Resilience Antecedents and Performance of Indian Supply Chains During Disruptions: Evidence from fsQCA

Nishtha Agarwal
Research Scholar, Department of Management
Indian institute of Foreign Trade, New Delhi
Nishtha_phdmf19@iift.edu

Prof. Nitin Seth
Professor, Department of Management, Quantitative Studies
Indian Institute of Foreign Trade, New Delhi
nitinseth@iift.edu

Abstract

The global functioning of supply chains has exposed them to volatility and turbulence making them vulnerable to disruptions. Resilience has become an important ability for supply chains that enhances event readiness and aids recovery to a better operational state. The restoration of supply chains ensures business continuity and improves performance against the firms whose supply chains are not resilient. The importance of resilience towards supply chain and firm's performance has resulted in several studies on its analysis. The literature is replete with studies analyzing antecedents of resilience and their effect on supply chain performance amidst disruptions. Despite the abundance of the empirical literature, only a few have examined the resilience antecedent configurations to assess supply chain performance. Even fewer studies have examined the necessity and sufficiency conditions of these configurations. Limited research evidence exists in the context of global supply chains having partners in India. The present study explores the antecedents of resilience influencing supply chain performance amidst disruptions. Furthermore, the study aims to obtain the necessary and sufficient configurations of these antecedents for enhancing supply chain performance and provide managerial suggestions. Therefore, the research questions are (1) What are the antecedents of resilience that may impact the supply chain performance amidst disruptions? (2) What configurations of resilience antecedents can explain the supply chain performance? The research question are solved via following methods: Firstly, based on literature review and expert interviews, the antecedents of resilience are obtained for Indian supply chains. Furthermore, Fuzzy Set Qualitative Comparative Analysis (fsQCA) is utilized to obtain necessary and sufficient configurations of the antecedents that can explain supply chain performance amidst disruptions. The output of fsQCA software reveals the presence of multiple, equally effective configurations of causal factors that exist for explaining the interplay of antecedents towards enhancing supply chain performance amidst disruptions.

Keywords
Supply chain resilience, fsQCA, supply chain performance, disruptions and configurations.

1. Introduction

An element of risk surrounds the functioning of supply chains as they operate in the turbulent and volatile global business environment (Agarwal and Seth, 2021). Managers have to strive to not only reduce the vulnerability of supply chains towards the elements of risk but also work towards responding and recovering operations if a disruption strike. Resilience is an important ability that enables the supply chains to anticipate, adapt, respond and recover promptly from unpredictable events (Ali et al., 2017). A resilient supply chain is perceived to absorb disturbances, restore its function and "bounce back" from adversity while maintaining a competitive advantage against the supply chains that are not resilient (Agarwal et al., 2022). Therefore, it is vital to identify its antecedents and work upon them to enhance the resilience of supply chains (Rajesh, 2017). These antecedents are called enablers and are the building blocks of resilience which must be implemented into practice. The enablers have a positive influence on the risk mitigation environment of supply chains and function in the different phases that a supply chain experiences while encountering disruptions (Hsu et al., 2021). The enablers enhance the resilience of supply chains during disruptions and consequently ensure business continuity, prevents the decline in the performance and ensure competitive advantage

(Chowdhury et al., 2019). Therefore, it becomes imperative for managers to identify the enablers and analyse their effectiveness in enhancing supply chain performance amidst disruptions. However, injecting the enablers into supply chains involves a cost bringing the trade-off of prioritisation of money versus effectiveness (Li et al., 2017). The review of existing literature also points to the inter-twined nature of enablers which further complicates the implementation (Rajesh, 2017).

1.1. Research Objectives of the present study

Despite the abundance of the empirical literature, only a few have examined the resilience antecedent configurations to assess supply chain performance. Even fewer studies have examined the necessity and sufficiency conditions of these configurations. Limited research evidence exists in the context of global supply chains having partners in India. The present study explores the antecedents of resilience influencing supply chain performance amidst disruptions. Furthermore, the study aims to obtain the necessary and sufficient configurations of these antecedents for enhancing supply chain performance and provide managerial suggestions. Therefore, the research questions are (1) What are the antecedents of resilience that may impact the supply chain performance amidst disruptions? (2) What configurations of resilience antecedents can explain the supply chain performance?

The present study attempts to bring a solution to the aforementioned problems by identifying the enablers for supply chains and studying their linkages using fuzzy set qualitative comparative analysis (fsQCA). fsQCA is based on the principle of equifinality meaning that a particular outcome (here, supply chain performance) may be caused by a different combination of elements, here, supply chain resilience enablers (Pappas and Woodside, 2021). In the present context, managers can prioritise the different resilience enabler configurations based on the prevailing conditions of cost and industry requirements thereby preventing the cost constraint. The analysis is performed for the supply chains of the Indian automobile industry which functions amidst high turbulence, involves global partners and, hence, is vulnerable to disruptions. The importance of the Indian automobile industry for several global supply chains is important which makes the study of resilience in this context a very important investigation (SIAM, 2022). The fsQCA proposition is developed for the present study and six equally effective configurations of resilience enablers that are sufficient for explaining superior supply chain performance are obtained with a satisfactory score of consistency and coverage.

The rest of the study is organised as follows: The literature review (section 2) reviews the existing literature and identifies the gaps present. This section is followed by the research methodology (section 3) which explains the fsQCA methodology and the solutions obtained from fsQCA. The interpretations are provided in the results section (Section 4) followed by concluding remarks and scope for future work.

2. Literature Review

The present section briefly reviews the existing literature on supply chain resilience enablers and the different models describing the relationship between enablers and supply chain performance during disruptions. The review shall help in determining the research gaps and deriving suitable research propositions.

