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Resilience and agility in sustainable supply chains: A relational and dynamic capabilities view

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ABSTRACT

The outbreak of COVID-19 has exposed vulnerabilities of supply chains (SCs) and has further accentuated the importance of creating resilient, agile and sustainable SCs. The present study assesses the role of SC technology capabilities in supporting organisations to enhance their SC resilience, thereby improving them on the sustainability front. Drawing from the relational and dynamic capabilities view, the study develops a conceptual model to test the hypothesised relationships. We test the hypotheses employing a survey-based approach that utilises a cross-sectional design. The study uses factor analysis and structural equation modelling techniques to test the fit of the measures to the structural models. We collected the data from the manufacturing / logistics firms in the UK and the US. The findings indicate that SC technology capabilities, agility and visibility positively enhance SC resilience, which in turn affects SC sustainability positively. We understand how SC resilience can determine the effectiveness of the efforts towards enhancing technology capability. Firms must collaborate and build technology capabilities to achieve resilient and sustainable SCs. This research would assist the practitioners and researchers in understanding the role of technology capability and SC resilience and guide them with respect to the configuration of sustainable SCs.

1. Introduction

Supply Chain (SC) resilience is how SCs combat susceptibilities, difficulties and disruptions (Scholten & Schilder, 2015). SC resilience is defined as the ability to carry out operations effectively, even when facing disruptive events (Mandal, 2014). It has become a critical feature that indicates the success of modern firms. Focusing on real-time visibility to make SCs resilient and agile, setting up manufacturing plants closer to the sourcing units or the customers are strategies to foolproof the SCs against potential disruptions (López & Ishizaka, 2019). The disruption in SCs brought by the pandemic caught several firms off-guard and subjected them to vulnerabilities to the extent that SCs across the globe came to a grinding halt. The above scenario suggests that many of the recognised SC resilience strategies (Martini & Vespasiano, 2015) and tools have not been able to mitigate the SC risks imposed by COVID-19 (Kumar & Kumar Singh, 2021). These issues have opened gateways through which we look at the SC management domain from a vantage point of resilience and agility. In SC management, resilience is frequently characterised as quick recovery from disruptions (Behzadi, O'Sullivan, & Olsen, 2020). Several SCs have responded to this disruption by actions such as improving their location choice (López & Ishizaka, 2019), diversifying their product portfolio or making new products based on existing technology and knowledge (Urciuoli, Mohanty, Hintsa, & Boekesteijn, 2014). In line with the discussion above, it is clear that SC activities are accompanied by an inherent risk of unforeseen disruption, which can result in unexpected consequences and therefore, a capacity to sustain SC operations even during disruptions must be developed (Mandal & Sarathy, 2018). To detect SC disruptions, firms need to monitor their environment and make decisions quickly (Bargoni, Bertoldi, Giachino, & Santoro, 2022). Firms often consider innovative and dynamic ways to manage SC disruptions (McClements et al., 2021; Yin & Ran, 2021). Technology capabilities help firms make real-time decisions and respond quickly to market changes. SCs with enhanced technological capability would have better information-sharing and governance practices (Cai, Huang, Liu, & Liang, 2016). Particularly, disruptions caused by the pandemic have

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emphasized the importance of building SC technology capability. The present study focuses on assessing the role of technological capabilities and agility in building sustainable and resilient SCs. Following the seminal work of Rice & Sheffi (2005), the scholarly discussion on SC resilience has come a long way. However, explorations of how SCs develop resilience are still in the nascent stage and there is a need for such assessment in the wake of the massive disruption by the COVID-19 pandemic (Sajjad, 2021). Specifically, there is a muddled understanding concerning how SCs become resilient and why there is a need to move beyond resilience as stability towards resilience as an adaptation and transformation paradigm (Wieland & Durach, 2021). This study is an essential attempt in this direction.

In the extant literature, information and technology capabilities have been linked to superior firm performance (Alkatheeri, Jabeen, Mehmood, & Santoro., 2021). Technologies such as big data and predictive analytics can be utilised to locate the sources of potential disruptions and improve resilience (Benzidia, Makaoui, & Bentahar, 2021; Dubey et al., 2018; Papadopoulos et al., 2017). Information technology (IT) capabilities can detect the relevant patterns in the extensive datasets available from the SCs and thus help SC managers improve the availability of information for the key metrics. Thus, managers can not only better understand complex SCs, but this could be the steppingstone on the way to SCs, which are autonomous and resilient to shocks. As restrictions placed to battle the spread of COVID-19 ease-out, transparency across all stages of SCs has become extremely crucial (Chauhan, Akram, & Gaur, 2021). Firms need to ensure that they are responsive to the rise in demand (Bresciani, Ferraris, Romano, & Santoro, 2021). The foundation of technology capabilities lies in such type of collaboration and information sharing among partners (Alkahtani et al., 2021; Kramer, Bitsch, & Hanf, 2021). The internal and external actors can collaborate to make their SCs equipped with IT technologies such as artificial intelligence and the Internet of Things to increase collaboration (Ayala et al., 2020; M. Chi, Wang, Lu, & George, 2018). With the help of technology capabilities, SCs can bend during times of disruptions such as COVID-19 (Belhadi et al., 2021). The collaboration needs to be utilised in every phase of the SC, right from investing in technology capabilities to co-creating sustainable SCs (Benzidia et al., 2021). The extant literature has also pointed out the role of relational factors such as trust for enhancing collaboration within the SC.

Nonetheless, important effects such as these are yet to be empirically tested or explicated from a theoretical standpoint (Dubey et al., 2019). Therefore, focusing on trust and SC collaboration from the theoretical standpoint of relational capabilities, our conceptual model is built. As discussed earlier, the external environment for a firm is typified by continuous changes and uncertainty. For example, consumer expectations and demands are shifting (Showrav, Hassan, Anam, & Chakrabarty, 2021), regulatory frameworks are changing, and new technologies are coming up (Chauhan et al., 2021). In such conditions, firms need to adjust and revamp rapidly in order not only to survive but also to respond efficiently and viably to several environmental exigencies. Strategic actions by firms to develop dynamic capabilities (DCs) can help. The literature on DCs accentuates that firms must change their resource and capability base and overcome the inertia inherent in their routines, as this inertia prevents them from spotting external changes in the environment and making adjustments (Makkonen, Pohjola, Olkkonen, & Koponen, 2014).

The above discussion highlights the role of SC visibility, trust, SC collaboration, SC technological capabilities, SC resilience and agility. Given the same, the objectives of the present study can be explicitly specified through three key research questions (RQs):

RQ1. How can the role of trust and SC visibility be explicated in SC collaboration?

RQ2. What is the role of SC technological capabilities and SC agility towards SC resilience?

