Capabilities for enhancing supply chain resilience and responsiveness in the COVID-19 pandemic: exploring the role of improvisation, anticipation, and data analytics capabilities

Capabilities for Enhancing Supply Chain Resilience and Responsiveness in the COVID-19 Pandemic: Exploring the Role of Improvisation, Anticipation, and Data Analytics Capabilities

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Abstract

Purpose

This study aims to identify critical capabilities to address unforeseen and novel disruptions such as those instigated by COVID-19 and explore their role as essential enablers of supply chain resilience and responsiveness, leading to improved performance.

Design/methodology/approach

The structural equation modeling technique was employed for analyzing the proposed associations using survey data from 206 manufacturers operating during the COVID-19 pandemic in a developing country, Pakistan.

Findings

Key findings show how improvisation and anticipation act distinctly yet jointly to facilitate supply chain resilience and responsiveness during the COVID-19 pandemic. Also, data analytics capability positively affects anticipation and improvisation, which mediate the effect of data analytics on supply chain resilience and responsiveness.

Research Implications

The findings contribute to the theoretical and empirical understanding of the existing literature, suggesting that a combination of improvisation, anticipation, and data analytics capabilities is

highly imperative for enhancing supply chain resilience and responsiveness in novel and unexpected disruptions.

Originality

This is the first study to examine the impact of data analytics on improvisation and anticipation and the latter as complementary capabilities to enhance supply chain resilience and responsiveness. The empirical investigation explores the interplay among data analytics, improvisation, and anticipation capabilities for enhancing supply chain resilience, responsiveness, and performance during the unforeseen and novel disruptions such as brought to bear by the COVID-19 pandemic.

Key Words

Supply chain, resilience, responsiveness, data analytics, improvisation, dynamic capabilities, developing country

1. Introduction

The recent disruptions instigated by the COVID-19 pandemic happen to be of unprecedented magnitude affecting numerous global supply chains testing their resilience (Sarkis, 2020; Van Hoek, 2020). Along with the pandemic's propagation and unpredictable scaling of disruption, firms experienced simultaneous disruptions in supply, logistics, and demand infrastructure (Ivanov, 2020; Mishra *et al.*, 2021; Schleper *et al.*, 2021). Disruptions sparked by COVID-19 resulted in the closure of numerous factories and loss of critical suppliers and led to demand disruptions resulting in shortages of various products, e.g., personal hygiene products, food and beverages, and several pharmaceutical supplies (Essuman *et al.*, 2020; Harbour, 2020; Ivanov, 2020). During the pandemic, practitioners found their existing plans and playbook inadequate to handle the disruptions caused by the pandemic (Van Hoek, 2020; Schleper *et al.*, 2021). As a result, many improvised responses were seen across various functions and sectors, e.g., repurposing the production process to deliver high-demand products (Betti and Heinzmann, 2020).

The existing research on supply chain (SC) resilience and responsiveness offer limited insight into the disruptions caused by the COVID-19 pandemic (Chowdhury *et al.*, 2021; Dani *et al.*, 2021), where exception became the rule. Hence, more research is required to extend the current understanding regarding the maintenance of SC resilience and responsiveness in the context of novel disruptions triggered by the pandemic (Lee *et al.*, 2020; Schleper *et al.*, 2021). Ambulkar *et al.* (2015) argued that highly disruptive and volatile contexts might require a more creative approach to responding to disruptions. Given the novelty and magnitude of disruptions, there is a need to explore the role of intuitive and extemporized decision-making in responding to sudden, unexpected, and unpredictable changes and upheaval. Improvisation has typically been viewed as an exception, the need of which arises when routines fail. Therefore, firms have found it necessary

to promote their capacity to respond to the unexpected (Weick, 1993) as well as cultivate resilience (Suarez & Montes, 2020).

While supply chain (SC) managers do improvise as a response to surprise events, improvisation is rarely explored in the supply chain management literature (Richey *et al.*, 2022). The current literature on SC resilience and responsiveness has mainly focused on a planned approach to dealing with unexpected situations. While the importance of planning and preparing is undeniable, no matter how hard they try, firms cannot plan and prepare for every potential risk and contingency and have to adapt on an ad-hoc basis (Kaplan *et al.*, 2020; Suarez and Montes, 2020). Thus, given the novelty and magnitude of disruptions firms are now faced with, there is a need to explore the importance of intuitive and ad hoc decision-making to respond and adapt to unexpected and unpredictable change and disruption.

This study grounds on the dynamic capabilities view (DCV) to introduce improvisation, which refers to the ability to spontaneously and intuitively respond and reconfigure resources for addressing unpredictable, sudden, and novel environmental conditions as an alternative to addressing highly turbulent environments. Earlier studies have used DCV to explore the capabilities required to prepare for unavoidable risks and respond to and recover from unexpected disruptions (Golgeci and Ponomarov, 2013; Brusset and Teller, 2017; Chowdhury and Quaddus, 2017; Yu *et al.*, 2019). DCV stresses the need for firms to have the capability to adapt, integrate and reconfigure their resources and capabilities to address dynamically changing and uncertain environments (Teece, 2007). Dynamic capabilities have been deemed critical in moderately turbulent or roughly predictable environments (Eisenhardt and Martin, 2000). However, as dynamic capabilities can only be implemented after careful planning, they may not suffice in cases of unforeseen and highly unpredictable events (Winter, 2003; Pavlou and El Sawy, 2010).

Therefore, in environments where change is rapid and unpredictable patterns prevail, firms must have the capabilities that are less preparation-intensive and can deal with prompt, unforeseen, and novel events (Pavlou & El Sawy, 2010). Thus, we propose the notion of anticipation (dynamic) and improvisation capabilities that operate distinctly but jointly to facilitate SC resilience and responsiveness under urgent and unexpected change and disruptions. Consequently, this study seeks to underpin the associations between anticipation, improvisation, SC resilience, SC responsiveness, and performance by investigating the following research question:

(1) How do anticipation and improvisation contribute towards enhancing SC resilience and responsiveness?

Recent research has emphasized the role of data-driven approaches for managing SC disruption as managers seek decision making support to identify risks, recognize and monitor disruptions in real-time, and take appropriate actions for response and recovery (Ivanov *et al.*, 2019; Ivanov and Dolgui, 2020; Bag *et al.*, 2021). A particular concern in this regard is how digitalization and data analytics can aid in predicting the future and identifying real-time events (Wang *et al.*, 2016; Wamba *et al.*, 2017). Data analytics capability improves a firm's information processing capability by processing, organizing, visualizing, and analyzing the data to derive valuable insights (Srinivasan and Swink, 2018; Zhu *et al.*, 2018; Dubey *et al.*, 2021). The ability to derive reliable information regarding environmental conditions allows mitigation of uncertainty and anticipation of change and disruptions enabling responsiveness (Reichhart and Holweg, 2007; Oliveira and Handfield, 2019) and resilience (Dennehy *et al.*, 2021; Dubey *et al.*, 2021). Moreover, real-time information visibility created by data analytics allows managers to instantaneously observe events in the internal and external SC environment, empowering decision-makers to interpret information and make rapid decisions in response to change events and

disruptions (Oliveira and Handfield, 2019; Kozyrkov, 2020). Thus, research in data-driven decision-making, including proactive planning activities and reactive controls and recovery plans, is becoming increasingly important (Ivanov *et al.*, 2019; Ivanov and Dolgui, 2020).

However., despite the growing importance of data analytics, its role in SC operations decision making is less understood (Kache and Seuring, 2017; Srinivasan and Swink, 2018; Dubey *et al.*, 2021), and likewise, less attention has been given to the process through which firms employ data analytics for managing SC risks and disruption (Fan *et al.*, 2016; Dennehy *et al.*, 2021). Ivanov et al. (2019) suggested extensive utilization of digital technologies, including data analytics, to form SC risk analytics decision support system for developing resilient SCs. Srinivasan and Swink (2018) argued that data analytics capability produces insights on what needs to be changed to content with environmental uncertainty by processing big data. Thus, building on this argument, we posit that data analytics capability provides the insights to develop and exercise anticipation and improvisation.