2.1 Supply Chain Resilience Enablers (SCRE)

The discussion on enablers is as deep-rooted as the study on supply chain resilience. The enablers are the building blocks of resilience (Ali et al., 2017) that must be acknowledged and implemented into practice to enhance resilience of a supply chain (Rajesh, 2017). Fundamentally, enablers are attributes for building resilience by having a positive influence over total supply chain risk mitigation environment. The analysis of enablers is of great consequence to managers as it can help them in taking proactive steps for reducing total risk and disruption impacts on the supply chain (Rajesh, 2017). The existing literature suggest a range of enablers that help in building and enhancing supply chain resilience (Ali et al., 2017). Supply chain re-engineering, agility, collaboration and risk management culture are the enablers that were identified in the initial studies on resilience (Christopher and Peck, 2004). Following this, several studies provided a generic list of enablers (Pettit et al., 2013; Scholten and Schilder, 2015; Scholten et al., 2014; Rajesh, 2017). However, studies on the classification became more prominent as complexities arose because of identification of more such enablers and for simpler modes of understanding (Ali et al., 2017). Majorly, two kinds of classifications are observed in the literature. The first classification distributes the enablers based on whether the enablers are generic (non-industry specific) or they belong to a specific industry in which the supply chain is functioning (Ali et al., 2017). The second classification involves categorising the enablers based on the phases of disruption that the supply chain undergoes while facing a disruption (Ali and Golgeci, 2019). Broadly, three phases of supply chains are discussed in the literature namely discovery, response and recovery. In both the classifications, enablers are not strictly confined to a particular class but can belong to different classes simultaneously (Agarwal et al., 2021).

The literature is replete with studies on these different classifications while several of them have combined all the classifications to analyse the enablers. For example, Piprani et al. (2020) have identified fourteen enablers in context of Pakistani textile industry and classified them into the different phases namely readiness, response and recovery. The enablers belonging to readiness phase are situational awareness, visibility, robustness, security, risk management, pre-disruption knowledge management. The enablers in response phase are flexibility, redundancy, collaboration and agility. Contingency planning, market position, social capital and post-disruption knowledge management are part of recovery phase. On the other hand, Ali and Gölgeci (2019) have identified 22 enablers of supply chain resilience through a systematic literature review and classified them into preparedness, resistance and rebound. The enablers in preparedness phase are flexibility, collaboration, redundancy, resilience culture, information sharing, innovation, top management support, employees training and development, public-private partnership, co-opetition, Industry 4.0, Big Data Analytics and Blockchain. The enablers in resistance phase are visibility, robustness, agility and velocity. Resource configuration, adaptation, disruption mitigation, supply chain re-design and additive manufacturing. In the context of industry specific resilience studies, enablers such as risk management culture, agility, integration and re-engineering are identified for liner shipping industry of Taiwan (Liu et al., 2018). Enablers such as reconfiguring company resources, risk monitoring, responsibility sharing, real-time information sharing, staff training and leadership, interoperability and culture of trust and accountability are identified for Chinese fashion industry. A case of automobile industry of Brazil has also been studied where enablers redundancy, flexibility, adaptability, collaboration, visibility and agility are identified (da Silva Poberschnigg et al., 2020). A multi-industry survey resulted in the identification of fourteen resilience enablers namely flexibility in sourcing, flexibility in order fulfilment, capacity, efficiency, visibility, adaptability, anticipation, recovery, dispersion, collaboration, organisation, market position, security and financial strength (Pettit et al., 2013). Several studies have identified and modelled the enablers for better understanding of supply chain resilience. Kumar and Anbanandam (2019) modelled knowledge management, agility, redundancy, flexibility, visibility and social capital for Indian manufacturing industry. A resilience model was also built for medical equipment industry that modelled agility, collaboration, information sharing, trust among actors, risk management culture, adaptability (Jafarnejad et al., 2019). A generic model involving collaborative culture, information sharing, resilience goal alignment, supplier development, top management commitment, resource sharing, co-adaptive transformation, resilient system design was developed by Aggarwal and Srivastava (2019) for Indian industries. The importance of enablers can be ascertained from the fact that their analysis is a pre-requisite for enhancing resilience which in turn enhance supply chain performance.

2.2 Linkages between Resilience Enablers and Performance

Resilient supply chains boast of quick restoration to their normal operating conditions amidst disruptions thereby ensuring business continuity and enhanced performance against the supply chains that are not resilient. The enablers play a major role in enhancing resilience of supply chains that in turn aids better performance during disruptions. The significance of resilience enablers in supply chain performance makes the analysis of their linkage an essential course of study. There are several constraints that surround the analysis between resilience enablers and supply chain performance making it complicated. Firstly, the existing studies have noted that the resilience enablers are inter-twined with each other and one enabler can be the cause/effect of one or more enablers of supply chain risk mitigation (Rajesh, 2017; Agarwal et al., 2021). Secondly, the implementation of resilience enablers into supply chains require firms to make more investments. This brings the trade-off of prioritising selected enablers for resilience enhancing activities as insights have to be developed regarding whether or not implementing supply chain resilience practices is truly beneficial (Li et al., 2017). The importance of and the complications involved in analysing linkages between resilience enablers and supply chain performance makes it vital for analysis among managers.