RQ3. Can SC sustainability be achieved through SC resilience and SC agility?

The study addressed these research questions by developing and examining a conceptual model substantiated by the DC and relational view. In this regard, the study addresses several important gaps. With the help of the DC view, the present study posits that SC agility and SC resilience together help build sustainable SCs. In this regard, the role of technological capabilities is also important to create resilient and agile organisations (Bresciani, Ferraris, Santoro, & Kotabe, 2022). However, the extant literature points to mixed findings with respect to the relationship between SC resilience and sustainability. Scholars have underlined clashing principles fundamental to sustainability and resilience, and therefore, the firms need to create trade-offs between the two concepts, as per their capabilities (Rajesh, 2021). Some studies highlight that the dynamics of the market and knowledge base help firms to adapt to the fluctuating environment of the market (resilience) and play an essential role in firms' sustainability (Eikelenboom & de Jong, 2019). To this end, the present study addresses an important gap that involves clarifying the relationship between SC resilience and sustainability.

Despite the immense focus on SC sustainability through the DC perspective (Amui, Jabbour, de Sousa Jabbour, & Kannan, 2017; Beske, 2012; Shan, Li, & Shi, 2020), not much attention has been paid towards building DCs for SC resilience and SC agility. The present study posits that sustainable SC can be achieved with the help of DCs in the form of agility and resilience (or adaptability). SC resilience and SC visibility require firms to act by recognising and combining suitable resources. For example, SC resilience requires firms to utilise technological resources. Agility is often seen as a capability that allows an organisation to develop, amalgamate, and reconfigure the capabilities related to efficiency and effectiveness (Baškarada & Koronios, 2018). The sustainability literature has widely utilised the DC perspective, and much has been said about various capabilities in general. However, the present study attempts to bring about a clear focus on technological capabilities and how these capabilities accentuate SC resilience and agility, thereby making it more sustainable.

Lastly, the study offers a relational view of SC collaboration and trust that focuses on building SC technological capabilities. According to Scuotto, Caputo, Villasalero, & Del Giudice (2017), visibility in the SC improves the coordination cost and buyer–supplier relationships by facilitating transactions between them. It is often recommended that individual SC actors should invest in systems that enhance the visibility of the entire SC (Chauhan, Kaur, Arrawatia, Ractham, & Dhir, 2022). In this regard, it would be interesting to understand the role of visibility and trust among actors in improving collaboration in SCs.

Our study makes several contributions to the existing body of knowledge from three perspectives. First, we intend to establish a relational and DC view of the several key SC constructs which help firms achieve greater performance. These perspectives are tied through a conceptual model which highlights the different relationships between the constructs. Secondly, we underline the importance of SC technological capabilities and SC visibility as the crucial engine between relational and DCs. Finally, we establish how these perspectives help improve SC sustainability.

The structure of the paper is as follows: Section 1 is the introduction section. In section 2, we explicate the theoretical background of the study. Section 3 is dedicated to the development of the hypotheses. In section 4, data and methods have been highlighted. Section 5 presents the results of the study. In section 6, we discuss the findings. In section 7, the study concludes with theoretical and managerial implications and limitations.

2. Theoretical background: DC perspective and relational view

The theoretical background for the present study builds upon the DC and relational view. The DC standpoint in this study posits that SC sustainability is the combined effect of SC agility and SC resilience, achieved through technological capabilities. DCs denote a firm's ability to develop, assimilate, and reconfigure its competencies in response to

fast changes in the environment (Dangelico, Pujari, & Pontrandolfo, 2017; Teece, Pisano, & Shuen, 1997). A firm builds DCs in a certain period rather than outsourcing them (Makadok, 2002). DCs are the combination of a firm's tangible and intangible resources at a given time (Buzzao & Rizzi, 2021). In addition, DCs also incorporate the decisions firms have taken at earlier points in time (Ambrosini & Bowman, 2009). A firm needs DCs to adapt to technological opportunities and changes in consumer demand, and these DCs are difficult to replicate and, hence, an essential source of competitive advantage (Teece, 2007). SC resilience is an operational capability that enables a disrupted or broken SC to reconfigure and reconstruct itself and be more efficient than before (Brusset & Teller, 2017). Thus, the study adopts SC resilience as a DC, which is in line with some of the studies in the extant literature (e.g., Corrales-Estrada, Gómez-Santos, Bernal-Torres, & Rodriguez-López, 2021; Um & Han, 2021). According to Corrales-Estrada et al. (2021), resilience is a critical DC for firms, particularly during crises such as the current COVID-19 pandemic. The dynamics of the market and knowledge base that can be adapted to the fluctuating market environments (resilience) have an essential role to play for the firms moving towards sustainability (Eikelenboom & de Jong, 2019). In addition, it is contended that the focus of the DCs is to take measures that are context-specific and depend on the level of dynamism in the environment (Eisenhardt & Martin, 2000). Despite the focus of the SC sustainability literature on DCs, not much attention has been paid towards building DCs in terms of SC resilience and SC agility. SC resilience and SC visibility require firms to act by recognising and combining suitable resources. For example, SC resilience is often built by capitalising on the firm's technological resources. Technological resources encompass digital technologies that are effective in managing SC management processes (Ardito, Petruzzelli, Panniello, & Garavelli, 2019). Overall, the pivotal role of information gathering and processing has been reckoned to be valuable in explaining the behaviour of organisations during COVID-19. In this perspective, digitalisation technologies and tools can be seen as a means to eliminate the information gap which exists in ambiguous and disruptive situations (Azadegan, Mellat Parast, Lucianetti, Nishant, & Blackhurst, 2020). Technologies such as big data and predictive analytics can be utilised to locate the sources of potential disruptions and improve resilience (Benzidia et al., 2021; Papadopoulos et al., 2017). By detecting relevant patterns in the vast amount of data flowing from the SC, IT capabilities can help SC managers improve the availability of information for the key metrics and better understand the complex workings of their SC. This could be the first step towards an autonomous SC that is resilient to shocks. Firms must be flexible with suppliers while ensuring they can meet rising demand. Therefore, the foundation of these resilience capabilities is information sharing among the partners, which is facilitated by technologies (Alkahtani et al., 2021; Kramer et al., 2021). To detect the roots of issues such as disruption, the firm needs to have sound information processing capability. Information systems enable organisations to process information during the task and allow them to process data efficiently and intelligently, enabling the organisations to adjust or make new plans rapidly with minimal resource costs.

