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Supply chain resilience during the COVID-19 pandemic

Dilek Ozdemir ^a, Mahak Sharma ^b, Amandeep Dhir ^{c,d,e}, Tugrul Daim ^{f,g,*}

^a Izmir Katip Celebi University, Turkey

^b National Institute of Industrial Engineering, NITIE, Mumbai, India

^c Department of Management, School of Business & Law, University of Agder, Norway

^d Norwegian School of Hotel Management, University of Stavanger, Stavanger, Norway

^e Optentia Research Focus Area, North-West University, Vanderbijlpark, South Africa

^f Portland State University, USA

^g Chaoyang University of Technology, Taiwan

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ABSTRACT

The COVID-19 pandemic has challenged supply chains more seriously than ever before. During this prolonged global health crisis, supply chain managers were forced to rely primarily on solutions developed for limited and foreseeable crises. This study aimed to understand how well existing solutions facilitated supply chain resilience in the UK perishable goods market. Consistent with this aim, we developed a research model based on the supply chain resilience literature and tested it with covariance-based structural equation modelling. Data were collected from 282 retail employees. Supply chain velocity was the preferred measure of resilience. The findings demonstrate that pandemic-related disruptions have affected resilience-building activities. While both proactive and reactive approaches have promoted resilience building during the pandemic, they have not been sufficient to ameliorate all the pandemic's negative effects. Innovation featured as the most effective factor, followed by robustness, empowerment, and risk management via reduced risk. The effect of firm size was significant only on supply chain risk management, with larger companies more efficiently applying risk management practices. The results emphasise the importance of innovation for supply chain resilience. Regardless of firm size, innovation works for every company. Empowerment is another costless and effective tool. Therefore, it is safe to conclude that innovation and empowerment can help organisations to manage their supply chains effectively during crises. Companies can strengthen their supply chain resilience by developing strong relationships with their supplier and employees.

1. Introduction

The COVID-19 pandemic has made us painfully aware that we must reconsider our healthcare systems, business models, lifestyles, and many other things, including supply chain management. In 2020, shortages in the supply of many goods were among the most prominent topics in the media, policy discussions and everyday conversation. Demand structure changed drastically. The supply side witnessed closed factories and empty store shelves [1–4]. Prior to the pandemic, we concentrated on developing agile, lean, sustainable, green, optimised, and efficient supply chains. During the pandemic, we have not forgotten these subjects; however, our concerns have changed drastically.

As with many other goods, the equilibrium between the demand and supply of perishable goods, which refer to goods that have limited shelf-

lives—mostly food and beverages, was disrupted. Retailers have always had to sell such products before their expiration dates [5], but this concern has expanded during the pandemic. For example, because of social distancing and the rapid proliferation of the home-office concept, people now require fewer cosmetics; as a result, the expiration dates of cosmetic products have become an issue for retailers. On the other hand, the demand for some perishable goods has boomed [6]. The effects of the pandemic became visible in food supply chains very quickly, and the range of available products changed. Early in the pandemic, shortages in some products drove consumers into panic mode and caused them to buy more than they required [7,8], while others suffered from food shortages due to decreased incomes [9]. Not the consequences of a shortage of raw materials, these circumstances resulted instead from supply chain failures.

* Corresponding author. Portland State University, USA.

E-mail addresses: namandeep.dhir@uia.no (A. Dhir), Tugrul.u.daim@pdx.edu (T. Daim).

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The severity of product shortages increased alongside the increasing distances between processing units and retail stores [10]. Interruptions in international transportation and closed borders limited the availability of imported perishables [8] and left consumers facing supply shortages. Thus, the scene on the supply side was also troubling. Decreases in inputs, labour and prices reduced both the production capacity and income of producers, some of whom could not sell their products and thus were forced to allow massive amounts of goods to rot [11,12].

Addressing these current and potentially future challenges impel us to rethink resilience, robustness, and risk management concepts in the supply chain management domain. While these efforts were on our agendas before the pandemic, they figure differently—and more prominently—today. Prior to the pandemic, terrorist attacks, fires at plants and the loss of important suppliers were commonly discussed disruptions [13]. However, these and other disruptions discussed in the literature are generally local or regional, rarely impact demand structure, have a limited duration, and occur after predictable risks, such as strikes or bankruptcy. Meanwhile, the literature has neglected black swan events, such as the COVID-19 pandemic. With its global impact and long duration, the pandemic has altered demand structure more significantly than it has supply structure, and it has affected even financial systems. Unlike other disruptions, the COVID-19 pandemic came with no contingency plan or prior experience. In other words, it caught us off guard [14]. No industry is immune to pandemic-related disruptions [15,16]. Therefore, this study aimed to identify the factors that have affected the supply chain velocity of perishable food products during the COVID-19 pandemic and to investigate the ways in which these factors exert their effects. We proposed and tested a model via covariance-based structural path modelling. The rest of the paper proceeds with a literature review, hypotheses development, description of data and methodology, results, and conclusion.

2. Literature review

Vulnerability is defined as ‘... a condition that affects a company’s goal accomplishment dependent upon the occurrence of negative consequences of disturbance’ [17]. The ISO 31000 document defines risk as the ‘effect of uncertainty on objectives’, which it articulates as a combination of probability and consequences [18]. Therefore, vulnerability is related to risky or unforeseen events.