The linkages between resilience enablers and performance are analysed by different research methods. Gu et al. (2021) analysed the role of Information Technology (IT) as a resilience enabler on supply chain performance using Structural Equation Modelling (SEM). The impact of supply chain preparedness, supply chain alertness and supply chain agility are assessed on firm's financial performance through regression analysis (Li et al., 2017). In similar manner, the role of enablers like social capital (Jia et al., 2021; Asamoah et al., 2020); integrated logistics capability (Mandal et al., 2017); relational practices like flexibility, redundancy, visibility, collaboration, trust, cooperation and commitment (Chowdhury et al., 2019; Wieland and Wallenburg, 2013); Supply chain digitalisation (Zouari et al., 2020); dynamic remanufacturing capability (Bag et al., 2019); adaptability and alignment (Aslam et al., 2020); culture, re-engineering, collaboration and agility (Abeysekara et al., 2019), management policies (Liu et al., 2021) etc have also been analysed using SEM and other survey techniques. Other research methods used for analysing the role of resilience enablers on supply chain performance involve case study analysis. Here, the enablers for the case supply chain and their advantages or disadvantages during disruptions are analysed via interviews or semi-structured questionnaires (Tukamuhabwa et al., 2017; Dabhilkar et al., 2016; Chen et al., 2019; Scholten et al., 2019; da Silva Poberschnigg et al., 2020). Multi-criteria decision-making techniques like AHP (Piprani et al., 2020), Graph Theoretic Approach (Agarwal et al., 2021; Jain et al., 2017); DEMATEL (Karmaker and Ahmed, 2020; Aggarwal and Srivastava, 2019; Rajesh and Ravi, 2015); TISM (Rajesh, 2017) and ISM-FANP (Sangari and Dashtpeyma, 2019).

2.3 Observations from the Literature, Research Gaps and Research Propositions

The review of literature demonstrates the existence of rich literature on supply chain resilience enablers and their linkages with supply chain performance. The existing studies lack in providing different, and equally effective configurations of resilience enablers that are necessary and sufficient for achieving a superior supply chain performance. Fuzzy set Qualitative Comparative Analysis (fs-QCA) is a research method that helps in obtaining such configurations. FsQCA adheres to the principles of configuration theory which in essence allows for the examination of interplays that develop between elements of a messy and non-linear nature (Pappas and Woodside, 2021). fsQCA is based on the principle of equifinality meaning that a particular outcome (here, supply chain performance) may be caused by different combination of elements (here, supply chain resilience enablers). In the present context, managers can prioritise among the different resilience enabler configurations based on the prevailing conditions of cost and industry requirements thereby preventing the cost constraint. The technique also considers the relationship between the enablers by providing the best configuration for a superior performance. The following proposition is formulated:

Proposition 1: No single configuration of supply chain resilience enablers is sufficient for explaining high performance, instead multiple, equally effective configurations exist.

The review of existing literature also reveals the contextual nature of resilience enablers implying that different enablers are required based on the industry and country contexts. These enablers limit the scope of analysis as the scope of study is confined to a particular country or industry. Such studies have also not considered the interaction of global partners amidst a global crisis. To address this gap, the resilience enablers are identified for Indian supply chains while considering the interaction of global partners. The enablers are identified for Indian automobile supply chains which is important in current scenario as globally automobile industries are facing disruptive times. The importance of automobile industry in India and world makes the study of its resilience capability amidst global crisis (like the COVID-19 pandemic; semi-conductor chip crisis) a requisite.

3. Research Methodology

The present study follows a multi-step research approach consisting of study design and sample formulation; data collection and data analysis. It is based on the literature on configurational analysis and supply chain resilience

3.1 Study Design and Sample

Study Design: The main purpose of this phase is to identify and explore the enablers that enhance supply chain resilience in context of Indian automobile industry. Consequently, a brainstorming session was organised with experts from the automobile industry. The experts for the brainstorming session were selected with an aim of obtaining viewpoints of global supply chains. Therefore, experts having experience of working with global supply chain partners were also invited. Eventually, seven experts from academia (three in number) and industry (four in number) agreed to participate with each expert having more than five years of experience in the area of supply chain management.

Initially, the 40 enablers identified from the literature on supply chain resilience were explained to the experts along with the aim of the study. In this round, the experts were asked to give a Yes/No answer to whether a particular enabler from the literature is suitable or not. In this round, fifteen enablers were rejected as being unsuitable for the study. The rest 25 enablers were edited and modified to suit the needs of the automobile supply chains. Within a period of15 days, a brainstorming session was organized to identify the variables. In this session, experts identified seven most important resilience enablers which shall be used for the study. These are: (1) supply chain collaboration; (2) resilience system-design; (3) supply chain flexibility; (4) resilience orientation; (5) supply chain agility; (6) supply chain transparency; (7) relationship development with partners (Figure 1). The researcher employed a quantitative method and designed a formal questionnaire to validate the presented constructs. The items of the questionnaire were measured using a five-point Likert scale, allowing answers from strongly disagree (as 1) to strongly agree (as 5). The items for the construct were taken from the literature as suggested by the experts. The questionnaire was pre-tested with the expert panel of the brainstorming session. The result of the pre-test study was used fo;r improving the questionnaire design (Table 1).

Table 1. Operational Definitions of supply chain resilience enablers

Name of the Resilience Enabler	**Operational Definition of the Research Enabler**	**Author (Year)**
Supply Chain Collaboration	The partnership process where autonomous firms work closely to plan and execute SC operations toward common goals and mutual benefits.	Hsu et al. (2021); Chen et al. (2019); Piprani et al. (2020)
Resilience System-Design	The infrastructure design that incorporates readiness to enable an efficient and responsive supply chain.	Piprani et al. (2020); da Silva Poberschnigg et al. (2020)
Supply Chain Flexibility	The various states a system can adopt, the ability to move from making one product to making another and the ability to perform comparably well when making any product within a specified range.	Piprani et al. (2020); da Silva Poberschnigg et al. (2020); Karmaker and Ahmed (2020)
Resilience Orientation	The overall supply chain management and its strategic direction that places resilience as a priority.	
Supply Chain Agility	The ability of SC to produce, and deliver innovative products to their customers in a timely and cost-effective manner.	Piprani et al. (2020); da Silva Poberschnigg et al. (2020)
Supply Chain Transparency	It requires companies to know what is happening upstream in the supply chain and to communicate this knowledge both internally and externally.	Hsu et al. (2021); Chen et al. (2019); Piprani et al. (2020); Kaviani et al. (2020)
Relationship Development with Partners	The ability to develop networks of relationships in the supply chain by its trading partners to enhance resilience	Kumar and Anbanandam (2019); Agarwal et al. (2020); Rajesh (2020)

