than 100	82%
11 to 100	12%
10 or Less	6%
Firm Industries of Respondents	
Logistics and Supply Chain Management	40%
Manufacturing	22%
Healthcare	12%
Other Services	26%
Respondents' Work Experience	
More than 10 years	84%
6 to 10 years	8%
Less than 6 years	8%

From the sample used, the average supply chain-related work experience of the managers was greater than 10 years. Most of the companies (84%) have been in business for over 10 years, with 8% of the companies having been in business for either 6-10 years or 1-5 years each. From the sample used, over 82% of respondents reported that their firms employ more than 100 employees. Firms with 1-10 employees represented 6% of the sample, and firms with 11-100 employees represented 12% of the sample. In terms of revenue, over 88% of the firms reported more than $100 million in annual revenue, and 10% reported annual revenue of $10-$100 million. The remaining firms (2%) reported annual revenue of less than $10 million. In terms of the industry sectors that the companies operate in, 40% of the companies were from the Logistics/Supply Chain Management Services sector, 22% were from Manufacturing, 12% were from the Healthcare sector, and the remaining 26% were from other sectors.

Digital Technologies Used

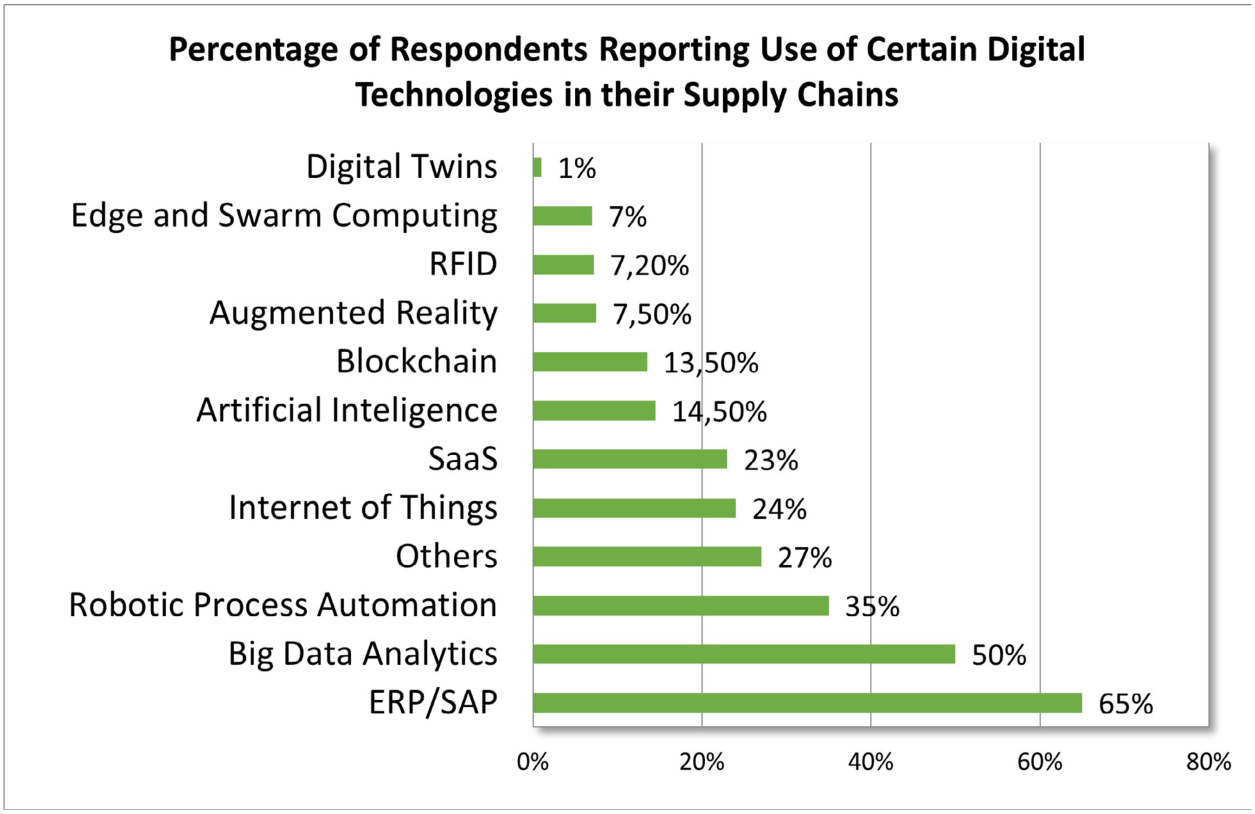

Figure 1. Percentage of Respondents Reporting Use of Different Types of Digital Technology in Their Supply Chains

As it is seen from Figure 1, the most used digital technology was ERP/SAP, with 65% of respondents reporting its use. This is expected as ERP has been around for a while, particularly when compared to other digital technologies. It is not surprising that many of the respondents use this technology that has become very popular in supply chains around the globe. Big data analytics was the next most used digital technology. Fifty percent of respondents indicated that they used some form of big data analytics in their supply chains. This is also not particularly surprising in today's world, where data has become a highly valuable resource for corporations. The next most reported digital technology was robotic process automation (RPA). The use of automated machines to replace manual labor has been increasing for many years now, which is understandable given the ability of well-programmed machinery to outperform human laborers in terms of speed, precision, and efficiency. About 35% of survey respondents reported using some form of robotic process automation in their supply chains.

