



Multi-dimensional supply chain flexibility and supply chain resilience: the role of supply chain risks exposure

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Abstract

Natural disasters and unexpected disruptive events have forced practitioners and researchers to build resilience capability into their systems to survive and grow in tempestuous and turbulent times. This study empirically examined the effect of multi-dimensional supply chain flexibility (MDSCF) in improving supply chain resilience (SCRES) under a high supply chain (SC) risk environment. The study incorporated a survey technique and utilized valid responses from 191 large-scale manufacturing (LSM) firms of Pakistan. PLS-SEM is employed to analyze the hypothesized relationships. The findings indicated that MDSCF significantly contributes to improving SCRES. Moreover, the study shows strong significant moderating effects of the customer-oriented and external risks and the weak moderating effect of supplier-oriented risks towards augmenting SCRES. The study contributes to the SC (SC) risk management literature by providing empirical support for the need for multi-dimensional SC flexibility measures in bolstering SCRES under the high SC risk environment.

Keywords Disruptions · Resilience · Supply chain flexibility · Supply chain risks

1 Introduction

With globalization increasing in the past few decades, it is becoming more common for businesses to get engaged in global supply chains to take advantage of internationally dispersed

resources and increase their level of network connectivity (Li and Chen 2019). As businesses reap the benefits of global supply networks, companies also become more susceptible, and they face a slew of uncertainties and difficulties as a result of their supply chain operations (Zhu et al. 2018). Hence globalization has put geographically dispersed supply chains at risk (Tan et al. 2019). As supply networks have expanded, with more and more sub-contractors involved, disturbances in far-flung corners of the globe may unexpectedly interrupt supply chains (Boin et al. 2010; Sawik 2020). The increasing risks in today's globalised supply chains are mostly attributable to rising consumer demands, a more volatile business climate, and the greater exposure to internal and external risk events (Shekarian and Parast 2020). Studies have documented various startling events, including the 9–11 terrorist attack, the 2008 financial crisis, and the earthquake that caused the 2011 Japan tsunami (Kamalahmadi and Parast 2016a, b; Dubey et al. 2019). Notably, the most recent shutdown halted the worldwide SC activities following the global COVID-19 epidemic (Ivanov and Dolgui 2020). The recent COVID – 19 outbreak is considered an unprecedented event that has dramatically shattered the local and international economies (Ivanov 2020; Faruquee et al. 2021).

However, other researchers have concluded that volatility and disruptions have become the new normal in SC management (Christopher and Holweg 2017). Significantly, the

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recent global COVID-19 pandemic stressed the fundamental rethinking of the SC in the new standard times. Companies, on the other hand, that depend on conventional thinking and systems may suffer serious repercussions, particularly when the inputs are strategic. As a result, these delays may lead to substantial losses in production, leading to long-term implications for the financial health of the company (Sreedevi and Saranga 2017). Notably, the impacts are substantial, particularly for lengthy and geographically scattered higher-value manufacturing SCs.

In an appalling scenario, the short or lack of supplies may force the halt of assembly or production line. Consequently, the firm's survival will be impacted, resulting in a significant increase in global economic effect (McKenzie 2020). For that reason, practitioners and scholars stress that to compete in today's tumultuous and unpredictable economy, companies must have the capability to effectively manage risk and disruption in their supply chain (Wiengarten et al. 2016; Oliveira et al. 2017). The risks and vulnerability in SCs may impact the success of the focus firm (Aggarwal et al. 2020). Failure to manage these risks effectively may jeopardise the market performance of focused companies and possibly result in their insolvency (Kamalahmadi and Parast 2016b). Given the unpredictable and changing business environment, a robust and resilient supply chain is essential for growth and survival (Li et al. 2020). The formation of resilience within SCs enables firms to prepare readily, adapt, respond to unforeseen events. Hence, in the worst-case scenario, they are better equipped to bound back from these disruptions (Blackhurst et al. 2007; Sáenz and Revilla 2014).

The extant literature documented various ways of improving SC resilience (SCRES) (Chowdhury and Quaddus 2017; Piprani et al. 2020a, b, c). For instance, some believe excess inventory and keeping a buffer stock would allow the organization to continuously feed into the manufacturing system when the need arises (Carvalho et al. 2011; Qrunfleh and Tarafdar 2014). Furthermore, splitting the SC into various streams may be another way to avoid serious consequences. Hence, if one stream of supplies is affected, firms would have another stream of the SC as a backup, enabling them to sustain the business operations during turbulent times (Jiang et al. 2009; Easen 2020). Meanwhile, for firms with multiple suppliers for their strategic input, it is critical for them to quickly re-activate their relationship with the suppliers to improve their supply base flexibility (Pujawan 2004; Tipu and Fantazy 2014). Moreover, some firms rely on specific suppliers, and their supply base is affected due to some disruptive event. In this case, they must switch to alternate suppliers in the non-impacted territory to continue their supply operations efficiently (Tukamuhabwa et al. 2017; Kilpatrick and Barter 2020). Similarly, there may be a chance of bottlenecks in logistics operations in disruptive times, delaying logistics activities. Firms may have to opt for logistics

flexibility either by looking for alternative routes or switching to another mode of logistics network. Hence, this move will enable them to release the supplies from the disruptive region to the non-disruptive area (Carvalho et al. 2012; Agigi et al. 2016).

Furthermore, it is vital to mention that emerging nations make a major contribution to global commerce by accounting for 50% of global output and consumption. In spite of their considerable participation in global trade, emerging economies are the most susceptible to SC disruptions (Tukamuhabwa et al. 2017). There is also evidence to suggest that SC disruptions have had the greatest impact on developing economies. (Lakovou et al. 2007; Piprani et al. 2020b). Terrorism, political instability, strikes, revolt drills, inadequate infrastructure, and corporate malfeasance are some of the examples of such occurrences. This research focuses on Pakistan's large-scale manufacturing companies, which account for about 12% of Pakistan's GDP (Economic Survey of Pakistan 2019). Contrary to expectations, this sector has had a poor performance owing to a variety of reasons including natural disasters, political turmoil, the unrest caused by the war on terrorism, and increased utility prices. The reflection of disruptive and volatile situations can be observed in the FM Global Resilience Index 2020, in which Pakistan is positioned at 115th out of 130 rankings. This position lags well behind neighbouring nations such as India(53), China(65), Sri Lanka(83), and Bangladesh (109). Additional studies have shown that there are disabling conditions such as in-country anarchy, terrorism, rising electricity costs and macroeconomic insecurity (Rana 2017). These considerations have compelled investors to postpone their investment decisions and, in some instances, relocate their assets to other regional nations as a result of these developments (Abbas et al. 2019). Pakistan's resilient positioning highlighted the need for large-scale manufacturing companies in rebuilding Pakistan's economy. Essentially, firms must have a reconfiguration mechanism aligned with networked organizations to tackle their SC risks (SCRs). Flexibility was identified as a key component in mitigating and handling SC risk, as well as improving supply chain resilience. (Ali et al. 2017; Piprani et al. 2020c). However, there is a paucity of research demonstrating the link between MDSCF (multi-dimensional SC flexibility) and SCRES. A lack of agreement exists as well on the moderating impact of different SC risks when they interact with dynamic capabilities such as supply chain flexibility. Having a clear understanding of their impact is critical, particularly in the context of a nation that has a reputation for being volatile and disruptive historically. Hence, this study can perceptibly contribute significantly to the SCRM literature. We also look at the connection between MDSCF and SCRES with various kinds of SCRs using data from 191 large-scale manufacturing companies. As a result, we can determine which risks are substantial in terms of changing