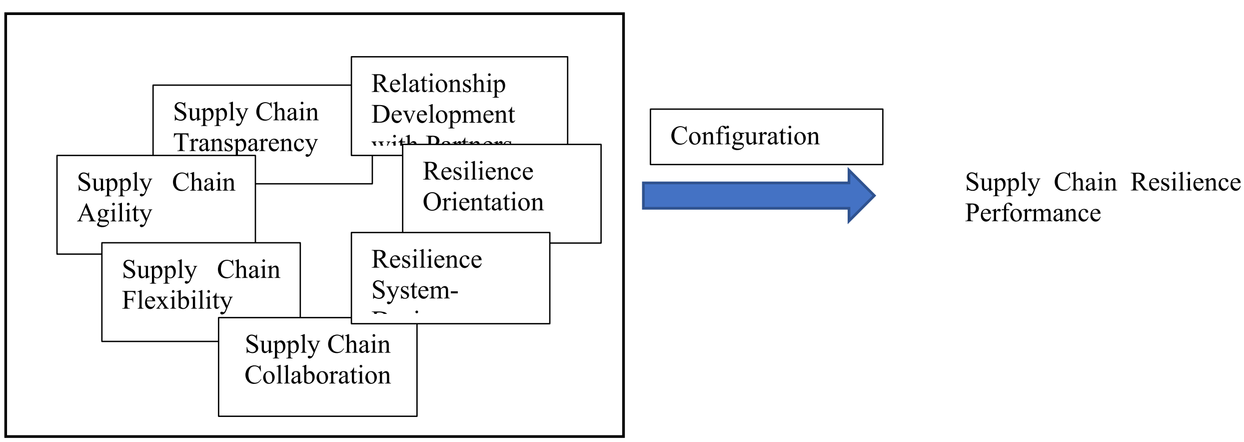

Figure 1. Conceptual Model for the present study

Data Collection and Sample

The empirical data for the study was collected via an online survey. Convenient sampling (non-probabilistic sampling) was performed to obtain responses for the final round of data collection. Managers, supervisors, top management, directors handling distribution, logistics services, retailing and manufacturing were contacted via an online questionnaire. The survey instrument was also sent to academicians and consultants as they also provide a fairly good industry understanding through their industry consultations. The final version of the questionnaire was sent to 200 respondents, out of which 77 responses returned. The analysis was performed on 62 responses which were complete and correct. The analysis for the study proceeded in two stages. First, a descriptive analysis was performed on the organizational dimensions and the resilience enablers. Second, fsQCA was performed to obtain their configurations for a superior supply chain performance. A brief overview of the demographic data of the sample is given in Table 2.

Table 2. Demographic characteristics of the respondents

Characteristic		**%**	**Characteristic**		**%**	**Characteristic**		**%**
Firm Type	Logistics	4	**Respondent Position**	Middle Management	66%	**Company size based on Sales**	1 crore – 10 crore	16%
	Original Equipment Manufacturer	23						
	Distributor	2		Top Management	16%		10 crore - 50 crore	16%
	Supplier	17						
	SAAS	1		Supervisor	15%		More than 50 crore	44%
	Academia	10						
	Consultation	3		Owner/President	3%		Less than 1 crore	24%
	Manufacturer	2						
Characteristic		**%**	**Characteristic**		**%**	**Characteristic**		**%**
Nature of Disruptions Faced by Firm	External firm SC disruption	20%	**Company Size based on number of Employees**	1000-10,000	27%	**Loss faced due to disruptions**	1% to 10 %	40%
	Internal firm SC disruption	4%		100-1000	34%		10% to 25%	16%
	Internal firm disruption	31%		Less than 100	21%		Less than 1%	26%
	External firm disruption	45%		More than 10,000	18%		More than 25%	18%
	Multiple disruptions faced	20%						

3.2 Fuzzy Set Qualitative Comparative Analysis (fsQCA)

Qualitative comparative analysis (QCA) is an asymmetric data analysis technique that combines the logic and empirical intensity qualitative approaches that are rich in contextual information, with qualitative approaches that are rich in contextual information, with quantitative methods that deal with large numbers of cases and are more generalizable (Ragin, 1987) than symmetric theory and tools. QCA has three main variations: crisp set QCA (csQCA), multi-value QCA (mvQCA), and fuzzy-set QCA (fsQCA). fsQCA extends csQCA by integrating fuzzy-sets and fuzzy-logic principles with QCA principles (Ragin, 2008), which offers for a more realistic approach since variables can get all the values within the range of 0–1 (Pappas and Woodside, 2021).Conducting an fsQCA comprises the steps *calibration* and *analysis of necessary and sufficient conditions*

Calibration: It is the process of transforming the composite scores of the latent constructs into fuzzy set membership scores between 0 and 1. For this purpose, itis necessary to set three qualitative anchor points for thesurvey data known as full membership, crossover point and full non-membership. To calibrate the data, values 0.95, 0.50, 0.05 as the three thresholds (or breakpoints), which will transform the data into the log-odds metric with all values being between 0 and 1. For a five-point Likert scale the thresholds value of 0.95, 0.5 and 0.05 are obtained at 4,3, and 2. In the fsQCA software, the calibration can be performed by Variables →Compute→calibrate(x,n1,n2,n3). Here, the target variable is the name of the variable after calibration, x is the variable to be calibrated, n1,n2 and n3 are the threshold values for 5%, 50% and 95% i.e., 2,3,4(Pappas and Woodside, 2021).