The Internet of Things (IoT) and Software-as-a-Service (SaaS) followed Robotic Process Automation (RPA) technologies with reported use by 24% and 23% of respondents respectively. The IoT and SaaS are useful services that require less initial cost than other technologies such as robust Artificial Intelligence systems. For this reason, it makes sense that some of our survey respondents have adopted these technologies in their supply chains. While having a higher upfront cost, RPA has a proven track record of increasing efficiency and reducing labor costs in the long run (Ruiz et al., 2022). Blockchain and artificial intelligence (AI) were each used by close to 15% of survey respondents. Given that these technologies are relatively new compared to RPA and ERP, we did not expect to see a high percentages of users reported. Implementing these technologies may be difficult for firms, as the technology is very unfamiliar and potentially expensive. Also, managers may be averse to such large-scale changes in their supply chains despite the potential benefits.

The remaining two digital technologies, Augmented Reality and Edge Computing, were only reported by less than 10% of companies. This can be attributed to a range of factors. Perhaps these technologies are too novel and unknown for most supply chain managers to be interested in seriously adopting them (Cimino et al., 2019).These technologies are in a similar position as blockchain and AI, with the exception that they are even more unfamiliar to the average supply chain manager. RFDI was surprising with around 7% reported use; however, RFDI use has been declining and we did not include retailers in our study. Next, we will address the measurement of the key factors of our research model.

Model

We ran a classic Structural Equation Model with 6 latent variables. One of the variables is an explanatory variable (Digital Technology Capacity prior to COVID-19 pandemic), and remaining five are response variables. Each latent variable was estimated by two to four questions. For instance, the level of digital technology usage cannot be estimated easily via a single question, but a better estimate can be achieved by using three questions. In Figure 2, we conceptualize the model for analysis.

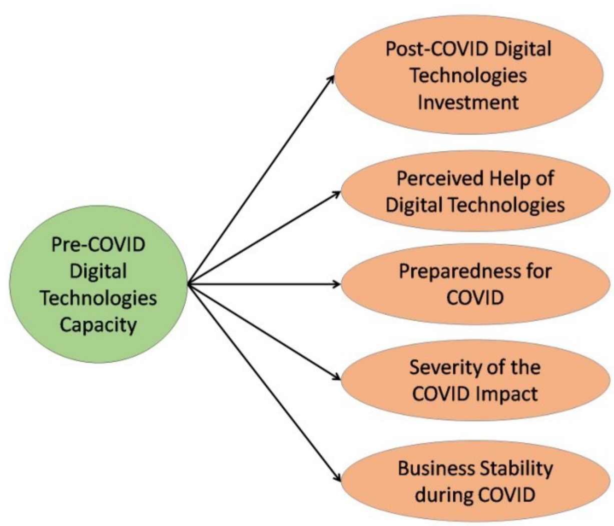

Figure 2. Research Model

Measures

In addition to basic demographic data, the survey was designed to collect data relating to (a) the firms' supply chain performance throughout COVID-19, (b) the use (or lack of use) of digital technologies in the firms' supply chain, and (c) the relationship between the two factors. In many cases, respondents were able to indicate the degree to which they agreed with a given statement by using a sliding scale (1-5) allowing more nuanced data to be gathered.

As indicated previously, the research model includes six latent variables. The questionnaire was designed as an instrument to collect data for measuring those variables. Consistent with classic business research methods (Schindler, 2021), we used initial-scale items from previously validated measures and adapted them in necessary cases. For the latent variables, all constructs were operationalized using a 5-point Likert scale. For each, multiple items with scales ranging from Strongly Disagree (1) to Strongly Agree (5) were used. For a list of constructs please see the following Table 2.