Building on information processing theory (IPT), we propose that data analytics capability aids the development and implementation of anticipation and improvisation capabilities by enhancing the information processing capability, facilitating SC responsiveness and resilience. Existing studies have utilized IPT to explore and better understand how firms can deal with uncertainty, manage risks, and enhance resilience (Munir *et al.*, 2020; El Baz and Ruel, 2021). IPT seeks to explain how firms can organize and utilize information effectively, particularly when confronted with high levels of uncertainty (Galbraith, 1973). The information processing capabilities play an essential role in mitigating risk and setting up measures to address disruptions in supply chains (Fan et al., 2016) by allowing firms to rapidly acquire reliable data and timely process and analyze it. With increased information processing capacity, uncertainty can be

reduced, especially when the prevailing conditions are volatile and complicated (Oliveira and Handfield, 2019; Munir *et al.*, 2020). Thus, data analytics capability is posited as an antecedent of anticipation and improvisation capabilities that improve supply chain responsiveness and resilience. To be more specific, the following additional research question is addressed:

(2) How does data analytics capability enhance anticipation and improvisation and, through them, promote SC resilience and responsiveness?

We respond to these research questions by developing and testing a research model that identifies the critical capabilities firms should possess to improve SC resilience and responsiveness to contend with the severe impacts and outperform in the unpredictable and competitive environment brought to bear by the COVID-19 pandemic. The DCV and IPT, serving as theoretical lenses, inform the proposed model's development and facilitate the discussion. A survey-based data collected from 206 manufacturing firms in Pakistan was used to test the hypotheses. Overall, the study examines SC responsiveness and resilience's antecedents and performance consequences given a highly turbulent context. It is argued that existing enablers of responsiveness and resilience in the literature focus on a planned and prepared (anticipation) approach towards responding to unexpected disruptions, ignoring the role of spontaneous decision making. We suggest that both anticipation and improvisation capabilities are imperative in novel and unexpected disruptions. Furthermore, the role of data analytics as an information processing capability facilitating resilience and responsiveness is highlighted.

The current study extends the existing literature in the following ways. Firstly, the study adds improvisation as a crucial factor to the literature regarding SC resilience and responsiveness enablers. In addition, this study establishes an empirical distinction between dynamic and improvisation capabilities, suggesting that a combination of anticipation and improvisation

capabilities is highly imperative for enhancing SC resilience and responsiveness in novel and unexpected disruptions. Secondly, this study contributes to the literature on the nexus of data analytics and SC resilience and responsiveness. The study proposes that by enhancing information processing capacity, data analytics capability provides the foundation required to develop and implement anticipation and improvisation capability to facilitate SC resilience and responsiveness. Finally, by conducting an empirical quantitative study in the context of COVID-19 (Chowdhury *et al.*, 2021), this study attempt to provide valuable insights for practitioners and academics on how to cope with the disruptions triggered by the pandemic by enhancing SC resilience and responsiveness (Lee *et al.*, 2020; Van Hoek, 2020).

The rest of the paper is structured as follows: the theoretical background and research framework are presented in the next section, followed by related hypotheses. Then the paper discusses the research methodology, data collection process, and statistical analysis used for hypothesis testing. Finally, a discussion of the findings of the study leads to the implications, limitations and future research directions, and the conclusion.

2. Theoretical Underpinning and Research Framework

2.1. Dynamic Capabilities View

DCV suggests that in a fast-changing dynamic environment, possession of dynamic capabilities enables rapid reconfiguration allowing firms to stay ahead of rivals through superior performance (Eisenhardt and Martin, 2000; Teece, 2007). Dynamic capabilities have been advocated to be of critical importance for addressing moderately turbulent or roughly predictable environments (Eisenhardt and Martin, 2000). However, despite the generally agreed positive role, it has been argued that dynamic capabilities may not be a universal solution to managing change (Winter, 2003). Dynamic capabilities are deemed insufficient and/or inappropriate to address highly volatile

stormy environments attributed with highly unexpected and sudden changes as they require advance planning (Winter, 2003; Pavlou and El Sawy, 2010). Thus, it has been suggested that in environments with rapid change and unpredictable patterns, firms need capabilities that require less preparation and can cope with unforeseen, prompt, and novel events, i.e., improvisation (Pavlou and El Sawy, 2010). Using DCV, Pavlou and El Sawy (2010) distinguished between planned dynamic capabilities and unplanned improvisational capabilities. They argued that improvisational capabilities are based on spontaneous decision-making while dynamic capabilities are based on judicious planning using stable and systemic routines. Building on the DCV, we propose anticipation capabilities as dynamic capabilities to prepare for, manage and adapt to changing environments and introduce improvisational capabilities as an alternative means to respond to unexpected and sudden changes in a highly volatile environment.

In the context of SC, many scholars have deployed the dynamic capabilities concept to investigate how firms and SC partners coordinate and modify their resources and capabilities in response to market shifts and SC risks (Chowdhury *et al.*, 2019; Yu *et al.*, 2019; Aslam *et al.*, 2020; El Baz and Ruel, 2021). Thus, DCV constitutes a relevant framework for exploring how firms realign their processes and resources following abrupt changes and disruption threats (Chowdhury and Quaddus, 2017; Fan and Stevenson, 2018; El Baz and Ruel, 2021). Existing literature has shown that dynamic capabilities are necessary to respond to disruptions quickly and achieve resilience (Gunessee *et al.*, 2018; Aslam *et al.*, 2020). However, the role of improvisation as a complementary means to address highly unexpected and dynamic contexts has been largely ignored (Richey *et al.*, 2022). By highlighting improvisation as a spontaneous capability that contributes to SC resilience and responsiveness, this study contributes to the enrichment of theory in the domain of SC resilience and responsiveness. Building on the DCV, we propose anticipation

capabilities as dynamic capabilities to prepare for, manage and adapt to changing environments and introduce improvisational capabilities as an alternative means to respond to unexpected and sudden changes in a highly volatile environment.

2.2.Anticipation and Improvisation Capability

Generally, firms use scripted routines and simple rules to respond to highly changeable environments (Suarez and Montes, 2020). This approach is useful when the situation is relatively predictable and may help speed up processes and decision-making in less predictable contexts. However, unfamiliar and complex contexts require spontaneous and out-of-the-box solutions that depart sharply from standard approaches (Kaplan *et al.*, 2020; Suarez and Montes, 2020). Dynamic capabilities are the routines through which firms integrate and reconfigure resources and capabilities to better match and respond to changing environments (Eisenhardt and Martin, 2000). They are best suited for contexts with relatively predictable change patterns, but they may not be sufficient or appropriate to address unforeseeable and unexpected change events as they require prior planning (Winter, 2003). Therefore, firms need alternative capabilities requiring less planning to address unpredictable, rapid, and novel events (Pavlou and El Sawy, 2010; Winter, 2003). Thus, we propose anticipation capabilities as dynamic capabilities to prepare for, manage and adapt to changing environments and introduce improvisational capabilities as an alternative means to respond to unexpected and sudden changes in a highly volatile environment. Firms that become more adept at anticipation and improvisation will be more resilient and responsive and better able to cope with highly uncertain and novel change conditions.

Anticipation denotes the ability to sense changes and critical developments in internal and external firm environments and SC networks (Duchek, 2019). This does not imply identifying and preventing every failure or crisis; instead, it infers that firms can see the unexpected change faster

and be better prepared to react to it immediately. Duchek (2019) suggested that anticipation comprises the ability to observe and sense internal and external environments, detect critical advances and potential threats, and prepare for the unexpected as far as possible. Drawing on DCV, we propose that anticipation capability, as a dynamic capability, includes sensing and observing the environment, identifying changes, potential threats, and opportunities, preparing for and responding to unexpected and sudden changes and disruptions by reconfiguring existing resources and capabilities when needed. In SC context, it can be regarded as the SC's alertness, preparedness, and reconfiguration to unexpected changes and disruptions.