Truth Table Formulation: In order to run the fsQCA algorithm truth table has to be created by choosing Analyse→Truth Table and select the variables that will be included in the analysis. detail, the causal conditions are the independent variables, and the outcome is the dependent variable. The truth table computes all possible configurations (or combinations) that may occur, providing 2^k rows, with k representing the number of outcome predictors, and each row representing every possible combination. When computing all possible configurations, the frequency is also presented (i.e., the number of observations for each possible combination), while several lines will have a frequency of zero, which means that none of the cases in the sample are explained by them. The frequencies must be sorted and the observations having frequencies less than the threshold must be removed. At this point a consistency threshold should be set, with the minimum recommended value being 0.7. After obtaining the observations qualifying the threshold frequency, the last step is to decide if the combination explains the outcome or not. Choosing 1 or 0 defines if a combination explains the outcome or not (Pappas and Woodside, 2021). Once this is complete, the researcher may proceed to obtain solution sets (command: *Standard Analyses*).

Obtaining the Configurations/solutions: FsQCA computes three solution, namely complex solution, parsimonious solution, and intermediate solution. Here, "solution" refers to a combination of configurations that is supported by a high number of cases, where the rule "the combination leads to the outcome" is consistent. The complex solution presents all the possible combinations of conditions when traditional logical operations are applied (Figure 2). The parsimonious solution is a simplified version of the complex solution, based on simplifying assumptions, and presents the most important conditions which cannot be left out from any solution (Figure 3). These are called "core conditions". The intermediate solution uses a subset of those simplifying assumptions used to compute the parsimonious solution, which should be consistent with theoretical and empirical knowledge. The intermediate solution is part of the complex solution and includes the parsimonious solution (Figure 4). While core conditions appear in both parsimonious and intermediate solutions, the conditions that are eliminated in the parsimonious solution and appear only in the intermediate solution are called "*peripheral conditions*" (Pappas and Woodside, 2021).

```
Model: c_perf = f(c_sysdes, c_flex, c_resor, c_agility, c_transp, c_rel, c_collab)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.901484
                                                                  raw        unique
                                                                coverage    coverage
consistency
                                                               ----------  ----------
----------
c_sysdes*c_resor*~c_transp*c_rel*~c_collab                     0.34184     0.0520684
0.895418
c_sysdes*~c_flex*~c_resor*~c_agility*~c_transp*~c_rel          0.286685    0.0203745
0.924353
~c_sysdes*~c_flex*~c_resor*c_agility*~c_transp*~c_rel          0.297592    0.0226384
0.894802
~c_sysdes*~c_resor*~c_agility*~c_transp*~c_rel*c_collab        0.306442    0.00432193
0.891617
~c_sysdes*c_flex*~c_resor*~c_transp*c_rel*~c_collab            0.281745    0.011525
0.909635
c_sysdes*c_flex*c_resor*~c_agility*~c_transp*c_collab          0.309529    0.01667     0.9244
~c_sysdes*c_flex*c_resor*~c_agility*~c_transp*~c_rel*~c_collab 0.265693    0.0109075
0.946481
c_sysdes*c_flex*~c_resor*~c_agility*c_transp*~c_rel*~c_collab  0.283598    0.0100843
0.927946
~c_sysdes*~c_flex*c_resor*c_agility*c_transp*~c_rel*~c_collab  0.248199    0.0119367
0.929838
~c_sysdes*~c_flex*c_resor*~c_agility*~c_transp*c_rel*c_collab  0.244083    0.00864369
0.905343
c_sysdes*c_flex*~c_resor*c_agility*~c_transp*~c_rel*c_collab   0.289977    0.00493932  0.91553
~c_sysdes*c_flex*c_resor*~c_agility*c_transp*~c_rel*c_collab   0.274542    0.0133772
0.941425
c_sysdes*~c_flex*c_resor*c_agility*c_transp*~c_rel*c_collab    0.265693    0.0137888
0.905965
~c_sysdes*c_flex*c_resor*c_agility*~c_transp*c_rel*c_collab    0.280305    0.00514507
0.922764
solution coverage: 0.699527
solution consistency: 0.814522
```

Figure 2. Complex Solution

```
*TRUTH TABLE ANALYSIS*
**********************

File:  D:/phd_final/dunno/final_part 2/fsqca papers/book2_calibrated.csv
Model: c_perf = f(c_sysdes, c_flex, c_resor, c_agility, c_transp, c_rel, c_collab)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.901484
                   raw       unique
                 coverage    coverage   consistency
                ----------  ----------  ----------
~c_agility      0.682857    0.0312822   0.686246
~c_resor        0.676682    0.0382795   0.657731
c_rel           0.676477    0.0374563   0.65439
c_transp        0.604857    0.0329286   0.641563
solution coverage: 0.936818
solution consistency: 0.570355
```