Supply chains must consider many risks and uncertainties, which impose diverse ways of handling. Such risks can originate from the firm itself, the supply chain of which the firm is a member or the supply chain’s environment. The risks that originate from a firm’s internal operations are process risks and control risks. Variability in operations and inbound and outbound logistics cause process risks, while managerial issues and poor supply chain visibility cause control risks. Firms bear full responsibility for these kinds of risks. Risks related to demand and supply occur within the supply chain. Demand risk is associated primarily with differences between forecasted and real demand. On the supply side, deviations from promised time, quality and quantity are the main antecedents of risk. Although many sources of risk exist, disruptions generally result from uncertainties that originate outside supply chains [19–21]. The World Economic Forum identifies 19 triggers of disruption under four categories: environmental, geopolitical, economic and technological; these triggers include pandemics [22].

Structural complexity and interdependencies within the supply chain increase vulnerability by creating a ripple effect [23], especially for firms that hold a central position. To be more specific, globalisation, outsourcing, lean philosophy, agility, specialised factories, centralised distribution, the volatility of demand and technological innovations are the factors creating complexity and interdependencies; therefore, they reinforce supply chain vulnerability [24–28].

Ripple effect, with its name disruption propagation, is defined as operational failures at the forward or backward nodes of a specific node

that suffers a disruption and fails to fulfil demand [29,30]. While it has a lower probability, it also entails more severe consequences. It has the potential to create a snowball effect and trigger other operational risks, the bullwhip effect, etc. [31]. Beyond its immediate effects, moreover, it may have long-term negative consequences [32]. Its results can be unpredictable not only for the firm of origin but also for other firms in the chain and for the whole supply chain [29,30]. To cope with supply chain vulnerability and its consequences, companies must invest in resilience.

Building resilience necessitates different strategies depending on the type of disruption, the position of the company within the supply chain, the effect of the disruption on the company and the supply chain and other factors [29,30,32]. Resilience development efforts can occur at the company- or supply chain-level. Each company within the chain can improve firm resilience by examining its vulnerability, but the effectiveness of this approach is limited because supply chain-level resilience is related to the integrated performance of firms in the chain. As the number of unaffected firms during a disruption increases, the supply chain becomes more resilient. Understanding the ways in which disruptions affect the supply chain enables optimal resource allocation and effective mitigation, improves supply chain performance and serves the interests of the entire supply chain [29].

Scholars in various disciplines, including psychology, ecology, economics, and organisational science, had discussed resilience even before the concept appeared on the supply chain management agenda. Supply chain resilience thus relies upon the vast existing knowledge of these disciplines [13,24].

As indicated previously, increasing vulnerability arouses interest in supply chain resilience. Resilience entered the supply chain domain in the early 2000s. At this time, the supply chain itself was a relatively new subject, and organisations concentrated solely on efficiency-related subjects, although even minor glitches were causing serious losses [25, 33–35].

Supply chain resilience indicates an ability to recover from an undesired performance level to a planned performance level by taking actions towards recovery or adaptation [13,36,37]. Preparedness, alertness and agility are three pillars of supply chain resilience [38]. Their aims are to minimise the effects of the disruption and ensure recovery as quickly as possible.

Velocity, or the pace of adaptation, takes different forms in the supply chain. Lead-time, the occurrence rate of risk events, the rate of losses and the speed of discovery of a risk event are all defined as different forms of velocity in the supply chain management and supply chain risk management domains. In the context of resilience, velocity is accepted as the pace of recovery or adaptation after a disruption. Higher velocity leads to more rapid tactical, operational, and strategic decision-making as well as more rapid adaptation to market changes. Therefore, it can be considered a determinant of supply chain resilience [24, 39–43].

Supply chain resilience relies upon both proactive and reactive approaches. To prepare themselves for both unexpected happenings and risky events, supply chains must develop an adaptive capacity; whether it follows a proactive or reactive approach, however, the reaction occurs at a point in time against a unique disruption or hardship [13,36,37].

Since the early 2000s, researchers have studied and proposed strategies to advance supply chain resilience [34,44–49] by improving diversity, efficiency, adaptability and cohesion, which are generally accepted characteristics of supply chain resilience [50]. As in the pre-pandemic period, strategies that became popular during the pandemic can be classified as proactive and reactive. Digital connectivity, supply chain automation, localisation/regionalisation of sourcing, collaboration, a social supply chain focus and human capabilities are proactive strategies. Deployed before the emergence of the pandemic, these strategies aimed to improve supply chain resilience, but this deployment did not consider the strategies’ use in the context of pandemics [15].

When the pandemic emerged, organisations employed reactive

strategies as a kind of lifebuoy. These strategies include lifeline maintenance, big data-driven and real-time information systems, virtual markets, simulations, inventories, reserve capacity, business continuity plans, collaboration and decision-making proximity [15].

Although capabilities for anticipating and overcoming disruptions reduce vulnerability and improve financial performance, they also increase cost [24]. Depending on their financial stability and resources available for resilience building, firms may apply different tools and be affected differently by a disruption. For example, original equipment manufacturers (OEM) possess a greater stockpile of resources to dedicate. Therefore, they can build more effective systems and exhibit greater resilience in the face of disruptions. In contrast, small- and medium-sized enterprises (SMEs) are, because their fragile financial positions, vulnerable to the negative effects of disruptions. Thus, they prefer to react to disruptions rather than to adopt proactive approaches [51–53].

The extant literature demonstrates that supply chain resilience positively affects performance outcomes [38,54], but neither proactive nor reactive strategies exist to address long-term, extraordinary and global disruptions, such as pandemics. The prevailing strategies to promote supply chain resilience concentrate more on local and small-sized disruptions [45]. Because such strategies are the *only* strategies available, organisations have been forced to adapt them. However, inventories can meet the demand only for an extremely limited time, and quarantines across the world may make subcontracting options inapplicable. Thus, their effectiveness is questionable [37].