As suggested by Lee (2004), SCs can gain a competitive advantage if they are — *Agile, Adaptable and Aligned.* SC responsiveness can be achieved with the help of DCs in the form of agility and resilience (or adaptability). The present study is in line with the stream of literature (Aslam, Blome, Roscoe, & Azhar, 2018; Baškarada & Koronios, 2018) that considers agility as a capability that allows an organisation to develop, amalgamate, and reconfigure the capabilities related to efficiency and effectiveness. Firms with better DCs proactively shape their environment (Teece, 2007), therefore, the critical role of DCs in SC sustainability has been highlighted. In the extant literature, the role of DCs in sustainability has been widely studied (Amui et al., 2017; Beske, 2012; Shan et al., 2020). The present study views SC agility and SC resilience as the constituents of DCs that lead to SC sustainability.

Further, the study offers a relational view of SC collaboration and trust for building SC technological capabilities. Relational view is understood as the idiosyncratic linkages between the inter-firm resources and routines that act as a cause of relational rents (Dyer & Singh, 1998). The authors define relational rent as extraordinary profit that is produced jointly in a trade relationship. Such rent cannot be created by the firms in isolation; it is created by the combined offerings of the partners in the alliance (Lee, Kim, & Kim, 2014). Hence, relational rents are created when collaborators associate, trade or exchange peculiar assets, knowledge, and resources or capabilities. Additionally, effective administration mechanisms are employed to bring down the transaction costs or grant the realisation of rents through the synergy of the combined resource base (Dubey et al., 2019; Dyer and Singh, 1998). The present study posits that trust facilitates a relational bond between the SC players that leads to sustained collaboration.

3. Hypotheses development

3.1. SC visibility, SC collaboration, trust and technology capabilities

There is mixed evidence in the extant literature regarding the linkage between SC visibility and SC collaboration. For example, Mafini, Pooe, & Loury-Okoumba (2019), in their study on South African manufacturers found that visibility has an insignificant influence on SC collaboration. However, a majority of studies have highlighted the increasingly important role of visibility and information sharing towards sustaining collaboration among SC players (Alkahtani et al., 2021; Baah et al., 2021; Kramer et al., 2021). It is widely accentuated in the literature that technology capabilities enhance SC collaboration (Jimenez-Jimenez, Martínez-Costa, & Sanchez Rodriguez, 2019; Raza, Alshebami, & Aziz, 2020). The present study argues that firms know the benefits of collaboration, and therefore, invest in strengthening their IT capabilities. Chi, Ravichandran, & Andrevski (2010) have argued that the benefits derived from collaborative networks are contingent upon the application of the technology capabilities since firms can exploit resources and information external to them if they are IT-enabled. Chae, Yen, & Sheu (2005), in a Delphi study with suppliers and retailers, have also suggested that cooperation between SC partners precedes the technological capabilities for linking the organisations. Considering the above, the following hypothesis follows:

H1: There is a positive relationship between SC visibility and SC collaboration

The extant literature has also pointed out the role of relational factors such as trust for enhancing collaboration within the SC. For example, it is argued that trust can play an important role in the collaboration-oriented SC relationship (Han, Huang, Hughes, & Zhang, 2021). However, the empirical evidence regarding the relationship between trust and SC collaboration remains mixed. For example, V. Talavera (2014) found that SC collaboration is significantly correlated with the relational construct of trust. Qu & Yang (2015), in their cross-country analysis, suggest that social trust has a direct and positive linkage with SC collaboration. On the other hand, Şahin, Çemberci, Civelek, & Uca (2017) argue that the relationship between SC trust and collaborative advantage is statistically insignificant. Ha, Park, & Cho (2011) introduce two forms of trust in the SC— affective trust and competency-based trust. It is argued that affective trust exerts a significant positive effect on knowledge-related collaboration, while competency-based trust has a positive effect on collaboration concerning decision-making (Ha et al., 2011). In light of the above, we frame the following hypothesis:

H2: There is a positive relationship between trust and SC collaboration.

When internal and external actors in the SC collaborate, the efficacy of which can be enhanced when SCs become equipped with technological capabilities (Ayala et al., 2020; Chi et al., 2018). Particularly, in times of COVID-19 disruption, the need for collaboration among SC partners has boosted the ongoing digitalisation wave (Chauhan et al., 2021). The disruptions caused by the pandemic have exerted stress on

building SC visibility. Managers are required to influence the collaborative efforts of different formal groups within and between organisations (Hogg, van Knippenberg, & Rast, 2012). Thus, internal and external actors need to equip themselves with IT technologies such as artificial intelligence and the Internet of Things to increase collaboration for sharing of critical information (Ayala et al., 2020; Chi et al., 2018). Digital technologies are important for SC management processes and can integrate these processes with effective information handling and therefore, are implemented across organisations (Ardito, Petruzzelli, Panniello, & Garavelli, 2019). Digitalisation technologies and tools can be seen as a means to eliminate the information gap which exists in ambiguous and disruptive situations (Azadegan et al., 2020). Thus, there has been considerable work in area of benefits accrued by digitalisation. In line with the above, we frame the following hypothesis.

H3: There is a positive relationship between SC collaboration and SC technology capabilities.

3.2. SC visibility, SC technology capabilities, SC agility and SC resilience

Faced with the extraneous risks and weaknesses that add to disturbances in the SC, organisations are looking for ways of identifying and defeating these threats. In such conditions, the idea of resilience was introduced, suggesting the capacity of an SC to face unanticipated disruptions (Sheffi & Rice, 2005) and having the inherent capability to reconfigure to come back to a state more efficiently than the pre-disruption level. Mubarik et al. (2021) strongly suggest that organisations must adopt strategies to improve visibility that would indirectly improve SC resilience. It is contended that SCs with better information-sharing practices can make decisions quickly regarding strategies that defy disruptions (Cai et al., 2016) and, therefore, be more resilient. In light of the above, the following hypothesis is developed:

H4: There is a positive relationship between SC visibility and SC resilience

Technologies such as predictive analytics and big data can be utilised to locate the sources of potential disruptions and improve resilience (Benzidia et al., 2021; Dubey et al., 2018; Papadopoulos et al., 2017). Technology capabilities help firms to improve the availability of information for the key metrics in complex scenarios. The key patterns in the immense amount of data flowing from the SC help the managers in their decision-making (Al-Talib et al., 2020). For example, Gu, Yang, & Huo (2021) posit that to achieve SC resilience, the use of IT with suppliers and customers has a significant positive effect. Mandal (2017) found that internal integration positively moderates the relationships between visibility and SC resilience. Michel-Villarreal, Vilalta-Perdomo, Canavari, & Hingley (2021) posit that actors in SCs thrive by improving their collective resilience with the help of digitalisation capabilities. This could be the first step towards an autonomous SC that is resilient to shocks. Firms must be flexible with suppliers while ensuring they can meet rising demand. Therefore, the foundation of these resilience capabilities lies in collaboration and information sharing among the partners (Alkahtani et al., 2021; Kramer et al., 2021). Information systems enable organisations to process information during the task. The information systems allow an organisation to process data efficiently and intelligently, thereby enabling the organisation to adjust or make new plans rapidly, with minimal resource costs. Together, with the help of technology capabilities and SC integration, SCs can bend during times of disruptions such as COVID-19 (Benzidia et al., 2021). Technologies such as big data analytics, advanced trace and tracking systems, and blockchain technology in particular, can help trace the roots of disruptions and detect disruption propagation (Ivanov, Dolgui, & Sokolov, 2015). In light of the above, the following hypothesis is developed:

H5: There is a positive relationship between SC technological capabilities and SC resilience

The extant literature presents mixed evidence concerning SC agility and resilience. For example, Gligor, Gligor, Holcomb, & Bozkurt (2019) suggest that SC agility and SC resilience share some common dimensions such as speed, anticipation and flexibility. 'Agile' means that the firm can flourish in an environment of continuous and unexpected changes (Sarkis, 2001). 'Lean' is a set of practices that can remove all the waste from the system and minimise resource usage. In line with these definitions, lean is a subset of agile (Sarkis, 2001). Going by these definitions, minimised usage of resources (agile) can have a negative impact on the firm's ability to remain resilient. SC activities are often at the risk of unforeseen disruptions and a capacity to sustain SC operations even during disruptions must be developed (Mandal & Sarathy, 2018). Dynamic and innovative ways to manage SC disruptions should be considered (McClements et al., 2021). SC resilience is the ability to sustain its operations in a profitable manner even when faced with disruptive events (Mandal, 2014). To become more resilient, firms should channel their efforts towards agility (Christopher and Peck, 2004). In light of the above arguments, the following hypothesis has been developed:

H6: There is a positive relationship between SC agility and SC resilience

3.3. SC agility, SC resilience and SC sustainability

The extant literature provides evidence regarding the positive linkage between SC agility and SC sustainability (Pratondo, Kusmantini, & Sabihaini, 2021). Specifically, the ecological and social necessities of a wide set of stakeholders indicate the need to be agile (Ciccullo, Pero, Caridi, Gosling, & Purvis, 2018). In a study carried out in the UK, it was found that agile practices have a positive direct as well as indirect effect on the sustainability performance of the firms (Geyi, Yusuf, Menhat, Abubakar, & Ogbuke, 2020). According to Rehman, Al-Zabidi, AlKahtani, Umer, & Usmani (2020), agility can be seen as a capability that can lead to competitiveness and foster sustainability in the SCs. On similar lines, Saengchai & Jermsittiparsert (2019), posit that agility can help the firms to encounter digitalisation-related challenges and provide enough sustainability to the firms. In light of the above, the following hypothesis has been developed.

H7: There is a positive relationship between SC agility and SC sustainability

The conflicting principles fundamental to sustainability and resilience have been highlighted and therefore argued that the firms need to manage trade-offs between the two concepts, as per their capabilities (Rajesh, 2021). For example, the establishment of more facilities to boost resilience leads to a rise in production and subsequently, more transport activities, which in turn leads to a rise in the level of environmental effects. In such cases, strategies like subcontracting are beneficial (Rajesh, 2021). There is mixed evidence in the extant literature regarding the nature of the relationship between SC resilience and SC sustainability. A major source of conflict is that sustainability has a clear focus on efficiency, while resilience focuses on effectiveness (Negri, Cagno, Colicchia, & Sarkis, 2021). A positive linkage is often highlighted in the extant literature (Cook & Jóhannsdóttir, 2021; Durmaz, Demir, & Sezen, 2021; Pratondo et al., 2021). A failure of SCs leads to economic losses and also puts them at systemic risks that include sustainability dimensions (Cook & Jóhannsdóttir, 2021). Therefore, more resilient SCs are found to be more sustainable (Durmaz et al., 2021). In light of the above, the following hypothesis has been developed:

H8: There is a positive relationship between SC resilience and SC sustainability

Fig. 1 presents the conceptual model. The operational description of all research variables is presented in Table 1.

4. Data and method

4.1. Data

A survey questionnaire was developed for the collection of data for the empirical investigation of the conceptualised model. The data was collected in the UK and US, in the most developed regions globally. The

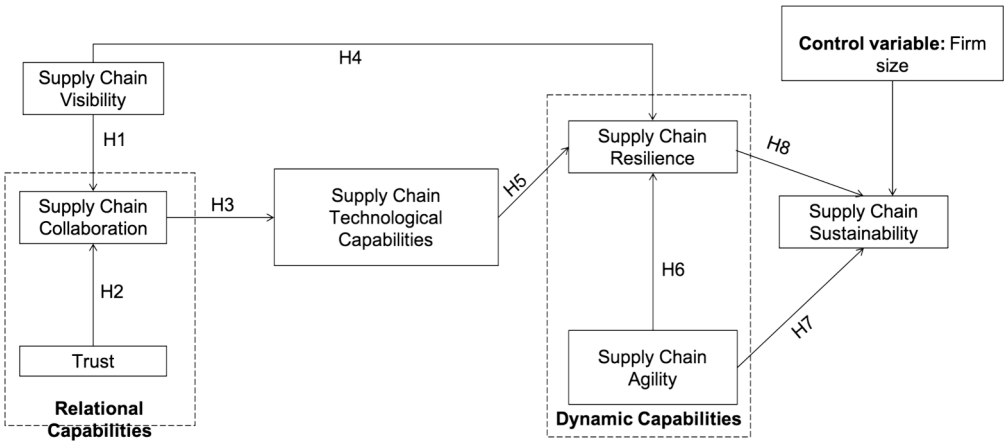

Fig. 1. Conceptual model.

Table 1
Operational description of variables.