Figure 3. Parsimonious Solution

```
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.901484
Assumptions:
                                                                    raw        unique
                                                                  coverage    coverage
consistency
                                                                 ----------  ----------
----------
c_sysdes*c_resor*~c_transp*c_rel*~c_collab                       0.34184     0.0520684
0.895418
c_sysdes*~c_flex*~c_resor*~c_agility*~c_transp*~c_rel            0.286685    0.0203745
0.924353
~c_sysdes*~c_flex*~c_resor*c_agility*~c_transp*~c_rel            0.297592    0.0226384
0.894802
~c_sysdes*~c_resor*~c_agility*~c_transp*~c_rel*c_collab          0.306442    0.00432193
0.891617
~c_sysdes*c_flex*~c_resor*~c_transp*c_rel*~c_collab              0.281745    0.011525
0.909635
c_sysdes*c_flex*c_resor*~c_agility*~c_transp*c_collab            0.309529    0.01667     0.9244
~c_sysdes*c_flex*c_resor*~c_agility*~c_transp*~c_rel*~c_collab   0.265693    0.0109075
0.946481
c_sysdes*c_flex*~c_resor*~c_agility*c_transp*~c_rel*~c_collab    0.283598    0.0100843
0.927946
~c_sysdes*~c_flex*c_resor*c_agility*c_transp*~c_rel*~c_collab    0.248199    0.0119367
0.929838
~c_sysdes*~c_flex*c_resor*~c_agility*~c_transp*c_rel*c_collab    0.244083    0.00864369
0.905343
c_sysdes*c_flex*~c_resor*c_agility*~c_transp*~c_rel*c_collab     0.289977    0.00493932  0.91553
~c_sysdes*c_flex*c_resor*~c_agility*c_transp*~c_rel*c_collab     0.274542    0.0133772
0.941425
c_sysdes*~c_flex*c_resor*c_agility*c_transp*~c_rel*c_collab      0.265693    0.0137888
0.905965
~c_sysdes*c_flex*c_resor*c_agility*~c_transp*c_rel*c_collab      0.280305    0.00514507
0.922764
solution coverage: 0.699527
solution consistency: 0.814522
```

Figure 4. Intermediate Solution

3.3 Interpretation of Solutions

FsQCA computes the complex and parsimonious solutions regardless of any simplifying assumptions employed by the researcher, while the intermediate solution depends directly on these assumptions. For better interpreting the results, combining the parsimonious and intermediate solutions is recommended. A table that will include both core and peripheral conditions should be created. To do this, the researcher should identify the conditions of the parsimonious solution in the intermediate solution. This leads toa combined solution, which will include all core and peripheral conditions, thus helping in the interpretation of the findings (Table 3). Furthermore, to improve the visualization of the results, the presence of a condition is presented with a black circle (●), the absence with a crossed-out circle (⊗), and the "do not care" condition with a blank space. The distinction between core and peripheral is done by using large and small circles, respectively. The overall solution consistency and the overall solution coverage are presented. Consistency measures the degree to which a subset relationship has been approximated, and overall coverage describes the extent to which the outcome is be explained by the different configurations, and is comparable with the R-square reported on regression-based methods (Pappas and Woodside, 2021)

Table 3. FsQCA findings

Name of the Resilience Enabler	**Solutions**					
	1	**2**	**3**	**4**	**5**	**6**
SC Agility		⊗	⊗	•	⊗	•
SC Flexibility		•	•	⊗		•
Resilience Orientation	•	•	•	⊗	⊗	⊗
Relationship Development	●		⊗	⊗	⊗	⊗
SC Transparency	⊗	⊗	⊗	⊗	⊗	⊗
SC Collaboration	⊗	•	⊗		•	•
Resilient System Design	•	•	⊗	⊗	⊗	•
Coverage	0.3418	0.309	0.265	0.297	0.3	0.2899
Consistency	0.8954	0.9244	0.946	0.894	0.89	0.915

4. Results and Discussion

The results for performance are shown in Table 2. The table also present consistency values for the overall solution and for each solution separately. All consistency values are higher than the recommended threshold (> 0.75). FsQCA also estimates the empirical relevance of every solution, by calculating raw and unique coverage. The table depicts the raw coverage of the solutions. The raw coverage describes the amount of the outcome explained by a specific alternative solution. For high performance, following solutions present combinations for which the different factors may be present or absent depending on how they combine with each other:

1) The solution 1 presents the combination of resilient system design, resilience orientation and relationship between partners for high supply chain resilience performance even when supply chain transparency and supply chain collaboration are absent
2) Combination of flexibility, resilience orientation, collaboration and system design can predict high supply chain performance in the absence of agility and transparency in supply chain regardless of the presence or absence of member relationship
3) Agility can offset the absence of flexibility, resilience orientation, member relationship, transparency and resilient system design for explaining superior supply chain performance regardless of the presence or absence of collaboration in supply chain
4) Collaboration can offset the absence of agility, resilience orientation, relationship development with members, transparency and resilient system design regardless of presence or absence of flexibility.
5) The combination of flexibility, transparency, resilient system design explains superior supply chain performance during disruption in the absence of agility, resilience orientation, relationships with partners and collaboration
6) The combination of resilience orientation, relationship development and resilient system design result in superior supply chain performance when the intensity of transparency and collaboration in supply chain are low irrespective of presence or absence of agility and flexibility.

The results provide support for the propositions of the present study. In detail, multiple configurations lead to high performance, verifying equifinality (Proposition 1). Also, the results provide configurations that explain performance in which conditions may be either present or absent, depending on how the combine with each other, verifying the existence of causal asymmetry. Finally, the configurations that explain high performance are not the exact opposites of those explaining medium/low performance. These solutions also boast high level of consistency and coverage values which also validates their statistical significance. The consistency values depict the strength of the solution and represent the degree to which the relationship can be approximated. The consistency values for all the solutions is above the threshold of 80%. The coverage values evaluate the empirical evidence of the configuration. it gives the extent to which the performance can be determined from the existing configuration. These values are closer to the threshold which gives satisfactory explanation of the solution.