Researchers contend that firms must recognize the early or weak signals of disruptions and crises and quickly respond to them, avoiding escalation (Burnard and Bhamra, 2011; Duchek, 2019). The ability to sense and identify changes in the SC network enhances SC visibility, i.e., firms can see flows of goods and information across SCs (Christopher and Peck, 2004), identify the changes in SC processes and their complex interconnection with firm capabilities (Sambamurthy *et al.*, 2003). Thus, observation and identification capabilities enhance the firm's alertness to developments and changes in the environment and enable quick reaction. Being prepared denotes that the firm can deal with uncertain and unexpected adversity and exploit unexpected and emergent opportunities (Gligor *et al.*, 2013; Duchek, 2019). Alert and prepared SCs can better respond to the sudden changes in the environment by reconfiguring SC resources and processes (Bhamra *et al.*, 2011). However, formal procedures and plans alone do not prepare firms for a great variety of unexpected events. Often, such events do not correspond with anticipated and planned assumptions and may require creative and intuitive decision-making (Bhamra *et al.*, 2011; Kaplan *et al.*, 2020).

Improvisation is an adaptive response to unanticipated and unexpected events beyond the boundaries of what a firm has anticipated. Initially grounded in the field of arts (e.g., jazz music and theater), existing research on improvisation expands into several management fields and contexts, i.e., new product development (Moorman and Miner, 1998) product innovation (Vera and Crossan, 2005), technology and change (Orlikowski, 1996), and crises (Weick, 1993). Traditionally the concept of improvisation has been associated with the handling of exceptions. It is characterized by nearness in time between planning action and its execution and implies deviation from existing knowledge or practice (Moorman and Miner, 1998). It occurs when firms are faced with novel situations for which no procedures exist, and there is a lack of time needed for formal planning, current circumstances do not allow the deployment of known procedures and capabilities, and the planning and execution happen concurrently (Moorman and Miner, 1998). Although improvisation has a negative connotation as it is sometimes viewed as a lack of or failure of formal planning (Moorman and Miner, 1998), its positive role has also been highlighted in the literature (Weick, 1993). Thus, improvisation is not innately good or bad (Vera and Crossan, 2005), and the absence of planning does not necessarily lead to inferior results.

Interestingly improvisation has not been explored frequently in operations and supply chain management literature (Richey *et al.*, 2022). Few recent qualitative studies argued the role of improvisation in enhancing resilience (Bradaschia and Pereira, 2015) and responsiveness (Richey *et al.*, 2022). They conceptualized improvisation as a means of finding other ways of getting things done (Morrison, 2015) by recombining available resources for a certain task requiring creativity and the ability to adapt using existing knowledge in different situations (Bradaschia and Pereira, 2015). Improvisation has also been described as actions taken by individuals lacking the necessary information to make an informed decision (Kanter, 2001). Increasing complexity and uncertainties

in supply chains require the ability to rapidly respond to emerging challenges and problem situations with quick responses. Thus, improvising serves as a means of addressing such situations by generating new ideas for managing surprises that formal plans and previously developed activities are not able to address (Miner *et al.*, 2001; Pavlou and El Sawy, 2010; Richey *et al.*, 2022).

2.3. Information Processing View

IPT characterizes firms as open social systems seeking to execute business practices, tasks, and strategies by mitigating uncertainty in the process of decision-making (Galbraith, 1973). To address high uncertainty, firms need to organize and utilize information effectively and competently (Oliveira and Handfield, 2019; Wong *et al.*, 2020). According to the IPT, a firm's information processing capabilities should match its information processing needs (Galbraith, 1973). Thus, the more a firm develops its ability to process information, the better equipped it is to cope with uncertainty (Munir *et al.*, 2020; El Baz and Ruel, 2021). SC disruptions pose significant uncertainties and equivocality due to the amount of information to be gathered, interpreted, and treated (El Baz and Ruel, 2021). Therefore, information processing becomes indispensable for developing practices to manage risks by improving resilience and responsiveness.

Information processing capability refers to a firm's ability to gather, synthesize and interpret information to produce meaningful decision-making insights (Galbraith, 1973). The use of information technology improves a firm's access to information and reduces uncertainty. In today's profoundly networked environment, the dependence on interconnected technologies generating a massive amount of data across SCs offers an opportunity for the firms to exploit their information processing capability and compete with it (Zhu *et al.*, 2018). However, firms need to

have advanced information processing capabilities to gain valuable insights that enable better decision-making to manage such data. Therefore, a firm's data analytics capability is crucial for creating knowledge and improving managerial decision-making by enhancing information processing capability (Arunachalam *et al.*, 2018; Zhu *et al.*, 2018).

2.4.Data Analytics Capability

Dynamic and uncertain environments create greater risks for firms and SCs. For alleviating potential risks and disruptions, and increasing responsiveness, firms are seeking to increase the visibility and transparency in their SCs (Zhu *et al.*, 2018; Dubey *et al.*, 2021). Subsequently, firms progressively leverage modern and existing technologies and analytics capabilities to track end-to-end SC operations carefully and make informed decisions about their SC practices (Arunachalam *et al.*, 2018; Zhu *et al.*, 2018). Data analytics capabilities are particularly beneficial for firms in terms of fostering quality SC decision-making and mitigating the impact of disruptions and crises (Davenport, 2006; Hsinchun *et al.*, 2012; Nichols, 2013; Dennehy *et al.*, 2021; Sheng *et al.*, 2021). Data analytics capability refers to the set of tools, techniques, and methods that allow a firm to manage, organize, analyze, and visualize data to provide managers with valuable insights for effective and efficient business and SC operations decision-making (Srinivasan and Swink, 2018). Data analytics techniques can be classified into three types: descriptive, predictive, and prescriptive (Trkman *et al.*, 2010; Holsapple *et al.*, 2014; Souza, 2014; Wang *et al.*, 2016). Descriptive analytics derives information from significant amounts of data for answering the questions i.e., ‘what has happened?’ and ‘what is currently happening?’ with the aim of identifying problems and opportunities within existing functions and processes. It has allowed the firms like Procter and Gamble (McDonald, 2011) and Tesco (Clark, 2013) to experience considerable cost savings over the years (Chae *et al.*, 2014). Predictive analytics aims at predicting the future

accurately to answer the questions of what will happen in the future and why it may happen. Prescriptive analytics involves deriving decision recommendations given the predicted future and addresses the question of what should be happening? (Souza, 2014). Predictive and prescriptive analytics play a vital role in aiding firms to make effective strategic decisions (Wang *et al.*, 2016). Overall, data analytics enables firms to better anticipate looming challenges, analyze their environments and make data-driven quality decisions assisting them to cope with unpredictable events and extreme uncertainties (Trkman *et al.*, 2010; Souza, 2014; Wang *et al.*, 2016; Sheng *et al.*, 2021).

Generally, firms acquire data from their supply chain partners to gain insight regarding potential SC risks and their disrupting effects (Fan *et al.*, 2016; Dubey *et al.*, 2021). Dubey *et al.* (2018) argued that information processing capacity can be enhanced through SC collaboration. Similarly, Munir *et al.* (2020) noted that SC integration is an important way to improve information processing capacity. Thus, with relevant, reliable, and timely data from SC partners, firms can increase their ability to process information and extract useful insights (Brandon-Jones et al., 2014), allowing decision-makers to mitigate uncertainty and anticipate change, enabling improved responsiveness (Reichhart and Holweg, 2007; Oliveira and Handfield, 2019) and resilience (Sabahi and Parast, 2020; Dennehy *et al.*, 2021). The existing literature views data analytics as a critical aspect of a firm's information processing capability (Zhu *et al.*, 2018), suggesting that data analytics capability improves firms' information processing capability (Srinivasan and Swink, 2018; Oliveira and Handfield, 2019; Dubey *et al.*, 2021). Dubey *et al.* (2021) showed that data analytics enhances information processing capability and improves SC resilience and competitiveness under uncertainty scenarios. Furthermore, increased information processing capability enhances SC visibility, helping firms prepare, respond, and mitigate SC risks and

disruption (Munir *et al.*, 2020). Thus, data and information technology assist managers in identifying potential sources of disruption or risks, preparing for, adapting to, mitigating, and speedily recovering from SC disruption. Ivanov *et al.* (2019) suggested using extensive digital technologies to form SC risk analytics decision support system based on data analytics, optimization, and simulation. In this study, we propose that data analytics capability aids anticipation and improvisation capabilities by enhancing the information processing capacity of the firm.