the MDSCF-SCRES connection. The impact of high or low-risk exposures in influencing resilience is a stepping stone for policymakers and SC professionals. With this strategy, they will be able to plan and strategize more effectively to minimise the negative impact of these risks. Additionally, meta-analysis of the relevant researches indicate that empirical research in this field is rather scarce in comparison to non-empirical research. Hence, our research makes a contribution to the resolution of some of these problems.

In the following section, we discuss the literature and developed hypotheses based on exogenous and endogenous constructs. Section 2 is concluded with a research framework, while Sect. 3 represents research design and methodology. The analysis and results are presented in Sect. 4, followed by a discussion of products discussed in Sect. 5. In Sect. 6, the conclusion and implications are presented, and lastly, in Sect. 6.2, limitations and future directions for research are discussed.

2 Literature review and hypotheses development

In recent years, there has been an explosion of supply chain risk management (SCRM) literature, indicating that companies are more concerned about supply chain risk and need to improve supply chain flexibility to become more resilient. Given the abundance of articles reviewing and synthesising the prior SCRM literature, the intent of this section is to review what has been studied to date to determine different types of supply chain flexibility as well as how these types impact the ability to achieve superior SCRES in a highly disruptive environment. This section offers definitions of three important topics (i.e. SCF, SCRES and SCR) specified in Table 1, followed by a short overview of the relevant state-of-the-art literature and then research framework that is presented in Fig. 1 to demonstrate hypotheses involved in this study.

2.1 SC flexibility

Unlike manufacturing flexibility, SC flexibility (SCF) is a process-based view; it is considered a broader concept that includes flexibility in all the activities across the entire value chain (Vickery et al. 1999; Delic and Eyers 2020). The SCF has been studied for many years, in which the subject has become a core part of the operations literature (Stevenson and Spring 2007; Pérez et al. 2016). Fundamentally, the SCF is regarded as the capability of the SC to act upon customer demand. Furthermore, SCF is considered as the extent to which chains can change their operations, speed, volume, and place, in line with the changes the market requires (Salavatihesari 2016). Essentially, SCF allows organizations to adapt to the matching supply and demand, which helps them introduce and modify the product to suit customers' needs efficiently. Thus, this method allows firms to acquire a competitive advantage. (Swafford et al. 2008; Jin et al. 2014).

Several authors (Vickery et al. 1999; Stevenson and Spring 2007; Manders et al. 2016) have discussed the different dimensions of SC flexibility, a network's wide phenomenon, and thus, proposed various forms of SC flexibility in other literature (e.g., Duclos et al. 2003; Manders et al. 2016; Salvador et al. 2007; Sreedevi and Saranga 2017). Vickery et al. (1999) noted five different categories of SCF, which can be indicated as integrative, ranging from product and volume flexibility (describing manufacturing). These categories are extended to distribution, responsiveness flexibility (covering marketing), and launch flexibility (new product design). However, Jin et al. (2014) classified SC flexibility into five different dimensions: production, product development, logistics, suppliers, and supply base flexibility. The first three flexibility measures were categorized as manufacturing flexibility, which represents the capacity of the organization to manage several aspects efficiently and effectively. These aspects include product development, production, and logistics resources, enabling them to adapt to

Table 1 Operational Definition

Construct	Definition	Source(s)
Supply Chain Flexibility (SCF)	Supply chain flexibility is the capacity of all supply chain participants to adapt or respond to environmental unpredictability and fulfil a growing diversity of customer demands without incurring excessive costs, time, organisational disturbances, or performance losses	(Manders et al. 2016)
Supply Chain Risks (SCR)	Supply chain risks are defined as the probability of occurrence of a certain event or result, as well as the consequences of that event or outcome happening, as well as the causal route leading to that event. The events can be originated from an organization, network or the external environment	(Trkman and McCormack 2009; Park et al. 2016)
Supply Chain Resilience (SCRES)	The ability of the SC to adapt to unforeseen events, react to disturbances, and bounce back from them while maintaining desirable levels of connectivity and control over structure and function	(Ponomarov and Holcomb 2009; Scholten et al. 2014)

changes occurring in the external environment (Zhang et al. 2003; Rogers et al. 2011; Sreedevi and Saranga 2017).

In contrast, logistics flexibility represents the organization's ability to handle numerous receipts and delivery requirements with precision, promptness, and efficiency (Barad and Even Sapir 2003). These three functions of manufacturing flexibility are significantly interconnected to each other within the organization. For instance, production and logistics flexibility enables the organization to accelerate product development flexibility. Without the strong support of these two functions, the organization's competitive advantage in introducing new products and product modifications would no longer last (Jin et al. 2014). Similarly, firms need to reconfigure their SC swiftly by encouraging the supplier and constantly collaborating to be more agile and responsive (Benzidia and Makaoui 2020).

2.2 SC resilience

In essence, SCs experience substantial complexity and dynamism, forcing them to acclimatize to the changes in the internal and external environments to sustain and survive in the global business environment (Jabbarzadeh et al. 2016; Adobor and McMullen 2018). Companies in today's dynamic and tumultuous times need to strengthen their resilience in the face of unexpected and unanticipated interruptions to their operations (Ponomarov and Holcomb 2009; Wieland and Durach 2021). The firms' dynamic capability serves as the vital constituent for building SCRES (Ali et al. 2017; Yu et al. 2019). In this way, companies may respond to the micro and macro environmental shifts in a dynamic, irregular, and volatile global economic environment (O'Reilly and Tushman 2008; Piprani et al. 2020a, b, c). SCRES makes it possible for businesses to react swiftly to unexpected events and reestablish operations by merging and rearranging their existing resources and capabilities. Resilient SCs are better able to anticipate and mitigate the harmful impacts of adverse incidents while still significantly reducing the time it takes to return to normal operations (Ruiz-Benítez et al. 2018). This strategy would provide them an edge over other businesses that lack the capacity to bounce back. (Scholten et al. 2020).