3. Hypotheses development

Supply chain risk management involves the collaborative and coordinated efforts of supply chain partners to identify and mitigate risks and thereby reduce the vulnerability of their supply chain [51,55]. The main difference between supply chain resilience and supply chain risk management is evident in the definition. Risk management aims to identify all risks, but identifying all risky events is impossible in large, complex supply chains. Thus, risk management serves resilience, but it does not sufficiently cover all resilience-related issues in supply chains [24].

Supply chain risk management follows a risk management process cycle, which involves the following steps: identification of hazardous events, assessment of risk, development and application of controls, and review. Several preventive and reactive instruments can be used in the cycle. Although all instruments are planned before any risky event occurs, proactive instruments are deployed to minimise the probability that any negative event will occur, whereas reactive instruments are deployed to minimise the damages that result from a negative event after it occurs [24,56]. Because firms aim to optimise the cost of their risk mitigation efforts, they prefer proactive or reactive instruments [53].

Among the proactive instruments are securing markets, producing products with less variety and a constant demand structure, working with dependable suppliers, building facilities in secure areas, such as areas with low natural disaster risks and close supplier relationships, and improving transparency within the supply chain. These approaches reduce disruptions and thereby improve the effectiveness of supply chain risk management [24].

HYPOTHESIS 1. Lower supply chain disruption is positively associated with more effective supply chain risk management.

Reactive instruments primarily rely on creating redundancies, such as multiple sources or safety stocks. They do not prevent a risky event but enable timely reactions to disruptions and offer some space for recovery [24].

HYPOTHESIS 2. Supply chain risk management is positively associated with reducing supply chain risks.

HYPOTHESIS 3. Lower supply chain risk is positively associated with

supply chain velocity.

Lower risk enables smoother and less disrupted operational processes. Therefore, risk management improves operational performance [55]. Moreover, engaging in supply chain risk management pushes firms to make changes in their operational processes, such as building effective information processing capabilities and integration. These changes create positive consequences for operational performance, and building these capabilities serves to improve the effectiveness of both risk management and operational outcomes regarding responsiveness, flexibility and cycle times [57–60].

HYPOTHESIS 4. Supply chain risk management is positively associated with positive supply chain consequences.

HYPOTHESIS 5. Supply chain consequences are positively associated with supply chain velocity.

Robustness in supply chains refers to the supply chain's ability to maintain predetermined performance levels—without changing system parameters—despite a disruption or series of disruptions [37]. It is constructed against both foreseen and unforeseen events and enhances preparedness or resilience in supply chains. It is the proactive dimension of resilience [38,61].

Organisations primarily employ redundancies, such as reserves or backups, to build robustness. These redundancies halt disruption propagation or lower its pace and reduce its effects on the supply chain [61]. In other words, during disruptions, organisations rely on capacities that are maintained for emergencies. Thus, each disruption 'consumes' the system's robustness [62].

HYPOTHESIS 6. Lower supply chain disruption is positively associated with supply chain robustness.

A robust system can tolerate disruptions in its current form [37]. This kind of supply chain deploys proactive strategies, anticipates future changes, prepares itself for these changes and requires minimal adaptations to new conditions as the changes occur. In turn, supply chains more easily recover when negative deviations from planned performance levels are small [43,63,64].

HYPOTHESIS 7. Supply chain robustness is positively associated with supply chain velocity.

Volatility and uncertainty always exist in dynamic business environments. Responding to changes quickly and effectively is essential for firms to survive in the business world. Therefore, under any conditions, agility is an unavoidable part of supply chain management. More than an ability, agility is a construct with multiple dimensions, such as enriching the customer experience, cooperating internally and externally and taking advantage of human capital and knowledge [65] to facilitate adjustments and modifications in operational processes in the face of disruptions [66].

Empowerment and innovation are strong antecedents of supply chain agility [67,68]. Supply chain empowerment refers to efforts to empower both employees and key partners to improve supply chain transparency, enable collaborative decision-making and thereby improve agility [67]. Employee empowerment enhances workforce agility. Proactivity, adaptability, flexibility, innovativeness, and resilience are the main characteristics of an agile workforce. Agile workers promote organisational agility by embracing changes and new responsibilities, remaining open to self-development and advancing their problem-solving capabilities [69–73].

Similarly, supplier empowerment produces positive performance outcomes. Four related supporting cognitive assessments—'potency', 'meaningfulness', 'autonomy' and 'impact'—effectuate supplier empowerment. Suppliers develop self-confidence as they understand the value, or 'impact', of their products within the supply chain. Their impact, in turn, makes their work more meaningful. With self-confidence, suppliers develop flexibility and decision-making

capabilities, which promote autonomy. Therefore, empowered suppliers are more willing to behave autonomously and assume responsibility [74]. The empowerment of key partners occurs through effective collaboration, cooperation and communication [61,65,75].

HYPOTHESIS 8. Lower supply chain disruption is positively associated with supply chain empowerment.

HYPOTHESIS 9. Supply chain empowerment is positively associated with supply chain velocity.

Another antecedent of agility [21,76], innovation refers to the ‘... generation, acceptance and implementation of new ideas, processes, products or services’, which involves intense knowledge work [77] and a continuous search for newness [67]. Innovation can be realised at both the firm- and supply chain-level. Research shows that firm innovativeness, the capability to introduce innovations within the firm, increases market value, accelerates the firm’s response to uncertainty and ensures its durability against volatility [78]. It forms the basis for many other capabilities, including resilience. The likelihood that a firm will react to a disruption in a timely and effectively manner and innovatively hedge the disruption’s negative consequences is higher for innovative firms [79,80].