Variable	Description	Reference
SC Visibility	SC visibility means information flow in terms of demand levels and inventory levels within the SC and it enhances the transparency of the SC. It can be understood as an organisational capability that can diminish the negative impacts caused by disruption.	(Kurniawan, Zailani, Iranmanesh, & Rajagopal, 2017)
SC Collaboration	SC collaboration can be understood as any action, or group of activities, vis-à-vis interaction, in which actors and or organisations work in cooperative ways for achieving mutually beneficial outcomes.	(Fawcett, Wallin, Allred, Fawcett, & Magnan, 2011)(L. Li, 2012)
Trust	Ensuring the integrity of the SC by the stakeholders.	(Dubey, Gunasekaran, et al., 2019)
SC Technological capabilities	SC technological capabilities enable the SCs to recognise, acquire and harness new knowledge to develop operational competencies for attaining better performance.	(Cai et al., 2016)
SC Agility	The extant literature emphasises that SC agility signifies the abilities possessed by a firm to sense changes and flexibly respond to changes	(Wamba, Dubey, Gunasekaran, & Akter, 2020b)
SC Resilience	The ability of SCs of coping with unanticipated disruptions, i.e. the ability that enables the organisation to survive in a turbulent environment	(Altay et al., 2018; El Baz & Ruel, 2021; Wieland & Durach, 2021)
SC Sustainability	A holistic perspective of processes within the SCs and technologies that beyond the focal areas such as delivery, inventory and traditional firm view	(Kamble, Gunasekaran, & Dhone, 2020) (Y. Li, Dai, & Cui, 2020)(Müller, Fay, & vom Brocke, 2018) (D. Kumar & Rahman, 2016)

respondents were the employees of manufacturing or logistics firms operating in the UK and US. A total of 340 firms were approached for the study. We chose the sector mainly to rule out the confounding effects of different sectors. Out of these firms, 250 gave their consent to participate. The purpose of the study was discussed with the managers of different departments of these firms. The employees were assured that the data they provided would be used for academic purposes only and that confidentiality would be maintained. A total of four hundred employees from various departments were asked to participate in filling out the survey form disseminated via email. The filling of the survey questionnaire was not accompanied by any kind of incentive. To ensure the validity of the responses, unique IP addresses and email IDs were deployed. In addition, the authors stayed in contact with the managers of different divisions by sending out emails or short messages. At first, 293 responses were gathered; but 11 responses were removed because of incomplete survey responses. The final sample size of 282 was eventually utilised for further examination.

4.2. Instrument

To develop the instrument for this study, we started with item generation from the extant body of research. We generated the items from the literature survey and in consultation with management academicians to achieve constructs' content validity (Bergkvist, 2016). SC visibility was measured using three items adopted from Kurniawan et al. (2017). SC collaboration was measured using three items adopted from Fawcett et al. (2011) and Li (2012). We used six items from Dubey et al., (2019a)Dubey et al. (2019) to measure trust. To measure SC technological capabilities, we used three items from Cai et al. (2016). SC resilience and SC agility were measured using three and six items each, adopted from Altay et al. (2018). Finally, we adopted a two-dimensional construct with a total of 7 items to measure SC sustainability adopted from the extant literature ((Dubey et al., 2019a; Li et al., 2020). To control for confounding effects, we used annual sales as a measure of firm size. The framing of the items was kept suiting the needs of our context.

The final questionnaire was reviewed by five experts (three academicians and two senior-level managers working in industry). This process helped us in improving the clarity and meaningfulness of the items. Finally, we used an instrument devoid of semantic discrepancies to collect data from the respondents.

4.3. Data analysis

The Z-scores were computed for all the measurement items, and it confirmed the absence of any outliers, due to which the collected data of 282 employees were found fit for further statistical analysis. The conditions of normality were established as the skewness and kurtosis values for all the measurement items were within the suggested threshold limit (George & Mallery, 2010). The Variance Inflation Factor (VIF) and tolerance values were computed to examine if multicollinearity is a problem in the dataset. VIF values below 3 and tolerance exceeded 0.1, which suggests that data is free from any multicollinearity

problem (McBride, Carter, & Phillips, 2020).

5. Results

The data obtained in the form of responses from the participants were analysed in AMOS. The Structural Equation Modeling (SEM) technique was utilised for the estimation of the measurement and structural model (Hair, Anderson, Tatham, & Black, 2010). Before testing the proposed hypotheses, a confirmatory factor analysis (CFA) was run to assess the measurement model's validity and reliability, following the two-stage method (Anderson & Gerbing, 1988).

5.1. Common method bias (CMB)

As per the suggestions of Podsakoff, MacKenzie, Lee, & Podsakoff (2003), it is possible that common method bias (CMB) issue in the responses could lead to wrong estimation since a single instrument was utilised for the collection of the responses. A multifaceted approach was applied to check for the issue of CMB in the study. As a first step, respondent-level CMB was reduced in the design stage of the questionnaire. To ascertain the respondents' attention, reverse item scales were employed in the questionnaire. In the second step, Harman's single-factor test was utilised to evaluate the study variables. Harman's single-factor test did not point out CMB-related issues since only 31.98 % of the total variance could be explained by a single factor, which was much below the maximum threshold of 50 % (Podsakoff et al., 2003).

5.2. Measurement model

The measurement model was tested using CFA, and it suggests the model has a good model fit because all the goodness of fit indices were within the suggested threshold values ($\chi 2/df$ = 1.86, *CFI*=0.93, *TLI*=0.92, *RMSEA*=0.06) (Hair et al., 2010). As evident from Table 2, the factor loading values are found to be within the range of 0.66–0.89, hence surpassing the desired threshold limit of 0.60 (see Table 2) (Hair et al., 2010). Table 3 depicts the average variance extracted (AVE) and composite reliability (CR). The CR value, a measure of internal consistency in scale items, for each construct needs to be more than 0.7. As evident from the results, the range of values varied between 0.764–0.926, which confirms that study measures possess sufficient internal consistency reliability. AVE, which measures the amount of variance explained by a construct as against due to measurement error, should be greater than 0.5 (Fornell & Larcker, 1981) to ascertain convergent validity. All the values of AVE surpassed the suggested cut-off as values ranged from 0.520 to 0.808. The study measures possess sufficient convergent validity as the item loadings for all study measures were above 0.60, and AVE exceeded the recommended cut-off of 0.50 for different measures. Similarly, the study measures possess sufficient discriminant validity because correlations between the study measures were below 0.80 and all square roots of AVEs were much greater than the respective inter-construct correlations as visible in Table 3. Furthermore, the heterotrait-monotrait (HTMT) analysis (See Table 4) also suggests the presence of sufficient discriminant validity as the correlations between the different study constructs were below the recommended threshold value of 0.85 (Henseler, Ringle, & Sarstedt, 2015).

5.3. Control variables

In the tested model, we have controlled the confounding effect of the firm size measured as annual sales (Azadegan et al., 2020) on the main outcome variable, i.e., SC sustainability. The rationale for choosing a firm size is that large firms tend to have greater access to resources and superior control over them (Ambulkar, Blackhurst, & Grawe, 2015). At the same time, extant literature posits that smaller firms can show the required agility and employ innovations when faced with revamping

Table 2
Factor loadings for the constructs.