2.3 SC flexibility and SC resilience

Considering the available research, it is clear that adaptation and reconfiguration mechanisms enabled by flexibility are critical for enhancing resilience (Brusset and Teller 2017; Piprani et al. 2020c). Flexible systems inject an organic capacity into the organization's structure, enabling it to confront and react to unforeseen environmental and operational crises (Sheffi and Rice 2005; Jüttner and Maklan

2011; Srinivasan and Swink 2018). Thus, businesses must strengthen their manufacturing system resilience by integrating flexibility into their operations to deal with SC interruptions (Kleindorfer and Saad 2005; Ponomarov and Holcomb 2009; Sheffi and Rice 2005). Even if a disruptive event happens, a SC founded on flexibility enables the company to rapidly react to any disruptive event, allowing the company to reorganise and realign its resources and capabilities in the case of a disturbance (Skipper and Hanna 2009; Sreedevi and Saranga 2017).

Moreover, supply chains may improve their resilience by reconfiguring their organisations to make better use of their current assets and structures. (Mackay et al. 2019) Such reconfiguration capabilities enable the firm to quickly recover to the most desirable state (Kyläheiko and Sandström 2007). As an example, after the 2011 tsunami in Japan, a company with SC capabilities and a flexible production process was claimed to have recovered from disaster more quickly than firms with SCs that lacked flexibility (Sáenz and Revilla 2014). It's also worth noting that, contemporary SC resilience research has given significant emphasis to flexibility capability. Perhaps flexibility is the forefront resilience measure used in various literature (Christopher and Holweg 2011; Fiksel et al. 2015; Rice and Caniato 2003; Sabahi and Parast 2020; Tang and Tomlin 2008). For example, a survey-based study conducted on the Indian manufacturing organizations has documented a strong connection between flexibility and resilience (Mandal et al. 2016). Likewise, Brusset and Teller (2017) found flexibility capability as one factor that enhances stability. Flexible distribution arrangements, production facilities, supply base, workforce skills, structures, and flexible capacity in the system develop the SC's resilience (Tang 2006; Tang and Tomlin 2008; Colicchia et al. 2010; Yang and Yang 2010). Additionally, flexibility builds SCRES by augmenting quick response in adapting and reconfiguring resources at the time of turbulence (e.g., Christopher and Holweg 2011). Notably, multiple aspects of SCF concerning SCRES are empirically scant (see Table 2). As discussed earlier, contemporary thinking in the SC views flexibility as a network-wide phenomenon covering all aspects from end-to-end flexibility measures. Hence it is inferred that incorporating MDSCF will make the SC even more resilient to disruptions. Thus it can be deduced that.

H1: Multi-dimensional SC flexibility is positively related to SC resilience

2.4 The moderating role of SC risk exposure

In this study, we are trying to analyze the role of various SC risks, potentially altering the manager's efforts to

establish SC flexibility as a dynamic capability, enhancing the SC's resiliency. Firms operating in a highly dynamic and volatile environment must set up and strengthen their ability to view the SC risks while constructing a resilient SC (Chopra and Sodhi 2004; Piprani et al. 2020a). The sources of risks are categorized into internal, network, and external threats. Internal risk refers to the risk factors on any issues within the organization, including operating, system, and labor risk. Furthermore, network risk stems from both customers and suppliers. Notably, these disruptions flow from upstream and downstream SC members. Essentially, SCs are vertical inter-organizational networks of businesses that are tightly connected to their upstream and downstream SC counterparts. As a result, both suppliers and consumers have an effect on developing SCRES (Teller et al. 2016). For example, a lack of dependability, long lead times, or delivery issues are some of the supplier driven risks that may impair a manufacturing firm's capacity to perform (Brusset and Teller 2017). Walters (2006) makes similar points about consumers presenting risks to upstream supply chain partners, such as failed to release funds on time, generating fluctuating demand, or having ordering issues. As a result, risks associated with suppliers and consumers, that is, risks that originate outside the business but are part of SC, have an effect on how companies may reap all of the advantages associated with improving their flexible capabilities to build resilience.

On the other hand natural catastrophes, political unrest, and economic downturns all pose external risks to the SC of a company. Walters (2006) demonstrates the substantial effect of external risks on SC performance and continuity of SC operations. These risks will undermine the supply chain manager's attempts to strengthen its overall resilience (Brusset and Teller

2017), as we argue in this paper. Such external threats may have a detrimental impact on building a resilient enterprise through flexible supply chain system. Further to this, it has been reported that disruptive events may have an effect at individual, regional or global level (Katsaliaki et al. 2021). Individual level effect is confined to a particular supplier (e.g. machine breakdown, process failure, etc.), regional are those that affect suppliers locally (e.g. a new legislation introduced by a State related to labour causing labour strike), while global are those that affect all suppliers or SC levels globally at the same time. Global events such as recent COVID 19 epidemic (El Baz and Ruel 2021), economic downturn or extensive labour strike in the transportation industry are examples of such global occurrences (Sawik 2020). As the business environment becomes more dynamic, it's important to point out the pressing need to match the company's capabilities to those of the environment. As a result of increasing unpredictability and dynamism in the business environment, existing literature reiterated the need to improve capabilities to ensure continuity and stability of SC operations (Sreedevi and Saranga 2017; Yu et al. 2019). Thus, we argue that businesses functioning in a high-risk SC environment should have the flexibility necessary to continue working effectively and attain a greater degree of SC resilience. Hence, we draw the following hypotheses:

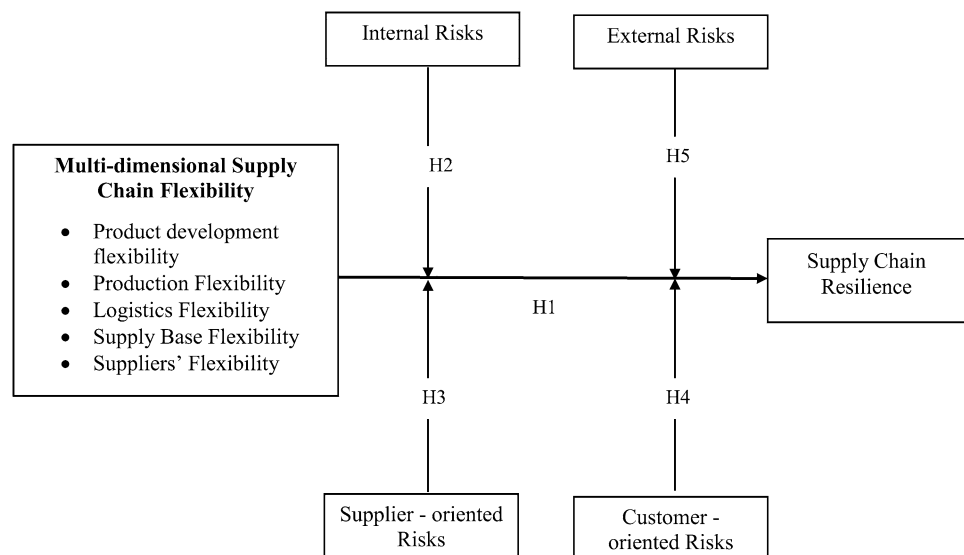
H2: Internal risk exposure positively moderates the relationship between SC flexibility and SC resilience.