In supply chains, a supplier’s innovativeness increases its responsiveness to the needs of its customers, reduces response time to changing market circumstances, increases quality, improves cost structure and contributes to product development [81]. During the COVID-19 pandemic, innovative companies have demonstrated extremely positive performances even as all industries were failing. They introduced new solutions in terms of products, business practices, information networks, etc. Vaccine innovators have been the living end of innovativeness during the pandemic [82]. Therefore, innovation became a lifebuoy. Buyer firms must play a leading role in motivating their suppliers to innovate, develop trust and long-term relationships [83].

HYPOTHESIS 10. Lower supply chain disruption is positively associated with supply chain innovation.

HYPOTHESIS 11. Supply chain innovation is positively associated with supply chain velocity.

Fig. 1 presents the research model. As mentioned previously, the activities a firm deploys against disruption may vary depending on the resources they can dedicate. Therefore, we used firm size as the control variable in the model.

4. Research methodology

Structural equation modelling (SEM) integrates factor analysis and multiple regression. It enables the simultaneous estimation of multiple

regression equations by using latent variables that cannot be observed but only approximated by other measurable or observable variables. Our research model includes several causal relationships among eight terms. Therefore, SEM is ideal for confirming the research model and assessing goodness-of-fit in both the overall model and measurement and structural models separately. Because it is more suitable for testing a theory, it is also preferable to the use of covariance-based (CB) SEM [84].

We recruited 300 online participants through the Prolific portal [https://prolific.ac/]. To be included, participants were required to speak English proficiently, work in UK retail stores, born and be between 18 and 60 years of age (M = 32, SD = 8).

We initially asked the participants pre-screening questions to determine their fit with our inclusion criteria, such as being currently employed in UK retail stores and understanding supply chain activities during the COVID-19 pandemic. Online quantitative self-report questionnaires were used to collect the data from the participants.

All participants were paid for their time at a rate consistent with Prolific recommendations. Thirteen participants who completed the survey in less than 5 min were removed from the overall analyses to avoid potentially invalid responses. Participants with missing data were also deleted from the dataset. The first page of the survey sought participant information and required all participants to provide online consent before accessing the survey.

Following our data analyses, we paid the participants an incentive of 50 cents for completing the survey accurately. Table 1 presents the participants’ demographic information.

We followed Hair et al. [84] to ensure that the model did not violate the assumptions and that the offending estimates problem did not exist. In the next step, we assessed the model fit using goodness-of-fit measures. Scholars have developed various goodness-of-fit indexes for CB

Table 1
Demographics.

| Gender | Female = 188 | | Male = 94 | |
|--------------------|---------------------------|------------------------|-------------------------|--------------------|
| Age (years) | 20 or below = 29 | 26–30 = 56 | 36–40 = 29 | 46–50 = 21 |
| | 21–25 = 66 | 31–35 = 40 | 41–45 = 21 | 51 or above = 20 |
| Education | Less than high school = 2 | College = 92 | Master’s degree = 14 | |
| | High school grad = 76 | Bachelor’s degree = 94 | Professional degree = 4 | |
| Experience (years) | 0–2 = 89 | 4–6 = 27 | 8–10 = 14 | |
| | 2–4 = 68 | 6–8 = 29 | 10+ = 55 | |
| Company size | 0–9 = 16 | 51–100 = 43 | 151–200 = 25 | More than 250 = 47 |
| | 10–50 = 87 | 101–150 = 35 | 201–250 = 29 | |

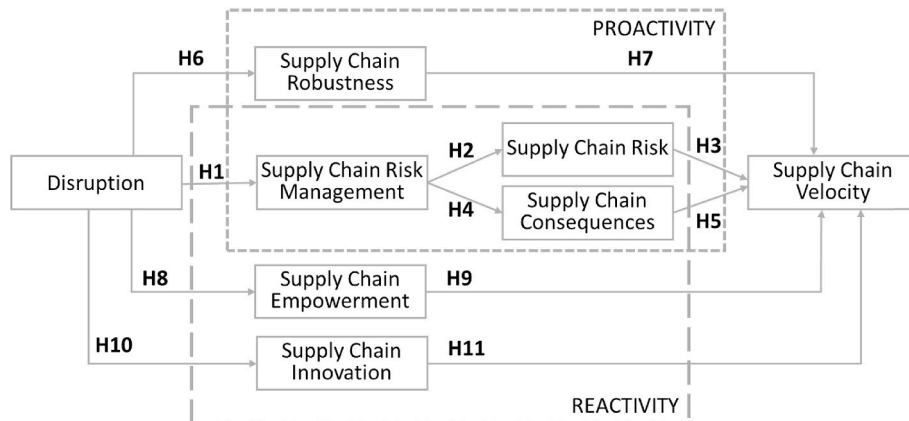


Fig. 1. Research model.

SEM since its introduction [85].

Chi-square is the most common measure for goodness-of-fit, but it is overly sensitive to sample size. Thus, experts recommend using it for sample sizes of 100–200. To overcome this sensitivity problem, other scholars have proposed relative chi-square (CMIN/DF). While CMIN/DF values lower than 5 are generally accepted as adequate, some researchers prefer it to be lower than 2 or 3 [85]. The CMIN/DF value of our model is 2.216, indicating an acceptable model. Hoelter’s critical N, which gives the minimum required sample size, indicates the sufficiency of our sample size. Because the sample size is larger than 200, alternative measures—the noncentrality parameter (NCP), goodness-of-fit index (GFI), root mean square residuals (RMR) and root mean square error approximation (RMSEA)—are advised. These measures of absolute fit generally cannot be statistically tested because they are descriptive [86]. For NCP and RMR, values closer to zero represent a better fit. Perfect fit exists if the GFI value equals 1, and the closer the GFI value is to 1, the better the model fits. RMSEA values between 0.05 and 0.08 demonstrate an acceptable fit. All values in Table 2 indicate that our model is acceptable [85,86].