Table 2. The List of Constructs

CONSTRUCTS
The digital technology capacity before COVID-19 (DT):
• The extent of digital technologies use prior to the COVID-19 outbreak (DT1)
• The dollar value placed by firms on adopting new technologies before the outbreak (DT2)
• The assessed degree (by the researchers) of technology implementation based on the type and number of digital technologies used by the companies (DT3)
Perceived help of Digital Technology Capacity during COVID-19 Pandemic (B) in:
• Mitigation (B1)
• Adaptation (B2)
• Profitability (B3)
The severity of the COVID-19 Impact on Supply Chain Performance (SE):
• Timely delivery of products and services (SE1)
• Relationships with supply chain partners (SE2)
• Relationships with supply chain customers (SE3)
The companies' preparedness for a crisis like COVID-19 pandemic (PR) by:
• Mindset in investing in the development of internal risk mitigation strategies (PR1)
• Mindset in investing money to improve business processes even if nothing is broken (PR2)
• Valuing adaptation (PR3)
• Able to handle sudden changes in the supply chain that are caused by disruption (PR4)
The stability of the companies' supply chain during COVID-19 (ST):
• The stability of the overall supply chain operations before versus during the COVID-19 outbreak (ST1)
• The costs of operations during the outbreak (ST2)
• The quality of products and services during the outbreak (ST3)
The technology investment after and during COVID-19 pandemic
• The dollar amount of new investment in digital technologies after and during COVID-19 (FT1)
• Percent budget allocation to new investments in technology after and during COVID-19 (FT2)

Data Reliability

We checked our model for general validity scores. Results can be seen in Table 3. Minimum factor loading across the model is 0.741 which is acceptable. Cronbach's alpha does not drop below 0.762 for any of the latent variables. Composite validity scores are high with minimum at 0.785. Average variance extracted scores dipped slightly below with minimum at 0.683 but still adequate for the study.

Table 3. Construct Validity Results

Instrument Reliability	Indicator	Factor Loading	Cronbach's alpha	CR	AVE
Pre-COVID-19 Digital Technologies Capacity (DT)					
	DT1	0.799	0.845	0.805	0.683
	DT2	0.894			
	DT3	0.798			
Post-COVID-19 Digital Technologies Investment (FT)					
	FT1	0.863	0.762	0.785	0.755
	FT2	0.873			
Perceived Help of Digital Technologies in Supply Chain Performance (B)					
	B1	0.814	0.894	0.839	0.749
	B2	0.814			
	B3	0.764			
Preparedness for a pandemic like COVID-19 (PR)					
	PR1	0.886	0.840	0.821	0.723
	PR2	0.805			
	PR3	0.916			
	PR4	0.752			
Severity of the COVID-19 Impact on Supply Chain Performance (SE)					
	SE1	0.983	0.768	0.804	0.828
	SE2	0.851			
	SE3	0.813			
	SE4	0.741			
Business Stability during COVID-19 (ST)					
	ST1	0.841	0.903	0.985	0.699
	ST2	0.742			
	ST3	0.917			

HYPOTHESES

H1: Pre-COVID-19 Digital Technologies Capacity (DT) had a positive effect (increase) on perceived help in supply chain performance (B) during COVID-19.

Digital technologies are considered to be beneficial to a firm's performance which would likely be translated into supply chain performance during COVID-19. This is because the use of digital technologies can offer firms a wide range of benefits like the automated identification and elimination of disruptions and inefficiencies. If firms do not believe that these technologies produce benefits, they would be more hesitant in investing them.

H2: Digital Technologies Capacity (DT) had a negative effect (reduced) on severity of the supply chain disturbance (SE) during COVID-19.

The more digital technologies a firm employed, the more reduced the degree of severity of their supply chain disruption was. Digital technologies provided firms with increased transparency and robustness such that they were able to quickly identify and address supply chain issues in an efficient manner. Lack of digital technologies made this more difficult, which made it more likely that there was a greater severity of their supply chain disturbance.

H3: Digital Technologies (DT) had a positive effect (increased) on supply chain stability (ST) during COVID-19.

Firms that employed digital technologies to a greater extent experienced more supply chain stability during COVID-19. Again, this is because digital technologies help managers efficiently, and often automatically, protect against supply chain disruptions by providing transparency and robustness. This offered firms more stability in the face of the pandemic.

H4: Digital Technologies (DT) had a positive effect (increased) on preparedness (PR) for COVID-19.

Digital technologies helped firms be more prepared for an unexpected, large-scale disruption like COVID-19. Since digital technologies helped firms quickly identify issues in their supply chain, having adopted them prior to the pandemic served an important function in helping firms be ready to rapidly find and address issues. Without digital technologies, firms were far less prepared for a supply chain disruption because they did not have the same methods in place to help detect and resolve issues.

H5: Previous investment in digital technology (DT) has a positive effect (increase) on the adoption of digital technologies post-COVID-19(During and After COVID-19) (FT).

If firms possessed some level of digital technologies in their supply chain throughout COVID-19 and witnessed how they mitigated the negative effects of disruption, they will be more likely to adopt even more digital technologies in the future, as they will have directly experienced the benefits of investment in digital technologies prior to a major disruption.

RESULTS

Table 4 provides the numerical results of the data collection.