H3: Supplier-oriented risk exposure positively moderates the relationship between SC flexibility and SC resilience.

H4: Customer-oriented risk exposure positively mediates the relationship between SC flexibility and SC resilience.

H5: External risk exposure positively moderates the relationship between SC flexibility and SC resilience.

Fig. 1 A research framework



3 Methodology

3.1 Measurement of variables

This study employed structured survey to gather data from large-scale manufacturing companies operated in Pakistan. The detailed methodology is presented in Fig. 2. In the first step, the measurement items of each construct were extracted after going through an extensive literature review. Table 3 presents the operationalization of each construct. SC flexibility is operationalized through five dimensions measured formatively, which are measured through various items reflectively. Furthermore, this study utilized product development, production, supply base, suppliers' and logistics flexibility to represent a manufacturing firm's SC, as proposed by Jin et al. (2014).

SC resilience is measured through four items adapted from Gölgeci and Ponomarov (2015); and Mandal et al. (2016). Meanwhile, the exposure of different types of risk is measured, representing the product of SC risk occurrences and SC risk consequences, adapted from Park et al. (2016). The 1 – 5 scales are used for both risk occurrences and risk consequences, in which rare, unlikely, possible, likely, and almost certain are utilized for risk occurrences. On the other hand, insignificant, minor, moderate, significant, and catastrophic are used for risk consequences. Initially, a pilot test was carried out on 46 manufacturing firms to identify the flaws in the instrument. Additionally,

the test was conducted to determine whether the measures used to operationalize the constructs possessed a reasonable or acceptable level of reliability.

3.2 Data collection

This research concentrated only on large-scale manufacturing organisations since establishing a resilient business involves a significant investment that only large-scale manufacturing companies can afford. Furthermore, Pakistan's complex social environment makes it a good place to research SCF and SCRES. The country has been devastated by a range of natural and man-made disasters during the last two decades.. More than \$10 billion has been spent on crisis management and resulting rehabilitation in the last ten years (GFDRR 2019). While Pakistan is ranked 33rd on the list of the world's worst carbon polluters (The Global Economy 2019), it is the seventh-worst afflicted nation in the world by climate change (Ahmad et al. 2019). The nation was left devastated by terrorism after the worldwide war on terror. Pakistan suffered more than \$200 billion in losses in the fight on terror during 2002–18. (Pakistan Economic Survey 2020). Further to this, in the face of threats of conflict with India, interruptions to the supply chain add to the numerous concerns of logistics managers about the safety of cargo and raw materials. The Pakistani government imposed a trade embargo on Indian goods after a recent standoff. As a result of this event, the

Fig. 2 Research Methodology

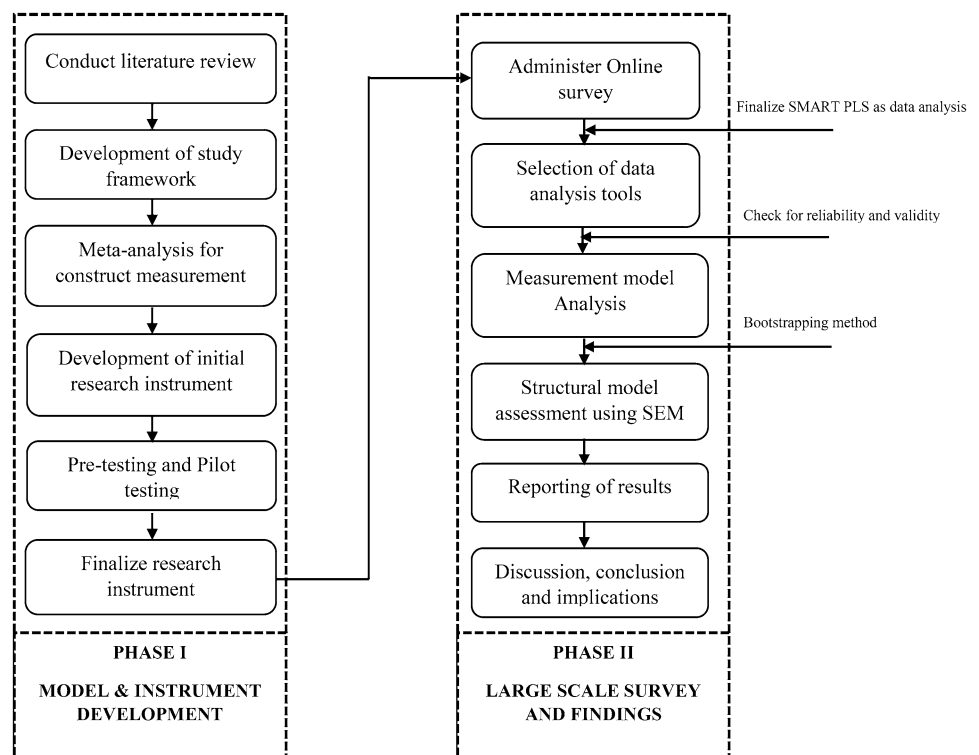


Table 2 Flexibility as a significant driver of resilience

Author	Flexibility type (s)	Methodology
Rice and Caniato (2003)	Multi-skilled workforce, flexible productions system, flexibility in sourcing	Conceptual
Sheffi (2005)	Transportation, production, labor and supply base	Conceptual
Tang (2006)	Flexible supply base, flexible transportation	Literature review
Tang and Tomlin (2008)	Flexibility via multiple suppliers, via flexible supply contracts, via flexible production, via postponement, via responsive pricing	Mathematical modeling
(Christopher and Holweg 2011)	Structural flexibility using dual sourcing, asset sharing, flexible labour arrangements and postponement	Conceptual
Ishfaq (2012)	Flexibility in transportation operations	Mathematical modelling
Diabat et al. (2012)	Flexible capacity, Flexible sourcing through multiple sourcing	Interpretive Structural Modelling
Vlachos et al. (2012)	Sourcing flexibility, postponement	Conceptual
Pettit et al. (2013)	Flexibility in sourcing, Flexibility in order fulfilment	Instrument development
Urciuoli et al. (2014)	Flexible contracts	Case Study
Fiksel et al. (2015)	Sourcing, manufacturing and order fulfilment	Conceptual
Mandal et al. (2016)	Supply Chain flexibility (uni-dimensional)	Survey
(Agigi et al. 2016)	Flexible transportation and factory re-design	Interview
Brusset and Teller (2017)	Flexibility capability	Survey
Song et al. (2018)	Procurement flexibility, Inventory capacity and Distribution center redundancy	Mathematical modelling
Mackay et al. (2019)	Proactive Flexibility and Reactive Flexibility	Conceptual
Dubey et al. (2019)	Organizational flexibility	Survey
Sabahi and Parast (2020)	Flexibility (uni-dimensional)	Conceptual

pharmaceutical supply chains were impacted negatively since a significant amount of the raw ingredients used in lifesaving medicines were imported from India. These findings indicate that Pakistani companies must give SC-Resilience a significant place in their business strategies.