Researchers use incremental fit measures to compare a proposed model with a reference model and thus capitalise on the improvement that the proposed model provides. In most cases, the proposed model is compared with the independence model, which is extremely restrictive. In the independence model, measurement error does not exist, all factor loadings are equal to one, constructs are uncorrelated and only parameters are estimated [84,86,87].

Table 2 reports the values of the incremental measures. These values should be as close to 1 as possible, and 0.90 is recommended as a threshold value for good-fit. The comparative fit index (CFI) indicates the reproducible part of covariation in the model [88]. The normed fit index (NFI) gives the ratio of improvement over the independence model, and the Tucker-Lewis index, or the non-normed fit index (NNFI), is similar to the NFI. It tends to give lower values for more complex models [88]. The adjusted GFI, which is an extension of the GFI, is adjusted by the ratio of the degrees of freedom of the proposed and null models. The incremental fit index (IFI) is preferred because it is less sensitive to sample size [87]. Table 3 also supports the research model’s acceptability.

Another important issue in model selection is parsimony; among equally well-fitted models, the model with fewer parameters and more degree of freedom is preferred over more complex models. This principle is operationalised via parsimony-related measures [89]. PRATIO is the ratio of the degree of freedom of the proposed model to the degree of freedom of the independence model. While PRATIO is not directly used as a measure, it is used in other parsimony measures [85]. PNFI, PCFI and PGFI are extensions of NFI, CFI and GFI, respectively. These values are used to compare alternative models. Models with higher values are preferred. A PNFI difference between 0.06 and 0.09 is accepted to indicate the difference between the two models [84].

Statistical information theory (STI)-based measures are used to compare alternative models with different numbers of constructs [84]. The Akaike information criterion (AIC) is a measure of ‘badness’; therefore, values closer to 0 are desired. After introducing the AIC, its variants are proposed. The consistent AIC (CAIC), Browne-Cudeck criterion (BCC) and Bayesian information criterion (BIC) are other STI-based measurements, which are used in the same manner as the AIC [88]. According to the values of parsimony and STI-based measures in

Table 2
Absolute fit measures.

| Model | NCP | | | RMR | GFI | CMIN/DF | HOELTER | | RMSEA | | | |
|--------------|----------|----------|----------|------|-------|---------|---------|-----|-------|--------|-------|--------|
| | NCP | LOW 90 | HI 90 | | | | .05 | .01 | RMSEA | LOW 90 | HI 90 | PCLOSE |
| Default | 436.556 | 358.735 | 522.105 | .073 | .825 | 2.216 | 143 | 150 | .066 | .060 | .072 | .000 |
| Saturated | .000 | .000 | .000 | .000 | 1.000 | | | | – | – | – | – |
| Independence | 5501.168 | 5255.937 | 5752.830 | .423 | .154 | 14.550 | 22 | 23 | .220 | .215 | .225 | .000 |

Table 3
Incremental measures.

| Model | NFI delta1 | RFI rho1 | IFI delta2 | TLI rho2 | CFI | AGFI |
|--------------|---------------|-------------|---------------|-------------|-------|------|
| Default | .865 | .848 | .921 | .910 | .921 | .788 |
| Saturated | 1.000 | – | 1.000 | – | 1.000 | – |
| Independence | .000 | .000 | .000 | .000 | .000 | .094 |

Table 4, the research model is acceptable.

SEM considers measurement items as a function of constructs; therefore, scale reliability, convergence validity, discriminant validity and unidimensionality must be examined before interpreting regression results [90].

Unidimensionality requires 0.6 as the minimum factor loading value [91]. All the model’s constructs were taken from previous research. Appendix A presents the items, the resources from which the constructs were taken and the factor loadings of the confirmatory factor analysis. Because the lowest factor loading value is 0.607, unidimensionality is satisfied. To assess the reliability and internal consistency, we calculated Cronbach’s α and composite reliability (CR; also known as Dillon–Goldstein’s rho or Joreskog ρ) values. All constructs have Cronbach’s α and CR values that exceed the suggested threshold value of 0.7 [55]. We then assessed convergence validity using average variance extracted (AVE) values [92]. All constructs have AVE values above 0.5 [93,94] (see Table 5).

For discriminant validity, AVE values that exceed the maximum shared variance (MSV) and average shared variance (ASV) values are expected [95]. The Fornell-Larcker criterion (FLC) is satisfied when the AVE values of each construct are greater than the correlation values in the same row or column as the AVE values [96]. Henseler et al. suggest using the heterotrait-monotrait (HTMT) ratio of correlations [97]. They advise 0.7 as a threshold value but leave researchers free to set their own thresholds. Smaller values are preferred. The greatest HTMT value in Table 4 is 0.782. All three approaches support the discriminant validity of the constructs (see Tables 5 and 6).