2.5.Supply Chain Resilience and Responsiveness

Over the past years, SC resilience literature has grown substantially. It has gained academics' and practitioners' interest due to its potential influence on firm continuity and competitiveness (Christopher and Lee, 2004; Pettit *et al.*, 2019). Building resilience is essential as it enables SCs to anticipate, adapt, respond and promptly recover from unforeseeable events (Ponomarov and Holcomb, 2009; Ambulkar *et al.*, 2015). A resilient SC absorbs disruptions, restores function, and recovers from setbacks while maintaining a competitive edge (Wieland and Wallenburg, 2013; Chopra and Sodhi, 2014). The existing research suggests that firms need to develop certain capabilities aligned with SC partners, to manage expected and unexpected change and achieve resilience (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009; Pettit *et al.*, 2010). Various elements have been highlighted as antecedents/enablers of SC resilience, i.e., flexibility, collaboration, redundancy, agility, integration, disruption preparation, visibility, information sharing, and innovativeness (Christopher and Lee, 2004; Golgeci and Ponomarov, 2013; Brandon-Jones *et al.*, 2014; Tukamuhabwa *et al.*, 2015; Ali *et al.*, 2017; Birkie *et al.*, 2017; Brusset and Teller, 2017; Kwak *et al.*, 2018; Kamalahmadi *et al.*, 2021). However, the question of what

influences/enhances SC resilience remains sketchy among the researchers and practitioners from diversified perspectives (Kamalahmadi and Parast, 2016; Chowdhury and Quaddus, 2017).

Due to the current volatile and global business environment, SC responsiveness is deemed a vital competitive factor (Qrunfleh and Tarafdar, 2013). Responsiveness has been described as the strength to respond to changing customer preferences and marketplace requirements to bring about or sustain competitive advantage (Holweg, 2005). It enhances service reliability, adaptability, and fast responses. Also, it has been dealt simultaneously with risk management as argued in the literature that responsive SC reduces risks by removing potential bottlenecks and sources of SC disruption (Roh *et al.*, 2014). It is required to develop capabilities for mitigating environmental uncertainties (Mandal, 2015). Various factors have been highlighted in the existing literature that affects SC responsiveness, e.g., visibility, integration, flexibility, and agility. (Swafford *et al.*, 2006; Braunscheidel and Suresh, 2009; Williams *et al.*, 2013).

While both concepts are essential to survive and prosper in volatile and unpredictable environments, they differ primarily in that responsiveness concerns faster response to changes in customer and market requirements (Carvalho et al., 2012; Gilgor et al., 2019), whereas resilience focuses on coping with unexpected disturbances for sustaining competitiveness (Ambulkar et al., 2015; Ponomarov and Holcomb, 2009). Responsive supply chain networks that can rapidly respond to changed environmental conditions are considered one of the most powerful ways of achieving resilience (Christopher and Peck, 2004). Wieland and Wallenburg (2013) argued that a resilient supply chain possesses the ability to maintain high visibility and responsiveness to ensure customer value and superior performance. The existing literature has highlighted important resources and (dynamic) capabilities as antecedents of SC resilience and responsiveness, whereas the role of ad hoc problem solving or improvisation has mainly been ignored. This paper posits

that anticipation and improvisation capabilities facilitate SC resilience and responsiveness by providing alternate means to respond and adapt to unanticipated SC disruptions.

3. Hypothesis Development

3.1.Data Analytics Capability and Anticipation and Improvisation Capabilities

Adopting information technology and its effective management is an enabler of dynamic capabilities (Sher and Lee, 2004; Pavlou and El Sawy, 2010), as digitization of specific processes may help in strengthening the underlying routines or dimensions comprising the overall capabilities of a firm. In this respect leveraging information technology includes collecting, codifying, combining, and utilizing new knowledge for knowledge management. Data analytics capability improves firms' information processing capability (Srinivasan and Swink, 2018; Oliveira and Handfield, 2019; Dubey *et al.*, 2021) by aiding the collection, exchange, and analysis of real-time information to make informed decisions for supporting strategic and routine operations (Wamba *et al.*, 2017). Increased information processing capability improves SC visibility, helping firms prepare for, respond to, and mitigate SC risks and disruption (Munir *et al.*, 2020). Firms require improved visibility into external and internal SC environments to recognize changes and problems arising from dynamicity (Christopher and Peck, 2004). Enhanced visibility facilitates observing complex interactions between firm capabilities and changes in SC processes (Sambamurthy *et al.*, 2003). Data analytics capability facilitates firms in developing business continuity and contingency plans and deploying resources and capabilities required to effectively address changes in the external business environment and internal SC network (Dubey *et al.*, 2021). Hence, data analytic capability helps firms identify and prepare for changes and threats and respond to them by adapting rapidly and, when required, to speed up recovery. Thus, we hypothesize that:

H_1: Data Analytic Capability is positively related to anticipation capability

There is a consensus in the existing literature that information technology capabilities provide more value in turbulent environments (Pavlou and El Sawy, 2010; Oliveira and Handfield, 2019). A highly uncertain and volatile environment stresses the need for acquiring and processing information in real-time to reduce uncertainty. Recent research highlights the importance of using data analytics to collect, process, and analyze real-time information for decision-making (Srinivasan and Swink, 2018; Oliveira and Handfield, 2019). IPT contends that improved managerial analysis capability improves firm performance (Daft and Lengel, 1986). Building on IPT, Oliveira and Handfield (2019) proposed that a real-time SC relies on effective data integration, data visibility, data reporting, and information sharing analytic capabilities, i.e., data analytics capability. As improvisation heavily relies on real-time knowledge and information flows (Moorman and Miner, 1998; Vera and Crossan, 2005), using data analytics capability to aid real-time information flows by augmenting information processing capability becomes more pronounced for enhancing improvisational capabilities. Thus, advancing the following hypothesis:

H_2: Data Analytic Capability is positively related to improvisation capability

3.2. Anticipation, Improvisation, and SC Resilience and Responsiveness

Anticipation involves actively forecasting and predicting the future to be prepared and alert and identify potential changes and disruptions to mitigate them in foresight. However, no disruption ever fits the plan, and regardless of how mindful a firm is, it can never anticipate and prepare for every contingency, error, or consequence of its actions. Thus, improvising effectively and appropriately adds another dimension to a firm's ability to respond and adapt to unpredictable situations (Suarez and Montes, 2020). Improvisation provides for dealing with disruptions and

emergencies when firms experience them despite their anticipatory efforts. Thus, in addition to anticipation, this study identifies improvisation as an equally important element in the context of SC resilience and responsiveness and as an instrument for responding to unanticipated SC disruptions.

Anticipation capabilities broadly comprise preparing for, alerting, and responding to change and disruption by reconfiguring existing resources and capabilities. Preparedness refers to SC's capacity to withstand the impact of potential deviations (Tang, 2006). It is built by developing continuity and contingency plans and aligning SC partners' interests to mitigate and resist risks collaboratively at SC level (Carvalho *et al.*, 2012). Alertness denotes the SC's ability to detect changes in external business environments and internal SC networks (Li *et al.*, 2009). Prepared and alert SCs can quickly react to sudden environmental changes by reconfiguring SC resources and processes, reducing lead time, and increasing on-time delivery (Bhamra *et al.*, 2011), thus, enhancing responsiveness and resilience.

H_3: Anticipation capability is positively related to (a) SC resilience and (b) SC responsiveness.