Notably, the number of companies identified through the collaborative efforts with different industrial associations and the SC Association of Pakistan (SCAP) amounted to 736. Samples were drawn from the population using a stratified random sampling method. Stratification was carried out based on the organisations' sector (e.g. textile, pharmaceutical, electronics, FMCG, e.t.c). However, there is some limitation of getting the required and appropriate contact details, which limits the distribution of the survey instrument to all 736 companies. Hence, we selected 70% of each stratum from the identified population to obtain representative samples from each sector, which is considered an adequate representation for the study (Sekaran and Bougie 2016). Hence, for that matter, a total of 515 questionnaires were sent to the company via email and through personalized contact. We received 156 responses in the first round, and after gentle reminders through email and telephone calls, another 74 responses were received. However, 39 sets of answers were excluded from the data analysis as some of them were monotone responses, and some of the respondents were other than the associated SC department. Hence, 191

valid responses were incorporated for the data analysis with an effective response rate of 37.1%. Lastly, SC professionals, including professionals working in operations and logistics, were engaged as critical informants regarding the resilient practices utilized within the organization.

3.3 Non-response biased

The non-response bias was tested through early and late responses, as suggested by Armstrong and Overton (1977). We observed insignificant differences in any variables between the early and late respondents. Furthermore, to limit common method bias, we opted for possible measures in developing instruments as advocated by Podsakoff et al. (2003). Thus, the conventional Herman's single-factor analysis was conducted, and the results of 29.3% suggest the absence of common method bias in the dataset. However, this technique possessed limitations (Guide and Ketokivi 2015), and thus, we have opted for a contemporary approach with the PLS marker variable technique. We included four items of the social desirability scale as a marker variable, in which the results indicated an insignificant difference in R^2 between the with and without a marker variable. In other words, the results demonstrated that the effects were not overestimated because of the standard method variance in the data set.

4 Analysis and results

We employed the structural equation modelling technique through the variance-based Partial least square approach (PLS-SEM) to assess the interrelationships among various latent variables. PLS-SEM is suitable when the path model contains any formative constructs (Hair et al. 2019). Furthermore, the approach offered greater statistical power than CB-SEM, given the sample size, which is less than 200 (Hair et al., 2017a). For the application of SEM, at first, reliability and validity tests of measurement scales were conducted, followed by the structural model assessment (Hair et al. 2014).

4.1 Measurement model assessment

As reported by Hair et al. (2019), the constructs that are formative and reflective nature have distinct criteria for assessment of measurement models. SC flexibility is utilized as a formative construct in this study, while SC resilience and exposure to different types of SC risks as reflective measures. In the context of formative action, redundancy analysis is carried to assess the convergent validity. This method is followed by the multi-collinearity assessment and the significance of the outer weights for SC flexibility (SCF), as suggested by Hair et al. (2017b). Figure 3 represents the path model for the redundancy analysis, where the endogenous variable is labelled as Global-SCF and measured through global items.

At the same time, the exogenous construct constituted the latent variable scores of each dimension. The path model results indicated that the path coefficient between the exogenous formative construct and endogenous global construct is 0.791 with an R^2 value of 0.626, more significant than 0.7 and 0.5, respectively. Thus, this result indicated strong support of convergent validity for SC flexibility as a formative construct (Hair et al. 2017b). In the next step, multi-collinearity assessment and significance of outer weights were examined. The results signified that the constructs LF, PDF, MFGF, SBF, and SUPF possessed less than 3.3 VIF values. Their outer weights are significant at less than 5% significance level, indicating the accurate representation of each dimension towards developing SC flexibility as a formative construct, as presented in Table 4.

For the reflective measurement model assessment, the outer model of each construct was analyzed to measure reliability and validity through item loadings, composite reliability, and Average Variance Extracted (AVE). Table 3 demonstrates that all item loadings, CR, and AVE values are more significant than 0.5, 0.7, and 0.7.

Meanwhile, for the assessment of discriminant validity, two techniques were performed, including conventionally used Fornell and Larcker's criteria and the contemporary technique of HTMT (Henseler et al. 2015). In the first technique, as presented in Table 5, the AVE of each construct is more significant than inter squared correlations of the constructs. Additionally, Table 6 shows the values of HTMT. The values are all less than the cut-off value of 0.85, which signifies an adequate level of discriminant validity for all constructs in the study.

4.2 Structural model assessment

For the structural model assessment, Hair et al. (2017b) recommended the standardized path coefficient and the significance of path estimates (t-values), effect size (f^2), and R^2 for endogenous construct. In this study, a bootstrapping procedure with 5000 subsamples was conducted, where in the first phase, the direct effect was tested. Table 7 specifies an assessment of the immediate influence of SC flexibility on SCRES, bearing in mind the moderating role of exposure to different forms of SC risks. Model 1 represents the direct effect of SC flexibility on SC resilience, in which the result indicates that MDSCF ($\beta=0.619$, $p<0.01$) positively influenced SC resilience, supporting hypothesis H1. Hence, focusing on multi-dimensional flexibility increases the organizational ability to prepare, responding, and recovering from the SC disruptions.

Model 2 shows the interaction effect of exposure of different types of SC risks on the relationship between MDSCF and SCRES. The findings revealed significant positive moderating effects for customer-oriented risks ($\beta=0.450$; $t=8.824$; $p<0.01$) and the external risks ($\beta=0.180$; $t=2.813$; $p<0.01$), thus supporting hypotheses H4 and H5. Contrastingly, a weak moderating role was noted for the supplier-oriented risk exposure ($\beta=0.100$; $t=1.712$; $p<0.1$), supporting hypothesis H3. However, there is no significant effect for the internal risk ($\beta=-0.011$; $t>0.1$; $p>0.1$) exposure, thus rejecting hypothesis H2.