The research model consists of 11 hypotheses. Of these, our results require us to reject only one hypothesis. The results do not support the positive impact of supply chain consequences on supply chain velocity. Supply chain consequences are defined as an additional benefit that a supply chain gains due to supply chain risk management activities. For example, disruption not only contributes to risk management but also improves operations management effectiveness. In other words, supply chain consequences represent unintended benefits of risk management. All other constructs—supply chain innovation, supply chain empowerment, supply chain robustness and supply chain risk—positively and significantly affect supply chain velocity. Among these constructs, supply chain innovation appears as the most effective, with a standard regression weight of 0.373. Lower supply chain risk and supply chain empowerment follow supply chain innovation with declining regression coefficients.

Supply chain risk management is more effective in reducing supply chain risk than it is in reducing supply chain consequences. Its effect on both items can be considered high, with standard regression weights of 0.762 and 0.685 respectively.

The effectiveness of all resilience activities improves with lower disruption. The effect of disruption is high on all constructs. Hypotheses

Table 4
Parsimony and statistical information theory-based measures.

| Model | PRATIO | PNFI | PCFI | PGFI | AIC | BCC | BIC | CAIC |
|---------------------------|--------|------|------|------|----------|----------|----------|----------|
| Default model | .884 | .765 | .814 | .681 | 947.556 | 965.723 | 1224.341 | 1300.341 |
| Saturated model | .000 | .000 | .000 | | 870.000 | 973.984 | 2454.230 | 2889.230 |
| Independence model | 1.000 | .000 | .000 | .144 | 5965.168 | 5972.101 | 6070.784 | 6099.784 |

Table 5
Construct reliability.

| Construct | Cronbach's alpha | CR | AVE | MSV | ASV |
|----------------------------------------------------------------------------------------------------|------------------|-------|-------|-------|-------|
| Supply chain velocity (SCV) | 0.898 | 0.899 | 0.748 | 0.629 | 0.467 |
| Disruption (DIS) | 0.880 | 0.881 | 0.649 | 0.629 | 0.515 |
| Supply chain risk (SCRi) | 0.876 | 0.877 | 0.640 | 0.610 | 0.410 |
| Paste Correlations Table into A1 and Standardized Regression Weights Table into F1, then click me. | | | | | |
| Supply chain risk management (SCRM) | 0.858 | 0.859 | 0.671 | 0.594 | 0.421 |
| Supply chain consequences (SCC) | 0.903 | 0.905 | 0.656 | 0.569 | 0.356 |
| Supply chain robustness (SCRo) | 0.854 | 0.857 | 0.666 | 0.610 | 0.470 |
| Supply chain innovation (SCI) | 0.883 | 0.884 | 0.717 | 0.496 | 0.358 |
| Supply chain empowerment (SCE) | 0.770 | 0.784 | 0.550 | 0.460 | 0.349 |

1, 6, 8 and 10 all receive support. The minimum standard regression weight is 0.691, which demonstrates the importance of the severity of the disruption (see Table 7).

Firm size has a significant effect only on supply chain risk management. While it does not affect other endogenous variables directly, it has an indirect effect through supply chain risk management (see Table 8).

Table 6
Discriminant validity.

| | SCV | DIS | SCRi | SCRM | SCC | SCRo | SCI | SCE | | |
|-----------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------------|--|
| SCV | 0.865 | 0.748 | 0.666 | 0.715 | 0.566 | 0.698 | 0.699 | 0.643 | HTMT | |
| DIS | 0.793 | 0.806 | 0.748 | 0.778 | 0.637 | 0.772 | 0.628 | 0.667 | | |
| SCRi | 0.662 | 0.741 | 0.800 | 0.569 | 0.720 | 0.782 | 0.435 | 0.485 | | |
| SCRM | 0.709 | 0.771 | 0.565 | 0.819 | 0.507 | 0.642 | 0.676 | 0.659 | | |
| SCC | 0.559 | 0.629 | 0.730 | 0.499 | 0.810 | 0.762 | 0.490 | 0.469 | | |
| SCRo | 0.705 | 0.773 | 0.781 | 0.650 | 0.754 | 0.816 | 0.525 | 0.560 | | |
| SCI | 0.704 | 0.628 | 0.434 | 0.677 | 0.485 | 0.527 | 0.847 | 0.703 | | |
| SCE | 0.628 | 0.667 | 0.479 | 0.634 | 0.448 | 0.561 | 0.678 | 0.742 | | |
| Variance-Covariance Matrix | | | | | | | | | | |

Table 7
Hypothesis testing.

| Hypothesis | Independent variable | Dependent variable | Standard regression weight | Regression weight | Standard error | Critical ratio | P |
|------------|----------------------|--------------------|----------------------------|-------------------|----------------|----------------|-------|
| 1 | DIS | SCRM | 0.916 | 0.976 | 0.081 | 12.108 | *** |
| 2 | SCRM | SCRi | 0.762 | 0.836 | 0.085 | 9.876 | *** |
| 3 | SCRi | SCV | 0.254 | 0.268 | 0.064 | 4.174 | *** |
| 4 | SCRM | SCC | 0.685 | 0.839 | 0.088 | 9.563 | *** |
| 5 | SCC | SCV | -0.058 | -0.055 | 0.05 | -1.093 | 0.275 |
| 6 | DIS | SCRo | 0.821 | 0.902 | 0.077 | 11.699 | *** |
| 7 | SCRo | SCV | 0.310 | 0.348 | 0.079 | 4.418 | *** |
| 8 | DIS | SCE | 0.716 | 0.829 | 0.082 | 10.137 | *** |
| 9 | SCE | SCV | 0.128 | 0.136 | 0.067 | 2.037 | ** |
| 10 | DIS | SCI | 0.691 | 0.964 | 0.089 | 10.868 | *** |
| 11 | SCI | SCV | 0.373 | 0.33 | 0.054 | 6.138 | *** |

*** 0.001 and ** 0.05 significance levels.

5. Discussion

The literature on supply chain resilience includes studies on various types of disruptions. However, pandemics are unique because they are unpredictable in terms of time and scale. The COVID-19 pandemic has caused business disruptions on an unprecedented scale. All industries have suffered sharp alterations in supply and demand structures. In fact, the pandemic disrupted markets so rapidly that companies could not develop and apply risk-aversion strategies, and they were simply unprepared when the disruption occurred [48]. The disruption thus forced them to make real-time decisions and act reactively [98]. Among all sectors, the perishable goods sector assumes exceptional importance because it provides people with essentials items [99]. Therefore, we aimed to investigate the ability of resilience-building efforts to absorb the effects of a disruption and enable recovery.