Improvisation comprises spontaneous and intuitive responses to unexpected and unpredictable sudden changes and disruptions in the internal and external SC environment (Pavlou and El Sawy, 2010). Improvisation is valuable when sensemaking collapses due to environmental conditions (Weick, 1993) and may bring about positive outcomes. The central premise is that firms cannot plan and prepare for every potential risk and contingency no matter how much they try, and thus they have to adapt on an ad-hoc basis (Kaplan *et al.*, 2020; Suarez and Montes, 2020). As the environmental conditions of uncertainty, complexity, and high volatility are becoming the norm nowadays, firms need to possess the necessary capabilities to address situations where prior

planning is inadequate and cannot be exercised. Thus, they need to be complemented with improvisation capability to manage unexpected changes spontaneously. The recent Coronavirus outbreak reinforced this realization that planning and anticipation are necessary but insufficient to address sudden and unpredictable disruptions. The repurposing of Ford's and GM motor's production operations to produce ventilators, H&M's SC retooling to source and produce facemasks, and L'Oréal's operations and production rearrangement to produce hand sanitizers (Betti and Heinzmann, 2020) are among the few industrial examples of improvised actions and their positive outcomes. Hence, the following hypothesis is advanced:

> *H_4: Improvisation capability is positively related to (a) SC resilience and (b) SC responsiveness*

3.3. SC Responsiveness, Resilience, and Performance

SC agility and SC resilience concepts have been identified as critical characteristics of modern SCs. (Hohenstein *et al.*, 2015; Gligor *et al.*, 2019). The roles of both concepts have been well recognized for supporting firms and SCs in dealing with constant environmental change, uncertainty, and volatility in market and customer requirements (Christopher and Peck, 2004). Agility has also been considered essential for developing and enhancing SC resilience (Hohenstein *et al.*, 2015; Kamalahmadi and Parast, 2016). In the SC management context, the concept of agility is perceived to focus on responsiveness (Swafford *et al.*, 2006; Braunscheidel and Suresh, 2009; Mandal, 2015). Bernardes and Hanna (2009) argued that agility is subsumed within the concept of SC responsiveness. Responsive SC networks, having the ability to rapidly respond to changed environmental conditions, are considered one of the most dominant means of attaining resilience (Christopher and Peck, 2004). Wieland and Wallenburg (2013) argued that a resilient SC could

maintain high visibility and responsiveness, ensuring customer value and superior performance. Thus, the following hypothesis is proposed:

H_5: SC responsiveness is positively related to SC resilience

When assaulted by disruptions, SC resilience is arguably a critical approach for enabling rapid recovery and ensuring material supply continuity and delivery of products and services, reducing negative impacts of disruption and enhancing customer satisfaction and value (Chowdhury and Quaddus, 2017; Wong *et al.*, 2020). Without a continuous supply of materials, which is a prerequisite for production and customer service, SC operations cannot be maintained, and demand cannot be met. On the other hand, SC responsiveness is recognized to facilitate performance in rapidly changing environments (Qrunfleh and Tarafdar, 2013). Moreover, SC responsiveness ensures continuous delivery of products and services as per customer demand under SC disruptions (Braunscheidel and Suresh, 2009; Chopra and Sodhi, 2014), safeguarding their loyalty and value.

The Covid-19 pandemic has severely disrupted operations in SCs around the globe creating considerable distortions in supplies and bottlenecks in logistics channels (Van Hoek, 2020; Schleper *et al.*, 2021). Considering the highly volatile and uncertain circumstances marked by the pandemic, it is imperative to highlight how resilience and responsiveness may enhance performance by enabling rapid response to meet dynamically changing customer needs in such conditions (Lee *et al.*, 2020; Dani *et al.*, 2021). However, the associations between SC responsiveness, SC resilience and performance have not been empirically investigated under such turbulent conditions. Hence, we propose to examine the following hypotheses:

H_6: SC responsiveness positively impacts SC performance

H_7: SC resilience positively impacts SC performance

3.4. Mediation Effects

SC responsiveness is essential to improving performance, especially in rapidly changing environments (Qrunfleh and Tarafdar, 2013; Shekarian *et al.*, 2020). The development of agility and responsiveness has been frequently considered a critical component for managing disruption risk and enhancing resilience (Braunscheidel and Suresh, 2009; Chopra and Sodhi, 2014; Mandal, 2015; Shekarian *et al.*, 2020). However, in a highly volatile and uncertain context, i.e., the COVID-19 pandemic, SC resilience is the key to survival, laying the foundation for performance enhancement. Thus, it can be argued that in highly volatile and uncertain contexts, resilience is essential for SCs, even for leveraging responsiveness. The previous discussion in H_5 and H_6 elaborates on SC responsiveness as a precursor of SC resilience and performance. Building on this argumentation, we suggest a mediating role of SC resilience in the association between SC responsiveness and performance.

H_8: SC resilience mediates the relationship between SC responsiveness and SC performance.

The existing literature provides sufficient empirical evidence that enhancing SC visibility reduces the probability and impact of disruption (Christopher and Lee, 2004; Jüttner and Maklan, 2011) and improves SC resilience (Jüttner and Maklan, 2011; Brandon-Jones *et al.*, 2014). Furthermore, SC visibility and data analytics complement each other (Brandon-Jones *et al.*, 2014; Srinivasan and Swink, 2018), such that data analytics improves SC resilience and competitive advantage through increased visibility (Sabahi and Parast, 2020; Dubey *et al.*, 2021). By arguing that data analytics facilitates anticipation and improvisation capabilities (H_1 to H_2) and anticipation

and improvisation enhance SC resilience and responsiveness (H_3 to H_4), we posit that data analytics can indirectly affect SC resilience and responsiveness through anticipation and improvisation capabilities. Based on the above arguments and combining the effects of H_1 through H_4, our study suggests the following hypotheses:

H_9: Anticipation capability mediates the relationship between data analytics capability and (a) SC resilience and (b) SC responsiveness.

H_{10}: Improvisation capability mediates the relationship between data analytics capability and (a) SC resilience and (b) SC responsiveness.

In conditions of high uncertainty, i.e., the COVID-19 pandemic, a firm's ability to reconfigure its capabilities is essential for its survival and growth (Chowdhury and Quaddus, 2017; El Baz and Ruel, 2021). Both dynamic and improvisational capabilities are reconfiguration capabilities of firms (Pavlou and El Sawy, 2010), which may result in performance improvements when coupled with SC responsiveness and resilience. Arguing that SC resilience and responsiveness are influenced by anticipation and improvisation capabilities (H_3 through H_4) and resilience and responsiveness are linked with improved performance (H_6 and H_7) implies that improvisation and anticipation can have indirect implications on SC performance through SC resilience and responsiveness. Building on these arguments, the following hypotheses are suggested:

H_{11}: SC resilience mediates the relationship between (a) anticipation and (b) improvisation and SC performance

H_{12}: SC responsiveness mediates the relationship between (a) anticipation and (b) improvisation and SC performance

The hypothesized relationships are illustrated in Figure 1.

----------**Insert Figure I Here**----------

4. Methodology

4.1. Sample and Data Collection

An online survey instrument was developed and administered with key informants to collect the data needed to evaluate the hypothetical model. The sampling strategy entails soliciting senior-level managers, including CEOs, operations, SC, procurement, and production managers, presumably having relevant knowledge concerning data analytics, anticipation and improvisation initiatives, SC responsiveness, resilience, and performance measures. We obtained data from firms operating in Pakistan – a developing country. The precarious market, economic and institutional conditions, and underdeveloped SC infrastructure and capital/financial markets render firms and SCs operating in Pakistan extraordinarily vulnerable. Generally, developing countries are more susceptible to particular types of risk, such as political turmoil, corruption, and poor transportation infrastructure (Essuman *et al.*, 2020). Specifically, energy shortage, technology and communication failure, transportation network failure, exchange rate volatility, and loss of skills/talent are the main sources of firm and SC disruption in the country, which the prevalent pandemic situation has intensified. Thus, making a study of SC resilience and responsiveness crucially important and timely.

The data were collected during the COVID-19 pandemic from late 2020 to early 2021 from a random sample of 800 firms registered with three large stock exchanges of Lahore, Islamabad, and Karachi, Pakistan. The contact information was extracted from the directory provided by the Chamber of Commerce and Industry of the three cities. The directory consisted of a wide range

of manufacturing industries, e.g., textile and apparel, pharmaceutical, chemicals, food processing, and FMCGs. Four academics and three managers first tested the survey to ensure the clarity of all questions and measurement items. Following final revisions, the survey was distributed through email accompanied by a letter explaining the study's goal. Subsequent follow-ups were made to improve the response rate. We obtained 206 completed surveys, reflecting a 25.75% response rate. The respondent firms' profile is shown in Table 1.