Fig. 3 Redundancy analysis

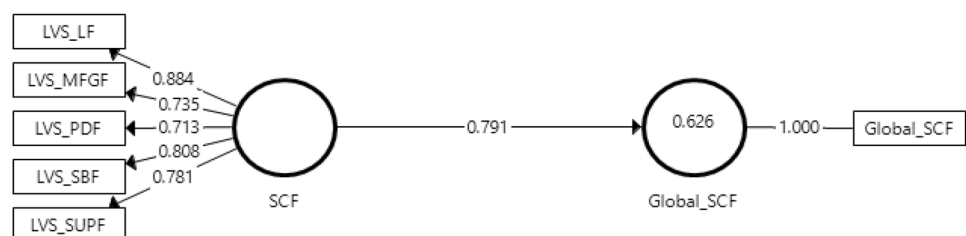


Table 3 Measurement items and reliability and validity assessment

Scale items	Source(s)	Loadings	t-value	Composite reliability	AVE
Multi-Dimensional Supply Chain Flexibility					
Logistics Flexibility					
LF1: We have the ability to fill a variety of inbound shipment requests	Adapted from Jin et al. (2014)	0.863	43.408	0.910	0.669
LF2: We have the ability to quickly respond to changes of inbound shipment requests	Jin et al. (2014)	0.869	42.897		
LF3: We have the ability to customize logistics facilities (Like warehouse space, loading capacity and other distribution facilities)	Moon et al. (2012); Swafford et al. (2006)	0.793	20.238		
LF4: We have the ability to change delivery modes (air, sea, road)	Moon et al. (2012); Swafford et al. (2006)	0.762	15.030		
LF5: We have the ability to transfer delivery schedules	Moon et al. (2012); Swafford et al. (2006)	0.798	18.856		
Manufacturing Flexibility					
PF1: Our firm's manufacturing system can operate at a variety of production volumes	Jin et al. (2014)	0.797		0.916	0.685
PF2: Our firm's manufacturing system can accommodate many different product mixes	Jin et al. (2014)	0.824			
PF3: Our firm's manufacturing system can quickly change product mixes	Adapted from Cao and Zhang (2008)	0.880			
PF4: Our firm's manufacturing system can quickly change machine setup	Moon et al. (2012)	0.874			
PF5: Our firm's manufacturing system has the ability to adjust manufacturing facilities and processes	Moon et al. (2012)	0.758			
Product development Flexibility					
PDF1: Our firm has the ability to introduce a variety of new products	Adapted from Jin et al. (2014)	0.848		0.897	0.686

Table 3 (continued)

Scale items	Source(s)	Loadings	t-value	Composite reliability	AVE
PDF2: Our firm has the ability to modify existing products		0.846			
PDF3: Our firm has the ability to introduce products in a short time	Chiang et al. (2012)	0.823			
PDF4: Our firm has the ability to implement product modifications in short time		0.794			
Suppliers' Flexibility				0.881	0.649
SUPF1: Our key suppliers can satisfy our firm's needs at different order quantities	Adapted from Jin et al. (2014)	0.839			
SUPF2: Our key suppliers can produce a variety of products for our firm		0.779			
SUPF3: Our key suppliers can adjust quantities without significantly increasing cost	Rogers et al. (2011)	0.830			
SUPF4: Our key suppliers can adjust quantities without significantly increasing lead time		0.773			
Supply base Flexibility				0.912	0.721
SBF1: Our firm can quickly identify a new supplier when necessary	Jin et al. (2014)	0.864			
SBF2: Our firm can easily make adjustments in the current relationship		0.841			
SBF3: Our firm can switch to alternative suppliers efficiently		0.855			
SBF4: Our firm encourages purchasing from multiple suppliers	Liao et al. (2010)	0.836			
Supply chain resilience				0.952	0.843
SCRES1: Our firm's supply chain is well prepared for unexpected events	Gölgöci and Ponomarev (2015); Mandal et al. (2016)	0.927			

Table 3 (continued)

Scale items	Source(s)	Loadings	t-value	Composite reliability	AVE
SCRES2: Our firm's supply chain is able to adequately respond to unexpected disruptions by quickly restoring operations		0.922			
SCRES3: Our firm's supply chain has the desired level of connectedness among its members during disruptions	Mandal et al. (2016); (Ponomarov and Holcomb (2009)	0.914			
SCRES4: Our firm's supply chain has the ability to maintain control over structure and function during disruptions	Gölgeci and Ponomarov (2015); Mandal et al. (2016)	0.919			
Internal risks exposure				0.778	0.526
INRE1: machine breakdowns	Park et al. (2016)	0.770	3.609		
INRE3: equipment operating out of specification		0.657	2.455		
INRE4: labor strikes / suspension of operations	Cardoso et al. (2015); Carvalho et al. (2012)	0.743	3.505		
Supplier oriented risks exposure	Park et al. (2016)			0.779	0.543
SORE1: abrupt capacity fluctuations		0.775			
SORE2: inconsistent product quality		0.794			
SORE3: poor delivery performance (e.g., inconsistent delivery)		0.630			
Customer oriented risks exposure	Park et al. (2016)			0.795	0.569
CORE1: inaccurate information about order quantities		0.605	4.850		
CORE3: unpredictable requirements for product features		0.767	9.298		
CORE4: orders for different product combinations		0.867	15.260		
External risks exposure				0.791	0.567
EXRE1: macroeconomic uncertainties (e.g., currency fluctuation, inflation)	Park et al. (2016)	0.541	3.302		

Table 3 (continued)

Scale items	Source(s)	Loadings	t-value	Composite reliability	AVE
EXRE3: legislation or international standards changes for supply chain operations (e.g., ISO9000, transportation laws)		0.787	6.326		
EXRE4: Unrest situations like terrorism, strikes and / or political instability	(Trkman and McCormack 2009; Carvalho et al. 2012)	0.888	9.653		

Table 4 Formative measure model assessment results

Constructs	VIF	Outer weights (Outer loadings)	T value	P value	95% Confidence Interval	Significance
LF	2.648	0.297 (0.869)	14.429	0.000	[0.260, 0.345]	Yes
PDF	1.616	0.285 (0.715)	11.575	0.000	[0.242, 0.345]	Yes
MFGF	1.674	0.193 (0.764)	6.563	0.000	[0.127, 0.244]	Yes
SBF	1.934	0.210 (0.784)	9.495	0.000	[0.164, 0.247]	Yes
SUPF	1.844	0.280 (0.789)	12.922	0.000	[0.245, 0.333]	Yes

Table 5 Fornell and Larcker's (1981) criteria

	CR	ER	IR	LF	MFGF	PDF	SCRES	SBF	SR	SUPF
CR	0.754									
ER	0.203	0.739								
IR	0.417	0.412	0.725							
LF	-0.188	0.151	-0.141	0.818						
MFGF	-0.053	-0.003	-0.095	0.58	0.828					
PDF	-0.055	0.149	-0.092	0.491	0.506	0.828				
SCRES	-0.274	0.265	-0.166	0.552	0.349	0.53	0.92			
SBF	-0.143	-0.001	-0.226	0.655	0.455	0.509	0.417	0.849		
SR	0.298	0.14	0.479	-0.193	-0.142	-0.056	-0.182	-0.156	0.737	
SUPF	-0.156	0.195	-0.263	0.652	0.393	0.456	0.531	0.522	-0.359	0.806