Our findings are twofold. Although all resilience-building efforts can

Table 8
Firm size effect.

| Dependent variable | Standard regression weight | Regression weight | Standard error | Critical ratio | P |
|--------------------|----------------------------|-------------------|----------------|----------------|-------|
| SCRM | 0.115 | 0.042 | 0.016 | 2.686 | *** |
| SCI | 0.078 | 0.038 | 0.024 | 1.536 | 0.125 |
| SCE | -0.004 | -0.002 | 0.022 | -0.076 | 0.940 |
| SCRo | -0.050 | -0.019 | 0.017 | -1.089 | 0.276 |
| SCRi | -0.078 | -0.031 | 0.021 | -1.514 | 0.130 |
| SCC | -0.084 | -0.038 | 0.024 | -1.595 | 0.111 |
| SCV | 0.068 | 0.029 | 0.017 | 1.703 | 0.089 |

mitigate disruptions within predetermined limits, the pandemic has exceeded these limits. Therefore, it has not only disrupted supply chains but also caused failures in resilience-building capabilities [100]. Our first significant finding indicates that organisations that were more effective in resilience-building activities were also less affected by the disruption. Some researchers have already sought to explain why some companies are more vulnerable than others. Belhadi et al. [15] report that service and manufacturing companies experience the negative effects of disruptions differently, and companies in global supply chains are more vulnerable to pandemic-related disruptions. Ivanov and Das likewise examined global supply chains and confirmed their greater vulnerability; however, they believe that local alternatives cannot replace the efficiency and effectiveness provided by global supply chains, which, they predict, will survive after the pandemic. Still, they suggest that working with local suppliers would create some flexibility during unexpected global crises [101]. Discussing the food supply chain performance of England during the pandemic, Garnett et al. [100] recommend investing in the agri-food sector and developing locally sustainable capacity that is sufficient to satisfy food demand in England. While they noted the inability of seasonal workers from other countries to cross the border during pandemics, the accuracy of this observation remains in question because such studies are rare and mostly compare companies from different industries. Our study examines only the perishable goods industry, and difference still exists.

Because the pandemic is recent and ongoing, very fewer papers in the supply chain literature have attempted to explain its interactions with supply chains. To the best of our knowledge, previous scholars have not statistically tested the effect of disruption on resilience-building activities or efforts. Our work also statistically demonstrates that less affected companies are perceived as higher performers in supply chain resilience activities. Understanding this phenomenon might provide clues for building more resilient supply chains in the future.

Understanding the effectiveness of existing practices must figure prominently on the agenda of the supply chain literature in the face of the pandemic. Our second main finding indicates that both proactive and reactive resilience-building activities have enhanced supply chain velocity during the pandemic. Studying the effect of supply chain risk management on supply chain resilience and robustness, El Baz and Ruel [102] report similar results. Examining supply chains of essential goods, Sodhi et al. assert that traditional approaches, such as redundancies, can be effective during pandemics [103]. Sharma and her colleagues state that focusing on resilience not only helps during pandemics but also exerts positive long-term effects on supply chain viability [104]. While noting that companies have applied multiple practices, Woong and Goh [105] identify ‘increasing capacity’, ‘diversifying single-product categories’, ‘local sourcing’, ‘prioritising critical categories’, ‘repurposing assets’, ‘establishing partnerships’ and ‘leveraging social media influence’ as the most common supply chain risk management practices. Consistent with our findings, they suggest that both proactive and reactive strategies have helped companies to overcome problems in their supply chains. Although these findings are valuable, the area

remains open to additional investigation.

Highly contradicting findings and diverse perspectives exist in the pandemic-era supply chain literature. Nevertheless, we know that the pandemic has affected every industry differently; thus, no one-size-fits-all solution exists. The extant literature on supply chain resilience in the pandemic context emphasises the need to think outside the box. Supply chains must be reconsidered and redesigned to enhance their viability [37,48,101,104–106]. Our results reveal that existing resilience-building approaches are effective but insufficient.

We also know that the pandemic has changed every aspect of life. Some of these changes will persist in the post-pandemic period, while others will be discarded as soon as possible [107,108]. In any case, people, firms and supply chains will continue to face new demands and new concerns that require innovativeness. Thus, post-pandemic markets may include highly innovative actors [109] who have experience in failing supply chains. We predict that the supply chain management discipline is poised to enter an extremely innovative era, whose seeds the pandemic has sown. Our findings clearly demonstrate the crucial role of innovation in resilience building. Therefore, the next step should be qualitative analyses of success and failure stories to gather in-depth information and identify the critical decisions that brought failure and the critical innovations that produced success. We suggest that future researchers concentrate on qualitative studies to accumulate insights useful for building more resilient supply chains.