Understanding the factors that affect assessment outcome, as well as their interrelationships, could contribute to the sufficient explanation and interpretation of the obtained high or medium/low performance. The existing research is replete with analysis of resilience enablers and their linkages with supply chain performance amidst disruptions. These studies give limited explanation about configurations of resilience enablers that are necessary and sufficient for achieving a superior supply chain performance. The present study employs fuzzy set qualitative comparative analysis (fsQCA) to arrive at these configurations of resilience enablers that equally effectively explain superior supply chain performance. Moreover, the multiple equally effective configurations using fsQCA helps in resolving two constraints of cost and inter-relatedness of enablers that is faced by managers while attempting to make the supply chains resilient. The configurations obtained are equally effective implying that either of them can be chosen for implementation. The managers can select the configuration based on the cost (or any other specification) and enhance the resilience of their supply chains. The analysis is performed for the supply chains of Indian automobile industry which functions amidst high turbulence, involves global partners and, hence, are vulnerable to disruptions. The importance of Indian automobile industry for several global supply chains is important which makes study of resilience in this context a very important investigation. Six solutions are obtained from the analysis which depict different combinations of resilience enablers in the context of supply chains of Indian automobile industry. It is noted that several configurations involve the interplay of different enablers (solution 1, solution 2, solution 5 and solution 6) while some of them involve single resilience enabler that can make supply chain resilient even when other enablers are absent. Hence, managers can work towards either a single enabler or combinations of enablers for enhancing the resilience of their supply chain with equal effectiveness.

5. Conclusions

The obtained configurations may be validated using variance-based techniques to gain a complementing insight into the linkages between the enablers and supply chain performance. The present study has a limitation of using a small sample which may be increased for obtaining more complex and important configurations which might have been missed. The threshold values used in the present study may also be varied to obtain different configurations which might have escaped the analysis. Future studies may also study supply chains of other industry and country contexts and combine the findings for a generalised framework for supply chain resilience.

References

Abeysekara, N., Wang, H., and Kuruppuarachchi, D., Effect of supply-chain resilience on firm performance and competitive advantage: A study of the Sri Lankan apparel industry. Business Process Management Journal. Vol. 25 No. 7, 2019 pp. 1673-1695, 2019

Agarwal, N., Seth, N. and Agarwal, A., "Evaluation of supply chain resilience index: a graph theory-based approach", Benchmarking: An International Journal, Vol. 29 No. 3, pp. 735-766., 2022

Agarwal, N. and Seth, N., "Analysis of supply chain resilience barriers in Indian automotive company using total interpretive structural modelling", Journal of Advances in Management Research, Vol. 18 No. 5, pp. 758-781., 2021

Agarwal, N., Seth, N. and Agarwal, A., "Modeling supply chain enablers for effective resilience", Continuity and Resilience Review, Vol. 2 No. 2, pp. 97-110., 2020

Agarwal, N., Seth, N., and Agarwal, A., Selecting Capabilities to Mitigate Supply Chain Resilience Barriers for an Industry 4.0 Manufacturing Company: An AHP-Fuzzy Topsis Approach. *Journal of Advanced Manufacturing Systems*, *21*(01), 55-83., 2022

Aggarwal, S., and Srivastava, M. K. A grey-based DEMATEL model for building collaborative resilience in supply chain. International Journal of Quality and Reliability Management.Vol. 36 No. 8, 2019 pp. 1409-1437, 2019

Ali, I., Nagalingam, S., and Gurd, B., Building resilience in SMEs of perishable product supply chains: enablers, barriers and risks. Production Planning and Control, 28(15), 1236-1250., 2017

Ali, I., and Gölgeci, I., Where is supply chain resilience research heading? A systematic and co-occurrence analysis. International Journal of Physical Distribution and Logistics Management. Vol. 49 No. 8, 2019 pp. 793-815, 2019

Ali, A., Mahfouz, A., and Arisha, A., Analysing supply chain resilience: integrating the constructs in a concept mapping framework via a systematic literature review. Supply Chain Management: An International Journal. 22/1 (2017) 16–39, 2017

Asamoah, D., Agyei-Owusu, B., and Ashun, E., Social network relationship, supply chain resilience and customer-oriented performance of small and medium enterprises in a developing economy. Benchmarking: An International Journal. Vol. 27 No. 5, 2020 pp. 1793-1813, 2020

Aslam, H., Khan, A. Q., Rashid, K., and Rehman, S. U., Achieving supply chain resilience: the role of supply chain ambidexterity and supply chain agility. Journal of Manufacturing Technology Management.Vol. 31 No. 6, 2020 pp. 1185-1204, 2020

Bag, S., Gupta, S., and Foropon, C., Examining the role of dynamic remanufacturing capability on supply chain resilience in circular economy. Management Decision.Vol. 57 No. 4, 2019 pp. 863-885, 2019

Chen, H. Y., Das, A., and Ivanov, D., Building resilience and managing post-disruption supply chain recovery: Lessons from the information and communication technology industry. International Journal of Information Management, 49, 330-342, 2019

Chowdhury, M. M. H., Quaddus, M., and Agarwal, R., Supply chain resilience for performance: role of relational practices and network complexities. Supply Chain Management: An International Journal. 24/5 (2019) 659–676, 2019

Chowdhury, M. M. H., and Quaddus, M., Supply chain readiness, response and recovery for resilience. Supply Chain Management: An International Journal.21/6 (2016) 709–731, 2016

Christopher, M., andamp; Peck, H., Building the resilient supply chain. The International Journal of Logistics Management. Vol 15 No. 2, pp. 1-13, 2004

da Silva Poberschnigg, T. F., Pimenta, M. L., and Hilletofth, P., How can cross-functional integration support the development of resilience capabilities? The case of collaboration in the automotive industry. Supply Chain Management: An International Journal. 25/6 789–801, 2020