Notably, it is vital to provide a visual presentation to evaluate the effect of moderators on the relationship between MDSCF and SCRES at low and high customer-oriented risk exposure. Hence, a template as proposed by Dawson (2014) was incorporated into this method. In Fig. 4, the green dotted line and dark blue solid line in the interaction graph exhibit the moderator's high and low positions, respectively. The plot indicates a stronger relationship between MDSCF and SCRES for high customer-oriented and external risk exposure than low-risk exposure. In other words, the plot signified that the relationship between MDSCF and SCRES is more vital when firms are subjected to high customer-oriented and external risk exposure. Hence, firms must improve their MDSCF capability across the SC network, especially when pressured from the customer side and external environment, supporting hypotheses H4 and H5, respectively. In the case of supplier-oriented risk exposure, the effect is found to be somewhat significant ($p < 0.1$). Despite this, the statistical findings show that when supplier-oriented risks rise, companies must enhance their MDSCF and their effect on SCRES. At the same time, no interaction effect is observed for the internal threats on MDSCF towards SCRES.

5 Discussion

5.1 Supply chain flexibility and supply chain resilience

The findings of this study showed that MDSCF has a significant favorable influence on SCRES ($p < 0.01$), corroborates prior research indicating that SCF influences SCRES (Brusset and Teller 2017; Mandal 2017; Siagian et al. 2021). SCRES is primarily concerned with a company's capacity to adapt rapidly to changing conditions. This SCRES can be amplified through versatile and flexible plans and alternative arrangements for production at the time of disruptions. Furthermore, the SC designed based on a flexible SC system can promptly respond to disruptive events, which allow organizations to reconfigure and realign their resources and competencies. Customer demand may be quickly adjusted with the flexibility in product creation and production capacity (Rajesh 2021). Moreover, flexibility practices are the alternative way that can be used to enable the risk prevention system of large organizations (Lavastre et al. 2012). For instance, flexible arrangements potentially allow organizations to manage their inventory for their short and long-term needs. Additionally, this approach enables

Table 6 HTMT Results

	CR	ER	IR	LF	MFGF	PDF	SCRES	SBF	SR	SUPF
CR										
ER	0.368									
IR	0.709	0.706								
LF	0.304	0.204	0.288							
MFGF	0.127	0.134	0.157	0.655						
PDF	0.168	0.213	0.273	0.57	0.584					
SCRES	0.34	0.324	0.229	0.605	0.38	0.594				
SBF	0.175	0.092	0.328	0.743	0.511	0.584	0.461			
SR	0.511	0.303	0.839	0.262	0.218	0.105	0.242	0.216		
SUPF	0.222	0.268	0.395	0.761	0.456	0.541	0.606	0.609	0.499	

Table 7 Structural model assessment

	Direct Effect				Indirect effect (Moderators)				
	Coefficient	t value	p	f ²	R ²	Coefficient	t value	P	f ²
MDSCF	0.618	13.716	0	0.618					
IR	-0.053	0.685	0.493	0.001		-0.011	0.2	0.842	0
SR	-0.034	0.649	0.516	0.001		0.1	1.712	0.087	0.041
CR	0.185	2.643	0.008	0.063		0.45	8.824	0.000	0.214
ER	0.160	2.225	0.002	0.037		0.180	2.813	0.005	0.078
SCRES					0.369				

schedules to develop productions accordingly, thereby alleviating the organizations' network risks (Stadtler 2005).

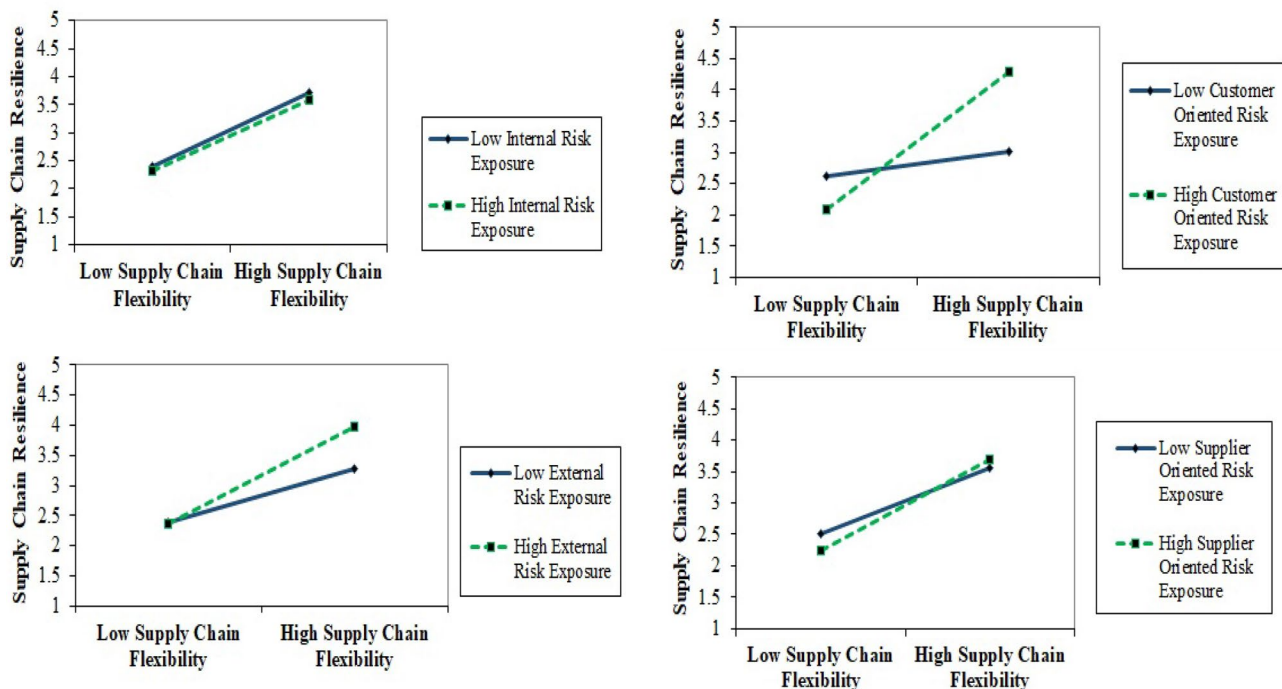
5.2 Moderating role of supply chain risks

The moderating role of the SC risk exposure's different dimensions vis-à-vis the SCF and SCRES revealed significant moderating effects based on the findings. These effects is observed in the supplier-oriented ($\beta = 0.100$; $p < 0.10$), customer-oriented risks ($\beta = 0.45$; $p < 0.01$), and external risk ($\beta = 0.180$; $p < 0.01$). In contrast, an insignificant moderating role was noted for the internal risk ($p > 0.1$).