----------**Insert Table I Here**----------

Non-response bias was checked by comparing early (first 35) and late (last 35) responses along demographic variables (Armstrong and Overton, 1977); there were no significant differences, implying that non-response bias was not a concern in this study. Also, following Podsakoff *et al.* (2003), both ex-ante and post ante common method bias (CMB) was tested. With respect to ex-ante analysis, firstly, different scale formats/anchors were employed for measuring dependent and independent variables. Secondly, items prone to CMB were positioned separately from each other in the survey. Thirdly, to minimize social desirability bias, firms and respondents were kept anonymous throughout the data collection procedure. Finally, to eliminate ambiguity, the questionnaire used objective terms and provided explanations of items where necessary.

Moreover, two post-tests were conducted to test possible CMB, i.e., Harman's one-factor test and CFA marker technique (Podsakoff *et al.*, 2003; Munir *et al.*, 2020). Harman's one-factor test results, conducted with principal component analysis and unrotated factor solution, indicated six factors whose eigenvalues exceeded 1. Only 32.9 percent of variance was explained by the first factor, which is not the majority of variance, thus supporting CMB not being problematic in this study. Furthermore, the CFA marker technique observes variance shared between a marker and hypothesized variables (Podsakoff *et al.*, 2003). There must be no theoretical relationship between

the marker variable and the variables being investigated (Lindell and Whitney, 2001; Williams *et al.*, 2010). An insignificant association between the marker variable and hypothesized variables signifies less CMB. Following Kim (2014) and Munir *et al.* (2020), a single-item five-point Likert scale measuring competitive rivalry within the industry was selected as a marker variable. Using a chi-square difference test within the CFA setting, we tested the statistical difference between the original measurement model and the new model, including the marker variables with hypothesized ones (Richardson *et al.*, 2009; Craighead *et al.*, 2011). The results showed no significant improvement in fit indices of original measurement model ($\chi^2 = 661.814$, CFI = 0.938, TLI = 0.930, IFI = 0.938, RMSEA = 0.053, SRMR = 0.055) and the extended one including marker variable ($\chi^2 = 698.178$, CFI = 0.936, TLI = 0.927, IFI = 0.936, RMSEA = 0.053, SRMR = 0.055) hence providing additional support that CMB not being a serious concern (Williams *et al.*, 2010; Munir *et al.*, 2020).

4.2. Measures

This study's constructs were operationalized as first-order reflective constructs measured on a 5-point Likert scale. For each construct, established scales were adapted from existing literature. The construct for data analytics capability was operationalized using 5 item scale derived from the works of Dubey *et al.* (2021) and Srinivasan and Swink (2018). SC resilience is treated as the ability to recover from disruptions. The scale for measuring SC resilience was adapted from Golgeci and Ponomarov (2013). SC responsiveness is operationalized as SC's ability to react to customer requirements and specifications changes, timely processing, and quickly deliver orders. The construct for SC responsiveness was adapted from Qrunfleh and Tarafdar (2013). Finally, SC performance was operationalized based on a 5 item scale adapted from Chowdhury *et al.* (2019) and Dubey et al. (2021).

Following Duchek (2019), anticipation was defined as the ability to discern possible future events and prepare for and respond to unexpected and sudden changes and disruptions by reconfiguring existing resources and capabilities when needed. The scale for anticipation was adapted from Gligor *et al.* (2013) and Wagner and Bode (2008). Likewise, improvisation, denoting the extent to which composition and execution converge in time (Moorman and Miner, 1998), is measured by asking respondents how their entities developed and executed plans, especially for SC function. Specifically, four items from Vera and Crossan (2005) were adapted.

Finally, firm size was treated as a control variable and measured by firm age (log of no. of years in operation) and the number of employees (log of no. of employees) (Essuman *et al.*, 2020; Munir *et al.*, 2020). Firm size is argued to impact firm's practices, experience in handling disruptions, and abilities in resilience (Wong *et al.*, 2020).

5. Results

5.1. Measurement Model Analysis

The empirical analysis was conducted employing a structural equation modeling (SEM) approach using AMOS statistical tool. A confirmatory factor analysis (CFA) was performed to ensure the proposed measurement model's validity, reliability, and dimensionality. The CFA model indicated good model fit (χ^2 = 555.289, CFI = 0.953, TLI = 0.947, IFI = 0.954, RMSEA = 0.046, SRMR = 0.051). Table 2 demonstrates the results for validity and reliability analysis for the proposed model.

----------Insert Table II Here----------

Based on Cronbach's α and Joreskog ρ, construct reliability and internal consistency were assessed (Braunscheidel and Suresh, 2009; Munir *et al.*, 2020). All values of Cronbach's α and

Joreskog ρ exceeded 0.70 (Nunnally and Bernstein, 1978), indicating that the model is internally consistent and reliable.

The factor loadings and average variance extracted (AVE) were assessed for each construct to establish convergent validity, meaning that all items in a construct measure the same construct (Bagozzi *et al.*, 1991). All factor loadings exceeded the proposed cutoff of 0.60 at $p < 0.001$ (Hair *et al.*, 2013), suggesting high convergence. Moreover, the AVE for each construct was higher than 0.05, which further supports convergent validity (Fornell and Larcker, 1981; Chin, 1998). Additionally, all constructs had CFI scores above 0.90, indicating unidimensionality (Bagozzi *et al.*, 1991).

To establish discriminant validity, which measures how much a construct differs from other constructs, the squared correlation between constructs should be smaller than the AVE value of each construct (Segars and Grover, 1993). For the proposed model, the value of AVE for each construct exceeded the squared correlation values between constructs of the remaining constructs (Fornell and Larcker, 1981), thus providing support for discriminant validity (See Table 3).

----------**Insert Table III Here**----------

Finally, to ensure the robustness of the proposed model, a measurement invariance analysis was conducted using the CFA approach (Steenkamp and Baumgartner, 1998). The data first divided into two groups based on firm size. The unconstrained CFA model with two groups produced a satisfactory fit (χ^2/d.f. = 1124.546/780, CFI = 0.906, TLI = 0.895, IFI = 0.908, RMSEA = 0.047) and all factor loadings were above 0.70 (at $p < 0.01$), thus ensuring satisfactory configural invariance for all constructs across the two groups. Furthermore, we performed a χ^2 test to check the significance of $\Delta\chi^2$ between constrained and unconstrained models. The results of constrained

CFA model, for which regression weights of all items were fixed across two groups, remained satisfactory (χ^2/d.f. = 1131.469/789, CFI = 0.906, TLI = 0.896, IFI = 0.908, RMSEA = 0.046). The $\Delta\chi^2$ ($\Delta\chi^2$ = 6.923, Δd.f. = 9) was insignificant, suggesting further support for measurement invariance.

5.2.Structural Model Analysis

An SEM analysis was performed to test the structural model. The results indicated a satisfactory fit for the structural model (χ^2 / d.f. = 559.941/391, CFI = 0.953, TLI = 0.947, IFI = 0.953, RMSEA = 0.046, SRMR = 0.07) (Hu and Bentler, 1999).

Figure 1 illustrates the results of structural model path coefficients. The effect of data analytics capability on anticipation ($\beta = 0.481$, $p < 0.001$) and improvisation ($\beta = 0.375$, $p < 0.001$) is positive and significant thus bearing support for H_1 and H_2. The paths from anticipation to SC resilience ($\beta = 0.226$, $p < 0.001$) and SC responsiveness is significant ($\beta = 0.382$, $p < 0.001$), thus supporting H_{3a} and H_{3b}. Likewise, the effect of improvisation on both SC resilience ($\beta = 0.365$, $p < 0.001$) and SC responsiveness is also significant ($\beta = 0.169$, $p < 0.05$) supporting H_{4a} and H_{4b}. SC responsiveness positively affects SC resilience ($\beta = 0.417$, $p < 0.001$), indicating support for H_5. Also, the hypothesized positive association between SC resilience and SC performance is significant ($\beta = 0.389$, $p < 0.001$), supporting H_6. However, the hypothesized association between SC responsiveness and SC performance was insignificant ($\beta = 0.150$, $p > 0.05$), rejecting H_7. Lastly, the associations between the control and the dependent variables are insignificant.