Study Measures (Reference)	Measurement items	CFA	SEM
SCV	SCV1: My organization informs our partners in advance about the changing customer needs during the ongoing COVID-19 lockdown	0.81	0.79
	SCV2: My organization informs our partners about customer's future needs during the ongoing COVID-19 lockdown	0.77	0.77
	SCV3: My organization communicates "future strategic needs" with our partners during the ongoing COVID-19 lockdown	0.83	0.84
SCC	SCC1: Our organization shares "production planning information and data" with channel partners even during the ongoing COVID-19 lockdown	0.76	0.74
	SCC2: Our organization shares inventory level information within the supply chain partners even during the ongoing COVID-19 lockdown	0.73	0.72
	SCC3: Our organization shares detailed "information about delivery schedule and responsibilities in contracts" with partners even during the ongoing COVID-19 lockdown	0.67	0.67
TR	TR1: Our organization can count on our partner to be sincere even during the ongoing COVID-19 lockdown	0.77	0.77
	TR2: When we share our problems with our partner, we know that the specific partner will respond with understanding even during the ongoing COVID-19 lockdown	0.80	0.80
	TR3: Whenever our partner gives us advice on our business operation, we know that the specific partner is sharing their best judgement even during the ongoing COVID-19 lockdown	0.74	0.74
	TR4: Although circumstances change, we believe that our partner will be ready and willing to aid and support even during the ongoing COVID-19 lockdown	0.81	0.81
	TR5: While making important decisions, our partner is concerned about the welfare of our organization even during the ongoing COVID-19 lockdown	0.77	0.77
	TR6: When it comes to things that are important to us, we can depend on our partner's support even during the ongoing COVID-19 lockdown	0.85	0.85
SCTC	SCTC1: Our organization provides IT enabled services to our customers even during the ongoing COVID-19 lockdown	0.89	0.89
	STCT2: Our organization has IT enabled services to our suppliers even during the ongoing COVID-19 lockdown	0.95	0.95
	SCTC3: Our organization use IT enabled services to our external partners for entrepreneurial collaborations even during the ongoing COVID-19 lockdown	0.85	0.85
SCR	SCR1: My organization's supply chain is able to adapt to the supply chain disruption easily during the ongoing COVID-19 lockdown	0.81	0.81
	SCR2: My organization's supply chain is able to provide a quick response to the supply chain disruptions during the ongoing COVID-19 lockdown	0.83	0.83
	SCR3: My organization's supply chain is able to maintain high situational awareness at all times during the ongoing COVID-19 lockdown	0.80	0.80
SCA	SCA1: Our organization is working towards measures that help in improving "manufacturing throughput times" even during supply chain disruption because the ongoing COVID-19 lockdown	0.75	0.76
	SCA2: Our organization is working towards measures that help in improving "customer delivery times" even during supply chain disruption because the ongoing COVID-19 lockdown	0.82	0.82

(*continued on next page*)

Table 2 (*continued*)

Study Measures (Reference)	Measurement items		CFA	SEM
	SCA3: Our organization is working towards measures that help in improving "replacement times of purchases" even during supply chain disruption because the ongoing COVID-19 lockdown		0.72	0.72
	SCA4: Our organization is ready to work towards delivery reliability brought by the supply chain disruption during the ongoing COVID-19 lockdown		0.82	0.81
	SCA5: Our organization is ready to work towards reducing replacement times of purchases brought by the supply chain disruption during the ongoing COVID-19 lockdown		0.75	0.75
	SCA6: Our organization is ready to work towards adjusting ordered of goods and services in the short-term brought by the supply chain disruption during the ongoing COVID-19 lockdown		0.72	0.72
SCS	EnSCS	EnSCS1: Our organization has optimized the waste (e.g., solid, liquid, gas, energy) even during the ongoing COVID-19 lockdown	0.86	0.86
		EnSCS2: Our organization has optimized the consumption of toxic material even during the ongoing COVID-19 lockdown	0.78	0.78
		EnSCS3: Our organization has improved the environmental condition even during the ongoing COVID-19 lockdown	0.82	0.81
		EnSCS4: Our organization has improved energy efficiency even during the ongoing COVID-19 lockdown	0.78	0.78
	EcSCS	EcSCS1: Our organization has optimized the "rework and rejection cost" even during the ongoing COVID-19 lockdown	0.71	0.71
		EcSCS2: Our organization has optimized the "purchasing cost for raw material" even during the ongoing COVID-19 lockdown	0.65	0.65
		EcSCS3: Our organization has best practices for assets utilization even during the ongoing COVID-19 lockdown	0.75	0.74

their operations to suit the requisites of a sustainable SC (Chowdhury & Quaddus, 2017). Therefore, the literature is ambivalent in terms of how the size of a firm impacts sustainable SCs. The study results suggest that firm size has no confounding influence on SC sustainability (β = -0.03, $p < 0.05$).

5.4. Structural model

The structural model testing suggests that the structural model possesses sufficient model fit ($\chi 2/df$ = 1.86, *CFI*=0.93, *TLI*=0.92, *RMSEA*=0.06). As evident from Table 5, the coefficients weights and the associated statistical significance for the different hypotheses are as follows: H1 ($\beta = 0.48$, $p < 0.001$), H2 ($\beta = 0.41$, $p < 0.001$), H3 ($\beta = 0.44$, $p < 0.001$), H4 ($\beta = 0.26$, $p < 0.001$), H5 ($\beta = 0.14$, $p < 0.01$), H6 ($\beta = 0.45$, $p < 0.001$), H7 ($\beta = 0.33$, $p < 0.001$), H8 ($\beta = 0.38$, $p < 0.001$). Finally, the proposed research model explained 57 % variance in SC collaboration, 18.9 % variance in SC technological capabilities, 44.1 % variance in SC resilience and 40 % variance in SC sustainability as shown in Fig. 2.

6. Discussion

The findings of this study contribute to the current literature on sustainable SCs, resilience and agility. Given the objectives of this study, some important conclusions can be drawn from the data analysis. Support for H1 corroborates a positive linkage between SC visibility and SC collaboration, and support for H2 leads to a positive association between trust and SC collaboration. The impetus for SC collaboration in studied companies with the help of enhanced visibility has been found. We add to the studies that have highlighted the increasingly important role of visibility and information sharing towards collaboration among SC players (Alkahtani et al., 2021; Baah et al., 2021; Kramer et al., 2021). Through this investigation, we answered research question 1.

The consonance between trust and collaboration is also in line with the existing studies. The existing studies have posited that trust has a significant impact on SC collaboration (Baah, Acquah, & Ofori, 2022; de Paula, Campos, Pagani, Guarnieri, & Kaviani, 2020; Salam, 2017; V. Talavera, 2014). The extant literature has pointed out the role of relational factors such as trust for enhancing collaboration with the SC. For example, V. Talavera (2014) found that SC collaboration is significantly linked to trust.

Support for H3 indicates a positive relationship between SC

Table 4
HTMT analysis.