Table 4. Model Results

Model						
Test Statistics	1759.168					
Number of Observations	104					
P-Value (Chi-square)	0.000					
		Estimate	**Std. Err**	**z-value**	**P(>|z|)**	**Null Hypothesis**
H1 (Perceived Help)	B~DT	0.878	0.362	2.204	0.028	Supported
H2 (Severity)	SE~DT	-0.967	0.372	-1.844	0.065	Supported
H3 (Stability)	ST~DT	0.628	0.399	0.863	0.388	Not Supported
H4 (Preparedness)	PR~DT	0.862	0.544	2.533	0.011	Supported
H5 (Future Tech Investment)	FT~DT	1.583	0.457	2.874	0.004	Supported

From the results, it is apparent that digital technology did not help as much in the area of stability compared to severity of the pandemic related to COVID-19 (hypothesis 3). Stability in prices, costs, sales, and outputs have been tremendously difficult to achieve during COVID-19. However, technology helped reduce severity, especially for firms with less competition (hypothesis 1). Companies who had invested in technology feel they were more prepared for the disruption compared to their peers, and they consider their technology investment to have paid off (perceived help). Because of this, companies who invested in technology continue to invest in technology in the future (hypothesis 5).

The data suggests that Digital technology investment prior to COVID-19 reduced the severity of disruption (SE) experienced by firms during COVID-19. Based on the reports of the managers surveyed, it appears that digital technologies did, in fact, help mitigate the severity of supply chain disruption experienced as a result of COVID-19. Moreover, we can also see that digital technologies increased firms' preparedness for a supply chain disruption (PR). This means that not only did digital technologies assist in mitigating the severity of the disruption once it arrived; it also helped firms be more prepared in general to deal with the disruption from the start. Firms that had invested more in digital technologies felt more confident in their preparedness as they value the positive impact of their digital technologies.

Our results also show a positive cycle with regards to the adoption of digital technologies. It appears that earlier adoption of digital technologies resulted with a firm's intention to adopt more digital technologies in the future. That is, prior to the pandemic, firms that had adopted digital technologies to a higher extent were far more likely to implement even more digital technologies into their supply chains after the peak of the pandemic disruption. We can likely attribute this to the firm's witnessing the benefits of their investment, which made them eager to increase the investment into digital technologies even more. The data was not able to prove a significant relation between the implementation of digital technologies (DT) and the stability of the firm during COVID-19 (ST).

CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

From our study, we can conclude that during the COVID-19 pandemic, firms clearly saw and recognized the benefits of having implemented digital technologies in their supply chain. This is important to note since it emphasizes that managers attribute positive disruption-mitigation effects to the digital technologies they implemented.

This study includes companies in the Midwest United States. Therefore, it is an idea to test to see if these conclusions can be extended to other areas in the world; however, we do not have any reason to believe the conclusions would not be applicable to other geographic areas since the companies we included in our study are global companies. However, it would be beneficial to extend the study into more regions and countries to see if the findings would be repeatable. The study was also focused on larger companies which was not the implicit intention of the design. Since the respondents were typically from larger firms, we do not know if the results are applicable for smaller sized companies. Studying small medium enterprises might be another extension of the study. With the arrival of Covid-19 pandemic, more and more digitalization is not only for born-digital companies or for large organizations (Salume et al., 2022) but for any organization and not only to go through this difficult period but to stay competitive in this challenging environment.

The findings of the study suggest a few avenues for future research. First, we would like to investigate what other factors played a role in mitigating the severity of the supply chain disruptions caused by COVID-19. Was there any factor other than digital technologies that played an important part? If so, what? Additionally, we might consider the different effects of each digital technology that the companies chose to use. A recent paper identified the Internet of Things (IoT) as the most commonly used new technology for supply chain firms in Australia (Hopkins, 2021); therefore, we wonder if the IoT is more effective than similar technologies in maintaining stability or decreasing severity. Exploring the extent to which these different technologies play a role in the supply chain could help managers understand which technologies are the most helpful and therefore most worthy of investment dollars. Lastly, we might consider a deep dive into *how* these different technologies made the supply chain disruption experienced by firms more bearable. What exactly was it about the digital technologies that mitigated the damage the firms experienced? Are there other ways of gaining this benefit? Future research on the aforementioned areas is important and we believe that our data has provided a promising first step moving forward. A recent study (Hopkins, 2021) found that whereas particular digital technologies expected significant impact on supply chains, investment estimates for those technologies were surprisingly low. A future study can be performed to find out if the supply chains investing the right amount on the right digital technology. Since competition is no longer among the companies but among the supply chains it is increasingly important to adopt innovative, customer-focused digital technologies that enable supply chain network participants to streamline existing processes across the entire customer experience. That is why compatibility of the digital technologies adopted is another rising research area among the academicians and practicing managers.

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