6. Conclusions

Supply chain failures during the COVID-19 pandemic motivated researchers to re-examine supply chains from a resilience-building perspective. Our study makes the following contributions to this end:

1. We adopted supply chain velocity as a measure of supply chain resilience and attempted to understand the factors that impact it.
2. We demonstrated that both proactive and reactive approaches have promoted supply chain resilience. Innovation seems an effective way to avoid or at least mitigate the pandemic’s devastating effects.
3. We found firm size to be a significant factor only for risk management. Therefore, we posit the existence of other hidden factors that influence the effectiveness of resilience-building efforts.
4. Our model represents a first step in the supply chain resilience journey. The model offers some clues about the subjects on which to concentrate, their potential contributions and possible ways of improving them.

Continuing this journey will contribute to the supply chain literature and provide insights and potential solutions to the issues facing supply chain practitioners.

Declaration of competing interest

We have no conflicts of interest.

Appendix A

| CONSTRUCTS | SFL |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| Disruption [102] (Cronbach’s $\alpha = 0.880$, CR = 0.881, AVE = 0.649) | |
| My organisation has an overall efficiency of operations with respect to perishable food stock during the ongoing COVID-19 lockdown. | 0.805 |
| My organisation has delivery reliability with respect to perishable food stock during the ongoing COVID-19 lockdown. | 0.781 |
| My organisation has sufficient quality assurance for supply related to perishable food stock during the ongoing COVID-19 lockdown. | 0.787 |
| My organisation has high-quality inventory management for perishable food stock during the ongoing COVID-19 lockdown. | 0.789 |
| Supply Chain Robustness [102] (Cronbach’s $\alpha = 0.854$, CR = 0.857, AVE = 0.666) | |
| My organisation’s supply chain has the ability to retain the same stable situation as it had before COVID-19 lockdown with respect to perishable food stock. | 0.771 |
| My organisation’s supply chain has the ability to perform well over a wide variety of possible scenarios without necessary adaptations with respect to perishable food stock during the ongoing COVID-19 lockdown. | 0.806 |

(continued on next page)

(continued)

| CONSTRUCTS | SFL |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| My organisation's supply chain, for a long time, is able to carry out its functions despite some damage done to it with respect to perishable food stock during the ongoing COVID-19 lockdown. | 0.86 |
| Supply Chain Risk Management [53] (Cronbach's $\alpha = 0.858$, CR = 0.859, AVE = 0.671) | |
| My organisation has multiple sourcing for perishable food stock during the ongoing COVID-19 lockdown. | 0.716 |
| Supply Chain Empowerment [70] (Cronbach's $\alpha = 0.77$, CR = 0.784, AVE = 0.550) | |
| My organisation encourages cooperation among members during the ongoing COVID-19 lockdown. | 0.792 |
| My organisation encourages delegation of authority during the ongoing COVID-19 lockdown. | 0.607 |
| My organisation encourages everyone's involvement during the ongoing COVID-19 lockdown. | 0.805 |
| Supply Chain Innovation [70] (Cronbach's $\alpha = 0.883$, CR = 0.884, AVE = 0.717) | |
| My organisation is creative in its methods of operation during the ongoing COVID-19 lockdown. | 0.858 |
| My organisation seeks out new ways to do things during the ongoing COVID-19 lockdown. | 0.829 |
| My organisation frequently tries out new ideas during the ongoing COVID-19 lockdown. | 0.848 |
| Supply Chain Risk (Cronbach's $\alpha = 0.876$, CR = 0.887, AVE = 0.640) | |
| In my organisation, the probability of transportation failure with respect to perishable food stock supplier is low during the ongoing COVID-19 lockdown. | 0.773 |
| In my organisation, the probability of delivery chain disruptions with respect to perishable food stock supplier is low during the ongoing COVID-19 lockdown. | 0.853 |
| In my organisation, the probability of failure of perishable food stock supplier is low during the ongoing COVID-19 lockdown. | 0.81 |
| In my organisation, the probability of quality problems with respect to perishable food stock supplier is low during the ongoing COVID-19 lockdown. | 0.758 |
| Supply Chain Velocity [39] (Cronbach's $\alpha = 0.898$, CR = 0.899, AVE = 0.748) | |
| My organisation's supply chain can rapidly deal with threats in our environment in the context of perishable food stock during the ongoing COVID-19 lockdown. | 0.817 |
| My organisation's supply chain can quickly respond to changes in the business environment in the context of perishable food stock during the ongoing COVID-19 lockdown. | 0.877 |
| My organisation's supply chain can rapidly address opportunities in our environment in the context of perishable food stock during the ongoing COVID-19 lockdown. | 0.896 |
| Supply Chain Management Consequences (Cronbach's $\alpha = 0.903$, CR = 0.905, AVE = 0.656) | |
| In my organisation, the consequence of a possible failure of perishable food stock supplier is low during the ongoing COVID-19 lockdown. | 0.834 |
| In my organisation, the consequence of supplier quality problems with respect to perishable food stock suppliers is low during the ongoing COVID-19 lockdown. | 0.82 |
| In my organisation, the consequence of delivery chain disruptions with respect to perishable food stock suppliers is low during the ongoing COVID-19 lockdown. | 0.876 |
| In my organisation, the consequence of transportation failure with respect to perishable food stock suppliers is low during the ongoing COVID-19 lockdown. | 0.785 |
| In my organisation, the consequence of malfunction of IT-systems for perishable food stock management is low during the ongoing COVID-19 lockdown. | 0.728 |

SFL: Standardized factor loadings, CR: Consistency reliability, AVE: Average variance extracted

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