	SCV	SCC	TR	SCTC	SCR	SCA	SCS
SCV							
SCC	0.638						
TR	0.438	0.586					
SCTC	0.344	0.397	0.425				
SCR	0.460	0.598	0.740	0.464			
SCA	0.408	0.521	0.474	0.347	0.590		
SCS	0.379	0.375	0.362	0.304	0.471	0.516	

Table 5
Regression results.

Hypothesis	Path	Estimate	P	Support
H1	SCV→SCC	0.48	<0.001	Yes
H2	TR → SCC	0.41	<0.001	Yes
H3	SCC→SCTC	0.44	<0.001	Yes
H4	SCV→SCR	0.26	<0.001	Yes
H5	SCTC→SCR	0.14	<0.01	Yes
H6	SCA→SCR	0.45	<0.001	Yes
H7	SCA→SCS	0.33	<0.001	Yes
H8	SCR→SCS	0.38	<0.001	Yes

Table 3
Reliability and convergent validity scores.

	CR	AVE	MSV	ASV	SCS	SCV	SCC	TR	SCTC	SCR	SCA
SCS	0.842	0.733	0.323	0.222	0.856						
SCV	0.846	0.648	0.388	0.210	0.441	0.805					
SCC	0.764	0.520	0.388	0.273	0.448	0.623	0.721				
TR	0.909	0.625	0.540	0.275	0.434	0.439	0.573	0.790			
SCTC	0.926	0.808	0.208	0.145	0.342	0.333	0.366	0.410	0.899		
SCR	0.856	0.665	0.540	0.329	0.568	0.462	0.577	0.735	0.456	0.816	
SCA	0.893	0.582	0.355	0.240	0.555	0.404	0.503	0.479	0.360	0.596	0.763

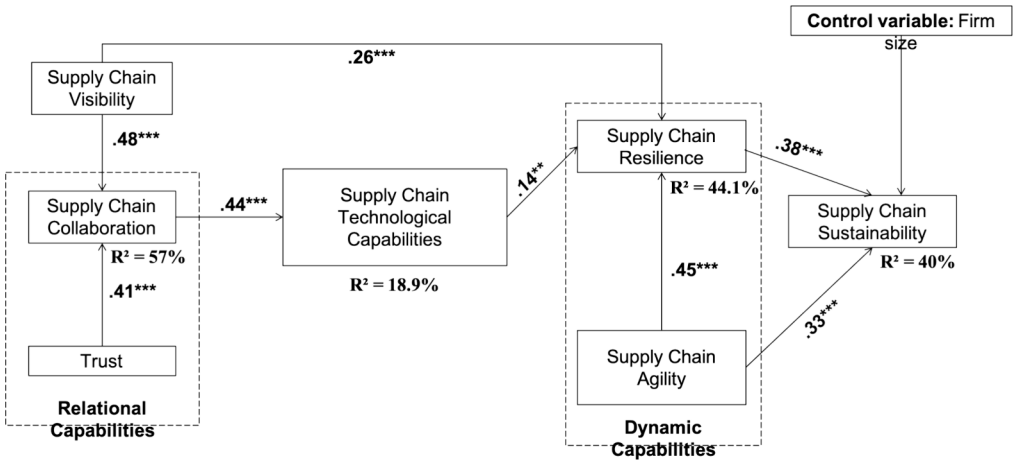

Fig. 2. Result of hypotheses testing.

collaboration and SC technology capabilities. When internal and external actors in the SC collaborate, SCs become equipped with technological capabilities (Ayala et al., 2020; M. Chi et al., 2018). Particularly, in times of COVID-19 disruption, the need for collaboration among SC partners has boosted the ongoing digitalisation wave (Chauhan et al., 2021). Support for H4 confirms a positive relationship between SC visibility and SC resilience. Specifically, disruptions caused by the pandemic have exerted stress on building SC visibility. SCs with better information-sharing practices can make decisions quickly (Cai et al., 2016) and therefore be more resilient.

Support for H5 confirms a positive association between SC technological capabilities and SC resilience. Technologies such as big data and predictive analytics can be utilised to locate the sources of potential disruptions and improve resilience (Benzidia et al., 2021; Dubey et al., 2018; Papadopoulos et al., 2017). Technology capabilities help firms to improve the availability of information for key metrics in complex scenarios. The relevant patterns in the vast amount of data flowing from the SC help the managers in their decision-making (Al-Talib et al., 2020). For example, Gu et al. (2021) posit that to achieve SC resilience, the use of IT with suppliers and customers has a significant positive effect.

The analysis also supported H6, which depicts a positive association between SC agility and SC resilience. The extant literature presents mixed evidence with respect to SC agility and resilience. For example, Gligor et al. (2019) suggest that SC activities often are at risk of unforeseen disruption and a capacity to sustain SC operations even during disruptions must be developed (Mandal & Sarathy, 2018) and dynamic and innovative ways to manage SC disruptions should be considered (McClements et al., 2021). SC resilience is the ability to sustain operations in a profitable manner even when disruptive events arise (Mandal, 2014). With these expositions, we were able to answer the research question 2.

The support for H7 and H8 was also established with the empirical examination. Therefore, a positive association between SC agility and SC sustainability was confirmed. It was also confirmed that SC resilience also exerts a positive impact on SC sustainability which is in line with the extant literature (Cook & Jóhannsdóttir, 2021; Durmaz et al., 2021; Pratondo et al., 2021). The results of the present study provide clarity with respect to the mixed findings in the literature and answer research question 3.

7. Conclusions

The present study highlights the role of SC visibility, trust, SC collaboration, SC technological capabilities, SC resilience and agility. The study addressed these research questions by developing and examining a conceptual model substantiated by the DC and relational view. The present study clarifies mixed findings regarding the role of trust and SC visibility SC collaboration. The findings of the present study are in line with V. Talavera (2014) and Qu & Yang (2015) as these studies found that SC collaboration is significantly correlated with trust.

The study offers a relational view of SC collaboration and trust that focuses on building SC technological capabilities. To strengthen the collaborative efforts of different inter-organisational and intra-organisational groups (Hogg et al., 2012), internal and external actors need to equip themselves with technologies. The conceptual studies in the extant literature have widely posited that technologies such as artificial intelligence, and the Internet of Things help to increase collaboration and enable sharing of information (Chauhan et al., 2022). The present study has addressed the recent calls for empirical studies in this domain (Chauhan et al., 2022). In the present study, it is found that digitalisation technologies act to reduce the information gap and facilitate collaboration.

Further, the study finds an important role of technological capabilities in building resilient organisations. In this perspective, digitalisation technologies and tools can be seen as a means to eliminate the information gap which exists in ambiguous and disruptive situations (Azadegan et al., 2020). The foundation of resilience capabilities lies in information sharing among the partners, which can be done with the help of technologies (Alkahtani et al., 2021; Kramer et al., 2021). This is the first step on the way to an autonomous SC that is resilient to shocks.