5.2.1 Supplier and customer-oriented risks as moderators

In their framework, Brusset and Teller (2017) found an insignificant moderating influence of the SC risks in the

association between the flexibility capabilities and SCRES. However, the current study's findings were consistent with the stance proposed by Yi et al. (2011), who noted that firms need to be responsive, agile, and flexible in a high-risk environment. Through this, firms could reconfigure and realign their competencies and resources so that their business processes can function appropriately and efficiently. This idea would, in turn, enable the firms to achieve superior business performances and other competing priorities. For instance, if firms experienced repeated quality products and delivery issues from their suppliers, they will be better prepared to cope with interruptions and resume normal operations more quickly and efficiently. Their actions may be sourcing the same supplies from different sources or switching to new suppliers. Similarly, if there would be an increase in customer demand for seasonal products, these firms can provide the products in the form of materials, fulfilling the

**Fig. 4** Interaction pattern

seasonal demands. This process allows the firms to avoid hiccups when the season is in full swing or peak demand for such particular products. Even with high customer risks, the vertical and large-scale setups often use the postponement strategy to complement their SC flexibility. In the case of production postponement, such firms usually carry semi-finished or intermediate inventories, especially at the very last stage when the demand reached the system. Additionally, firms prefer to carry standard materials to reduce the challenges of designing and producing highly varied product lines. This method would reduce not only the operational bottlenecks but also the operating costs.

5.2.2 Internal and external risks as moderators

The findings show that organisational risks do not have a substantial impact on the connection between flexibility and resilience of the supply chain. Because flexibility is more of an internal phenomenon that is linked with the existing organisational resources and competencies, this phenomenon may be the underlying cause of the internal risk exposure's negligible impact on the SC's ability to respond to changing conditions. The findings of this research also showed that the SC resilience of firms is very susceptible to the impact of external threats. Thus, companies must review their external environment aggressively and constantly, and should create tactical and operational-level measures to fortify SC resilience during times of tumult. The above findings lead to the conclusion that internal risk exposures have little impact on the SC flexibility of Pakistani manufacturing companies. Lastly, firms reacted more quickly to external and network risks concerning MDSCFs, which lead to better SC resilience.

6 Conclusion

This research study used the Dynamic Capability Theory (DCT) to assess the connection between MDSCF and SC resilience when confronted with a high SC risk environment. In this context, it was found that MDSCF significantly influences SC resilience. In addition, the research found the roles of network and external risks in shaping the connection between MDSCF and SC resilience. In the same vein, internal risk exposure appears to be a trivial moderator concerning the connection. Given these points, our study emphasized the multi-dimensional SC flexibility (MDSCF) as a genuinely dynamic capability to improve SC resilience on a theoretical front. The concept encompasses all the SC network's flexibility measures, which are essential for continued SC business operations and the continuation of SC activities. Hence, based on the existing empirical research,

this study appears to be the first to investigate the influence of the MDSCF scale on SCRES.

6.1 Theoretical and managerial implications

Managing disruptions is one of the most critical factors in ensuring an organization's long-term survival. Firms use several complementary strategies or approaches to enhance their resilience (Dabhilkar et al. 2016). Flexibility in the SC is an important strategy that allows companies to deal with interruptions and to develop SCRES. Several research papers have assessed the notion of flexibility as a single-pronged viewpoint about SCRES (Brusset and Teller 2017; Dubey et al. 2019; Mandal et al. 2016). The outcome, however, may not accurately portray the network's level of adaptability. Nevertheless, the SCRES is much aided by the MDSCF measures, as was shown by the findings of the research. In addition to this, when it comes to interacting with different supply chain risks, MDSCF impact on ensuring SC resilience is not yet understood. This research adds to the current body of knowledge by revealing the dynamic interplay between SCR and MDSCF, concerning SCRES. Additionally, it serves as an excellent starting point for further investigation into how other dynamic capability measures affect the development of SCRES in a high-risk supply chain environment. Hence, the impact of the high or low-risk exposures in influencing resilience is a stepping stone for policymakers and SC professionals to monitor these risk factors continuously. They also need to restructure their companies' MDSCF to become more resilient in this environment. The empirical findings obtained from this research may spur management to increase their investment in a SC system that can develop and thrive with constant flexibility.

However, it has been noted that Small and medium businesses (SMEs) in emerging economies are more susceptible to these SC risks. For this reason, SMEs must emulate the experiences of large-scale manufacturing organizations to avert or diminish the adverse effects of these disruptions. At the same time, in the context of Pakistan, policymakers should assist manufacturers by simultaneously helping the companies improve their operational efficiency. Furthermore, the firms need to be cognizant of the dangers so that they can take appropriate steps to address these risks. The interaction of network risks with MDSCF would determine the level of resilience. In other words, to further bolster their SC resilience, firms should improve their MDSCF capabilities by taking account of increasing network risks (supplier and customer-oriented risks) and external threats. Likewise, manufacturers that are vulnerable to network or external threats should realign their resources. Firms can employ

this strategy to prevent operational bottlenecks and restore themselves to a more desirable state swiftly.

6.2 Limitations and future directions

This study is faced with several limitations, where firstly, the relationship between the variables is only observed at a single point in time. In essence, resilience is a dynamic phenomenon that includes the pre, during and post-disruption phases. Hence, the efficacy of resilience can only be evaluated if measured at different time intervals. Secondly, the current study selected only large-scale manufacturing organizations situated in Pakistan. Other manufacturing firms, such as SMEs, which are more prone to SC disruptions, are ignored in the study. Moreover, even large-scale manufacturing companies are confined to one specific geographical territory. In the future, extending the study, which comprised SMEs, is a potential option that would provide more meaningful results in the context of Pakistan.

Furthermore, the study utilized a risk exposure scale computed based on risk occurrences and risk consequences. However, the measures used in this study were based on the respondent's perception, which may or may not represent reality. Therefore, future studies may need to consider the SC risk index exclusively in Pakistan, where the index value is used to assess risk exposure. Moreover, the risk exposure computed through the index value would reflect the turbulent situations in Pakistan, thereby producing effective results. Additionally, future studies should consider using larger sample sizes from different countries with different characteristics, values, and cultures. These factors should include other macro-environmental factors, especially in terms of geographic location. Notably, these varied characteristics of the sample countries may highlight meaningful insights on the role of MDSCF and its interaction effect with various factors towards strengthening the SCRES.

Declarations

Conflicts of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

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