Dabhilkar, M., Birkie, S. E., and Kaulio, M., Supply-side resilience as practice bundles: a critical incident study. International Journal of Operations and Production Management. Vol. 36 No. 8, 2016 pp. 948-970, 2016

Gu, M., Yang, L., and Huo, B., The impact of information technology usage on supply chain resilience and performance: An ambidexterous view. International Journal of Production Economics, 232, 107956., 2021

Hsu, C. H., Chang, A. Y., Zhang, T. Y., Lin, W. D., and Liu, W. L., Deploying Resilience Enablers to Mitigate Risks in Sustainable Fashion Supply Chains. Sustainability, 13(5), 2943., 2021

Jafarnejad, A., Momeni, M., Hajiagha, S. H. R., and Khorshidi, M. F., A dynamic supply chain resilience model for medical equipment's industry. Journal of Modelling in Management. Vol. 14 No. 3, 2019 pp. 816-840, 2019

Jain, V., Kumar, S., Soni, U., and Chandra, C., Supply chain resilience: model development and empirical analysis. International Journal of Production Research, 55(22), 6779-6800., 2017

Jia, X., Chowdhury, M., Prayag, G., and Chowdhury, M. M. H., The role of social capital on proactive and reactive resilience of organizations post-disaster. International Journal of Disaster Risk Reduction, 48, 101614., 2020

Karmaker, C. L., and Ahmed, T., Modeling performance indicators of resilient pharmaceutical supply chain. Modern Supply Chain Research and Applications..Vol. 2 No. 3, 2020 pp. 179-205, 2020

Kumar, S., and Anbanandam, R., An integrated Delphi–fuzzy logic approach for measuring supply chain resilience: an illustrative case from manufacturing industry. Measuring Business Excellence. VOL. 23 NO. 3 2019, pp. 350-375,2019

Li, X., Wu, Q., Holsapple, C. W., and Goldsby, T., An empirical examination of firm financial performance along dimensions of supply chain resilience. Management Research Review.Vol. 40 No. 3, 2017 pp. 254-269, 2017

Liu, C. L., Shang, K. C., Lirn, T. C., Lai, K. H., and Lun, Y. V., Supply chain resilience, firm performance, and management policies in the liner shipping industry. Transportation Research Part A: Policy and Practice, 110, 202-219., 2018

Mandal, S., Bhattacharya, S., Korasiga, V.R. and Sarathy, R., "The dominant influence of logistics capabilities on integration: Empirical evidence from supply chain resilience", International Journal of Disaster Resilience in the Built Environment, Vol. 8 No. 4, pp. 357-374., 2017

Pappas, I. O., and Woodside, A. G., Fuzzy-set Qualitative Comparative Analysis (fsQCA): Guidelines for research practice in Information Systems and marketing. International Journal of Information Management, 58, 102310., 2021

Pettit, T. J., Croxton, K. L., and Fiksel, J., Ensuring supply chain resilience: development and implementation of an assessment tool. Journal of business logistics, 34(1), 46-76., 2013

Piprani, A. Z., Jaafar, N. I., and Ali, S. M., Prioritizing resilient capability factors of dealing with supply chain disruptions: an analytical hierarchy process (AHP) application in the textile industry. Benchmarking: An International Journal.Vol. 27 No. 9, 2020 pp. 2537-2563, 2020

Rajesh, R., Technological capabilities and supply chain resilience of firms: A relational analysis using Total Interpretive Structural Modeling (TISM). Technological Forecasting and Social Change, 118, 161-169., 2017

Rajesh, R., and Ravi, V., Modeling enablers of supply chain risk mitigation in electronic supply chains: A Grey–DEMATEL approach. Computers and Industrial Engineering, 87, 126-139., 2015

Sangari, M. S., and Dashtpeyma, M., An integrated framework of supply chain resilience enablers: a hybrid ISM-FANP approach. International Journal of Business Excellence, 18(2), 242-268., 2019

Scholten, K., and Schilder, S., The role of collaboration in supply chain resilience. Supply Chain Management: An International Journal. 20/4 471–484, 2015

Scholten, K., Scott, P. S., and Fynes, B., Mitigation processes–antecedents for building supply chain resilience. Supply Chain Management: An International Journal. 19/2 211–228, 2014

Tukamuhabwa, B., Stevenson, M., and Busby, J. Supply chain resilience in a developing country context: a case study on the interconnectedness of threats, strategies and outcomes. Supply Chain Management: An International Journal.22/6 486–505, 2017

Wieland, A., and Wallenburg, C. M. The influence of relational competencies on supply chain resilience: a relational view. International Journal of Physical Distribution and Logistics Management. Vol. 43 No. 4, pp. 300-320, 2013

Zouari, D., Ruel, S., and Viale, L. Does digitalising the supply chain contribute to its resilience?. International Journal of Physical Distribution and Logistics Management.Vol. 51 No. 2, pp. 149-180, 2020

Biographies

Ms. Nishtha Agarwal is a research scholar at Indian Institute of Foreign Trade, New Delhi. She is pursuing research in the area of supply chain management. She has keen interest in action-based research and case study-based research. She has several research papers to her credit one of which has won the outstanding paper award in 2021 in the area of supply chain resilience.

Prof. Nitin Seth is Professor (Quantitative Techniques and Operations Management at IIFT, New Delhi and presently he is on deputation as a Director at Indo French Centre for the Promotion of Advanced Research. He has more than 25 years of teaching experience where his specializations include Supply Chain Management (with focus on sustainable business practices), Operations Management and Service Operations, Service Quality, Total Quality Management and Project Management. He has more than 80 research papers to his credit and has supervised several doctoral candidates.