Firms should be agile to ensure that they can adjust to fluctuating demands even during pandemic-like situations. The extant literature indicates mixed evidence with respect to the relationship between SC agility and resilience. Lean organisations are those that can remove all wastages from the system and minimise resource usage. However, minimised usage of resources (agile) can have a negative impact on the firm's ability to remain resilient. The present study clarifies this linkage as it is found that there is a significant positive relationship between SC agility and resilience.

By utilising a DC view, the present study also presents an important finding regarding SC agility and SC resilience as these capabilities build sustainable SCs. The present study clarifies the mixed findings (Rajesh, 2021) with respect to the linkage between SC sustainability and SC resilience that arise due to conflicting principles. Agility helps the firm to develop, amalgamate, and reconfigure its resource base and build capabilities related to efficiency and effectiveness (Baškarada & Koronios, 2018). The present study clearly finds that the agility of the firm is positively linked to sustainability. These findings are in line with the extant literature (Ciccullo et al., 2018; Pratondo et al., 2021), which indicates that the sustainability focus of a wide set of stakeholders leads to the need to be agile.

7.1. Theoretical implications

The present study has some important theoretical implications. First, the study conceptualised a far-reaching framework of SC sustainability which strengthens earlier theorisation of SC resilience, SC agility and SC technology capability. The SC trust, visibility and SC collaboration were posited as the antecedents of the SC technology capability, SC resilience, SC agility and SC sustainability constructs. Hence, the study provided a comprehensive framework to understand the role of each of these constructs. Our findings are in line with Aslam et al. (2020), which demonstrate how SC agility serves as a positive mediator between SC ambidexterity and SC resilience, underscoring its importance in adapting to challenges. Our findings are also in line with the stream of research that highlights the importance of technology towards SC resilience. For example, Hossain, Akhter, & Sultana (2022) have illustrated how enterprises leveraging technology emerge as successful and profitable entities following SC disruptions. Moreover, Tan, Cai, & Zhang *2020) and Wong, Tan, Govindan, Li, & Kumar (2023) highlight key elements contributing to SC resilience, including information security culture, information sharing effectiveness, processing requirements and capabilities, effective communication, and information management. Notably, SCs with heightened agility, as outlined by Aslam et al. (2020), demonstrate superior capabilities in sensing environmental threats and potential disruptions. Further, in the context of sustainability, our findings are in line with Singh, Hamid, & Garza-Reyes (2023), as it is explicated that resilience strategies exert the greatest influence on economic and environmental sustainability.

Second, the impact of the wide-ranging tenets of DCs (SC agility and resilience) and relational view (trust and SC collaboration) extend the prior work in the domain of sustainable SCs (Altay, Gunasekaran, Dubey, & Childe, 2018; Chowdhury & Quaddus, 2017; Dubey et al., 2019; Wamba, Dubey, Gunasekaran, & Akter, 2020a). The study would also serve as a foundation to utilise DCs and relational views to emphasise how SCs can be equipped to function sustainably without being impacted by disruptions by utilising technology capability and collaboration among SC players. These findings are in line with the extant SC studies (Baah et al., 2021; Chan & Chung, 2002).

Third, the present study is an endeavour to contribute to SC visibility, resilience, agility and sustainability literature and responds to the call of extant literature for further empirical investigation on the topic (Ivanov, 2020; Marchese et al., 2018; Nath & Agrawal, 2020). We provide empirical support to the call for further investigation of the work of Ivanov (2020), thereby extending their work. Further, through our conceptual model and theorisation, we extend the work of Marchese et al. (2018), whose work caters to the synthesis of work on resilience and sustainability. Finally, we extend the work of Nath and Agrawal (2020) to provide additional empirical evidence for agility and sustainable SCs.

Fourth, this research also contributes to the COVID-19-specific SC management literature by highlighting the applicability of the DC view and relational view in the context of managing disruptions. Organisations have been confronted with unprecedented disruptions, such as SC disruptions and regulatory changes. The literature contends that, by applying the DC view, organisations can identify and leverage their internal capabilities to respond effectively to these disruptions (Song, Chang, Cheng, Liu, & Yan, 2024). Further, the relational view emphasises the importance of networks. Our findings are in line with Yang, Liu, & Kholaif (2022). In the context of COVID-19, strong relationships that are characterised by trust and collaboration within the SC become even more critical for managing disruptions effectively (Yang et al., 2022).

7.2. Managerial implications

The study has some important practical implications. The modern business landscape exemplifies dynamism which can be taken care of by building robust SCs with the tenets of resilience and agility. In addition, modern businesses compete not just on the basis of firm-level resources and capabilities but through close collaborative efforts that span the SC of the firm. Further, firms are challenged by the increasing frequency of events, thereby exuding firms to build resilient SCs. This study envisages and builds on the characteristics of the resilient SC and ties it with the ever-increasing need for firms to be sustainable in the long run.

First, the model signified an all-inclusive and systematic assessment of the impact of SC-related practices instead of looking at standalone practices- SC collaboration or agility. Thus, the study presents an overarching view of important aspects of a SC, particularly with respect to the post-COVID-19 era.

Second, the findings exemplify the necessity for managers to deploy collaboration in the SC as a strategy that is augmented by practices such as information sharing and maintaining mutual trust (Dorn, Schweiger, & Albers, 2016). These practices would help the firms to build resilient and agile SCs that can deal with contingencies such as the outbreak of COVID-19.

Third, the findings provide empirical evidence of the sustainability orientation of agile and resilient SCs, providing managers with key insights towards strategic actions required to develop sustainable SCs.

7.3. Limitations

As is the case with any research, the present study also has its set of limitations that also act as a prospect for future exploration in this domain. First, the study design is based on cross-sectional data within the context of the UK and US firms. Therefore, future explorations in other countries might provide a broader range of information and nuances.

Second, the study focused on SC resilience, and SC agility as the strategic actions to manage disruptions. However, recent studies have deployed these concepts as an outcome of disruption caused by the pandemic outbreak (e.g., El Baz and Ruel, 2021). Consequently, future scholarly work should inspect the antecedents and outcomes of these concepts and specifically how both these constructs affect SC operational performance.

Third, future work can use longitudinal research design to understand the DC and how they affect SC sustainability in the long run. Finally, the present study utilises the data provided by the managers. Other sampling techniques may be employed in future studies.

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CRediT authorship contribution statement

Manzoor Ul Akram: Writing – review & editing, Writing – original draft, Validation, Methodology, Data curation. **Nazrul Islam:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Conceptualization. **Chetna Chauhan:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Muhammad Zafar Yaqub:** Writing – review & editing, Validation, Supervision.

Data availability

Data will be made available on request.

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