----------Insert Figure II Here----------

We used the AMOS Bayes estimation and resampling method to analyze and calculate specific indirect effects with user-defined estimates (Arbuckle and Wothke, 1999; Chen and Hung,

2016; Gaskin, 2016). While multiple mediations can be analyzed separately, we used the simultaneous testing approach following Chen and Hung (2016) because it is very flexible, efficient, and easy to use compared to other traditional tools. The bootstrapping method, which generates 5000 resamples, was adopted with bias-corrected confidence intervals (95%) to obtain more substantial confidence interval bounds and significance for indirect effects (Preacher and Hayes, 2008).

Table 4 summarizes the results of bootstrapping analysis. The indirect effect of SC responsiveness on SC performance through SC resilience was significant ($p < 0.001$), supporting H_8. For testing $H_{9a,b,}$ and $H_{10a,b}$, the indirect effects for multiple indirect paths were separated using a user-defined estimate (Gaskin, 2016; Munir *et al.*, 2020). The indirect impact of data analytics capability on SC resilience through both anticipation (at $p < 0.05$) and improvisation (at $p < 0.001$) is significant, supporting H_{9a} and H_{10a}. The indirect effect of data analytics capability on SC responsiveness through anticipation (at $p < 0.05$) is significant, supporting $H_{9b;}$ however, the indirect path from improvisation is insignificant, thus rejecting H_{10b}. The results indicate that SC resilience significantly mediates the relationship between anticipation (at $p < 0.05$) and improvisation (at $p < 0.05$) and SC performance, supporting H_{11a} and $H_{11b;}$ however, the indirect paths through SC responsiveness were insignificant, rejecting H_{12a} and H_{12b}.

----------Insert Table IV Here----------

6. Discussion and Implications

6.1. Discussion

Developed in the context of the COVID-19 pandemic, this study aims to identify and investigate critical capabilities to enhance SC resilience and responsiveness and achieve performance

improvements. The existing literature discusses various antecedents or enablers of SC resilience and responsiveness (Golgeci and Ponomarov, 2013; Brandon-Jones *et al.*, 2014; Birkie *et al.*, 2017; Brusset and Teller, 2017); however, attention has primarily focused on the planned approach towards developing resilience and responsiveness. The importance of planning and preparation is indisputable, yet disruptions never fit the plan, and firms inevitably have to evolve and adapt. The novelty and magnitude of disruptions triggered by COVID-19 require intuitive and spontaneous decision-making to respond to unexpected and unpredictable changes and upheavals. Many improvised responses have been seen during the pandemic as firms across various sectors repurposed and restructured their SC and production operations to cope with supply and demand disruptions that emerged as a response to the COVID-19 outbreak (Betti and Heinzmann, 2020; Harbour, 2020). This study extends the existing literature by introducing improvisation as a critical enabler of SC resilience and responsiveness.

Building on DCV, this study establishes an empirical distinction between dynamic capabilities (anticipation) and improvisation as two unique and complementary means to enhance SC resilience and responsiveness in a highly turbulent and volatile environment. This distinction allows a better understanding of improvisational capabilities as spontaneous capabilities that complement dynamic capabilities (Pavlou and El Sawy, 2010) in a highly volatile and turbulent environment. This study empirically determined that both anticipation and improvisation capabilities significantly and positively correlated with SC resilience and responsiveness, implying that in a highly turbulent and volatile environment, both dynamic and improvisational capabilities effectively strengthen the resilience and responsiveness of SCs and enhance performance. This finding complements the existing research arguing that improvisation is critical for responding and

adapting to unpredictable changes (Pavlou and El Sawy, 2010) and improving resilience (Suarez and Montes, 2020).

Using the IPT view, this study theorized data analytics capability as an information processing capability required to implement improvisation and anticipation. The study's findings are consistent with the proposed theorization, suggesting that data analytics capability has a significant positive relationship with anticipation and improvisation. This conforms with existing studies suggesting that data analytics capability improves information processing capability under uncertain scenarios (Srinivasan and Swink, 2018; Dubey *et al.*, 2021), thus facilitating firms to prepare for and mitigate the harmful effects of SC risks and disruptions (Munir *et al.*, 2020). Also, our results suggest that anticipation and improvisation significantly mediate the relationship between data analytics capability and SC resilience. This finding implies that anticipation and improvisation in a highly turbulent and volatile environment are the means through which data analytics capability facilitates SC resilience, thus extending the existing literature.

Cultivating agility and responsiveness has often been highlighted as critical for managing disruptive risk and enhancing resilience (Braunscheidel and Suresh, 2009; Mandal, 2015; Shekarian *et al.*, 2020). Furthermore, SC responsiveness is deemed especially relevant in the context of COVID-19 to respond to unprecedented changes (Lee *et al.*, 2020) by driving greater resilience (Shekarian *et al.*, 2020). Our research findings conform to these arguments by providing a significant and positive empirical association between SC responsiveness and SC resilience. Also, this supports the view that responsive SC networks, having the ability to swiftly respond to changing environmental conditions, are among the most powerful ways to achieve resilience (Christopher and Peck, 2004).

Consistent with existing studies (Wieland and Wallenburg, 2013; Chowdhury and Quaddus, 2017; Chowdhury *et al.*, 2019), our study's results propose that SC resilience positively impacts SC performance. However, contrary to our theorization, the effect of SC responsiveness on SC performance is found insignificant. This suggests that SC responsiveness may not directly affect performance in highly volatile and uncertain contexts, but it may assist through improvement in risk management and resilience that enhances SC performance (Braunscheidel and Suresh, 2009; Shekarian *et al.*, 2020). Moreover, SC resilience fully mediates the link between SC responsiveness and performance, suggesting that SC resilience is essential for leveraging SC responsiveness in a highly uncertain and volatile context. This conforms to Wieland and Wallenburg (2013) that a resilient SC can maintain higher visibility and responsiveness, ensuring customer value and superior performance. Moreover, SC resilience mediates the relationship between anticipation and improvisation capabilities and SC performance. Thus, this study infers that developing SC resilience is a precondition for developing and strengthening SC performance (Chowdhury *et al.*, 2019), without which firms and their SC will be affected by disruptions that adversely impact performance.

6.2. Theoretical Implications

This study adds to the SC resilience literature by presenting improvisation as a unique capability that can be harnessed to elicit spontaneous responses in a turbulent environment. Recently, Richey et al., 2022 argued that improvisation had not been extensively studied in SC and logistics literature. Previously, Pavlou and El Sawy (2010) distinguished between dynamic and improvisational capabilities and studied their implications for competitive dynamics literature. The current study extends the previous understanding by exploring the role of dynamic and improvisational capabilities in facilitating SC resilience and responsiveness. The inclusion and

dominating role of improvisation along with dynamic capabilities (anticipation) in a highly turbulent environment enrich the existing understanding of the association between SC resilience, responsiveness, and performance. It accounts for a missing link through which SC resilience and responsiveness can enhance performance and competitive advantage in a turbulent environment.

In addition, the current research speaks to the work of Dubey et al. (2021), who showed that data analytics capability increases information processing capability under uncertain scenarios. To alleviate potential risks and disruptions in uncertain and turbulent environments, firms increasingly leverage new and existing technologies and analytic capabilities for informed internal and external SC decision-making (Arunachalam *et al.*, 2018; Zhu *et al.*, 2018). Thus, research in data-driven decision-making has become increasingly important (Hosseini *et al.*, 2019; Ivanov *et al.*, 2019; Ivanov and Dolgui, 2020). This study adds to this research stream by showing that the path of data-driven decision-making for a resilient SC in turbulent environments is through improvisation and dynamic capabilities. Furthermore, by showing that data analytics helps boost improvisational capabilities, this study responds to Pavlou and El Sawy (2010) call to examine the impact of other types of IT systems on improvisation and in different functional contexts.

Also, this study extends the existing literature by exploring the role of data analytics in enhancing SC resilience and thus improving performance. Srinivasan and Swink (2018) empirically investigated and argued that supply and demand visibility is significantly associated with developing data analytic capability. Based on an empirical study, Brandon-Jones *et al.* (2014) have established that SC visibility is an enabler of SC resilience. Dubey *et al.* (2021) extended the arguments of Brandon-Jones *et al.* (2014) and, based on empirical evidence, suggested that data analytic capability is positively associated with SC resilience and leads to competitive advantage. Building on IPT, we explored how data analytics can help develop and implement anticipation and

improvisation capabilities, thus identified capabilities through which improved information processing can be translated into enhanced SC resilience and responsiveness in a highly turbulent environment. Existing operations and SC literature provide ample evidence that SC visibility promotes performance (Christopher and Lee, 2004; Barratt and Oke, 2007) and SC resilience (Brandon-Jones *et al.*, 2014; Sabahi and Parast, 2020; Dubey *et al.*, 2021). This study further provides an underlying explanation suggesting that data analytics is an information processing capability that antecedents anticipation and improvisation and, through these capabilities, enhances both SC resilience and responsiveness.

Finally, by conducting a theoretically grounded and empirically focused investigation in the context of COVID-19, this study echoes the recent call for empirical research in this area (Chowdhury *et al.*, 2021) to extend the current understanding of dealing with novel disruptions by enhancing SC resilience and responsiveness (Lee *et al.*, 2020). There have been consistent calls in the literature for more empirical research on SC risk and resilience (Sodhi *et al.*, 2012; Van Hoek, 2020) as a considerable part of existing literature in this domain consists of conceptual research (Scholten *et al.*, 2020). Our paper contributes to the existing literature by providing empirical validation of proposed claims. Also, this study examined the performance implications of SC resilience and responsiveness in a developing country context, i.e., Pakistan. In doing so, it addresses the call of Chowdhury and Quaddus (2017), suggesting more empirical studies to investigate the relationship between SC resilience and SC performance in different nations. Conforming to earlier studies, the results of this study revealed a positive association between SC resilience and SC performance (Wieland and Wallenburg, 2013; Chowdhury and Quaddus, 2017; Chowdhury *et al.*, 2019). The results also suggest that SC resilience is fundamental to survival in

highly turbulent and volatile environmental conditions (Scholten *et al.*, 2020; Van Hoek, 2020; Dennehy *et al.*, 2021) and a prerequisite for leveraging other initiatives, i.e., responsiveness.

6.3. Practical Implications

This study offers several significant implications for SC managers. First, as firms may face simultaneous supply and demand disruptions in highly unexpected situations, managers must appreciate the role of both responsiveness and resilience for performance benefits and competitive advantage. In this regard, SC resilience takes precedence as it is a prerequisite for leveraging other performance strengthening initiatives. Secondly, the paper identifies the key capabilities that enhance SC resilience and responsiveness. Managers are suggested to promote anticipation as a dynamic capability to stay alert for possible disruptions and their catastrophic occurrence as such alertness and preparedness would help firms to rapidly respond to sudden changes by planned reconfiguration and adaptation. In this vein, a mechanism should be developed to generate and store new information both internally and externally, increase SC coordination and enhance network relationships to deal with uncertainties and vulnerabilities. While the importance of planned reconfiguration and adaptation for unexpected disruptions can never be undermined, unforeseen and unprecedented contexts, i.e., the COVID-19 pandemic, require urgent and out-of-the-box solutions where extemporaneous actions become inevitable. Therefore, managers should appreciate the role of improvisation as a spontaneous capability that operates distinctly but complements dynamic capabilities in highly turbulent and volatile environments. Specifically for managers of resource-constrained manufacturing firms in developing countries which may not afford to build and maintain dynamic capabilities, this study provides insights to sustain normal operations and thrive under severe uncertainty by improvising timely and creatively. This implies that improvisation does not necessarily indicate failure of planning, rather it can be used

intentionally when deemed an optimal method to avoid expensive and lengthy planning processes especially when new conditions are expected to be unique and novel.

Thirdly, managers should invest in data analytics capability, which acts as an information processing capability for promptly processing, ingesting, and acting on information to identify and respond to change and disruptions. Generally, firms use historic data to predict future events, however, today's rapidly evolving conditions mean that firms are collecting more data from their supply chain partners as well as internal operations than ever before. In the face of extreme uncertainties, data analytics enables firms to make better sense of the surrounding environment and strategize and make informed decisions using reliable and accurate information with the support of an array of real-time analytics tools and techniques. By mobilizing and analyzing data about the changing conditions, managers can expand their production capacities (e.g., during the COVID-19 pandemic, 3M increased its mask production and doubled its respirator production capabilities) or redesign their production processes to cater the urgent demand of certain products during crisis (e.g., GM, Ford, and Tesla switched to produce ventilators to address the urgent hospital demands amid COVID-19 outbreak), eventually leading towards more well-grounded decisions. Thus, we contend that data analytics capability provides the visibility and transparency required to exercise anticipation and improvisation capabilities. Finally, this paper finds that anticipation and improvisation mediate the link between data analytics and SC resilience, suggesting that firms can benefit from the visibility created by data analytics through anticipation and improvisation under high uncertainty. Thus, the interplay between data analytics, anticipation, and improvisation capabilities is essential in quickly adapting and responding to changing environments and enhancing SC performance.

To sum up, managers of manufacturing firms seeking to improve SC performance in a highly volatile and uncertain environment, i.e., the aftermath of the pandemic, should focus on improving SC resilience and responsiveness by investing in improvisation, anticipation, and data analytics capabilities. Besides the typical risks firms and supply chains are exposed to, natural calamities, i.e., COVID-19, pose additional and different challenges that test SC resilience and responsiveness, yet how managers focus on building and strengthening these remains under-researched (Sarkis, 2020). Identifying and empirically testing the interplay of different capabilities in highly disruptive contexts in this paper may help managers design and improve processes to ensure survival during prolonged global disruptions. There will be many new normal practices and strategies post COVID-19 as a part of fundamental changes that managers must consider while devising their business continuity and recovery plans. This paper's findings suggest that improvisation capability along with dynamic and data analytics capabilities will be among the most important ones in enhancing supply chain performance.

7. Limitations and Future Research

The study's findings and limitations point to important future research avenues. First, single respondent and self-reported data were used for analysis. While the CFA marker technique and Harman's single factor test results suggest that CMB does not pose a grave issue, future studies should use multiple respondent data to reduce possible CMB. Second, this research employed cross-sectional data, limiting the ability to inspect the dynamic characteristics of proposed associations. Future studies could use longitudinal data or case-based analysis for exploring the associations between anticipation, improvisation, SC resilience, responsiveness, and their impact on performance. Thirdly, this research only investigated the role of data analytic capability in enhancing resilience and responsiveness through anticipation and improvisation. Future studies

could explore the impact of other emerging technologies, e.g., real-time SC and blockchain technology, on SC resilience. Fourthly, this study's data was collected after the COVID-19 pandemic and from a developing country; thus, the given context was highly turbulent and volatile by default. Future studies can explore different contextual factors, e.g., high vs. low turbulent environment, turbulent vs. non-turbulent industry, intense competition, and manufacturing vs. service sector. Finally, future studies could analyze the proposed associations in industries other than manufacturing to investigate this study's generalizability.

8. Conclusion

The existing studies on SC resilience and responsiveness offer limited insight into the novel disruptions, e.g., those caused by the COVID-19 pandemic (Dani *et al.*, 2021), as the existing enablers of responsiveness and resilience in the literature focus on a planned and prepared (anticipation) approach towards responding to unexpected disruptions, ignoring the role of spontaneous decision making. Given the novelty and magnitude of disruptions, there is a need to highlight the importance of intuitive and extemporized decision-making to respond to sudden, unexpected, and unpredictable changes and upheaval. In the same vein, building on DCV, the current research suggests that both anticipation and improvisation capabilities are imperative for enhancing SC resilience and responsiveness, especially in novel and unexpected disruptions. Furthermore, using IPT, the role of data analytics as an information processing capability positively affects both anticipation and improvisation, which also mediates the effect of data analytics on SC resilience and responsiveness. Thus, by conducting an empirical quantitative study in the context of COVID-19, the current research provides valuable insights for practitioners and academics on how to cope with the novel disruptions triggered by the pandemic (Chowdhury *et al.*, 2021) by enhancing SC resilience and responsiveness (Lee *et al.*, 2020).

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