Received: 15 September 2023 | Revised: 21 April 2024 | Accepted: 24 April 2024

DOI: 10.1002/bse.3801

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

# Smart, sustainable, and resilient food supply chains in disruptive events context

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## Abstract

Food systems include dynamic and complex networks made up of all the actors, processes, and infrastructures, as well as their interactions. Because of the growing supply chain's (SC) vulnerability, fragility, and operational disturbances, managing disruptions has become a crucial problem in the food SC. Thus, companies aim to improve their resilience to deal with unexpected conditions. Thus, this study aims to analyze and frame the food SC's resilience, sustainability, and smartness considering different causal conditions (e.g., digital technology adaption, providing traceability, and enhancing collaboration). This study also analyzes the numerous and complex linkages between outcome and causal variables. Thus, this study includes data on the food industry operating in Turkey. The Fuzzy Set Qualitative Comparative Analysis has been used to analyze different companies' data. SC resilience performance conditions have been determined and analyzed. According to the result of this study, it can be said that enhanced flexibility structure and adaptability skills in the SC, increased IT capability, and integration of digital technologies into the SC process are the key components for achieving high SC resilience, sustainability, and smartness in the food SCs. This study suggests various implications for policymakers and managers in the food SCs.

**KEYWORDS**

digital transformation, food supply chain, Fuzzy Set Qualitative Comparative Analysis, resilience improvement factors, supply chain resilience, sustainability

## 1 | INTRODUCTION

The food supply chain (FSC) is a complex production, processing, distribution, and consumption-related activity (Reddy et al., 2016) that has numerous connections between their various parts are dynamic, and frequently entail intricate feedback loops that may either reinforce one other or cause disruption (Béné et al., 2019; Chapot et al., 2021). A disruption to the FSC occurs when there's a significant malfunction in the system node that connects production and consumption activities. These stoppages can occur at any stage of the food product cycle (Reddy et al., 2016). Considering the crisis's impact on FSC resilience, decision-makers must promptly adapt and respond to manage interruptions and risks caused by market dynamics and side streams (Hosseini et al., 2019; Sharma et al., 2021).

The FSC is in a vulnerable position because of uncertainties brought on by diseases, policies, technology catastrophes, terrorism-

**Abbreviations:** AFSCR, Agri-food SC resilience; fsQCA, Fuzzy Set Qualitative Comparative Analysis; FSCs, Food Supply Chains; GSCs, Global Supply Chains; SC, Supply Chains; SCR, Supply Chain Resilience; SFSCs, Short Food Supply Chains.

related hazards, natural calamities (Xu et al., 2021; Zhao et al., 2020), earthquakes, and so on. FSC is more susceptible to deterioration and destruction than the SC of other items because of the vulnerability of both the product concept and the phases in the SC (Djekic et al., 2014; Kaur et al., 2020; Kazancoglu et al., 2021; Liu et al., 2020). Besides, because of the short shelf life of food, the current variability in raw material quality and availability, the slow manufacturing cycle time, and high reliance on chilled transportation that are prone to quality degradation as they move through the supply chain (SC), FSCs have an own unique vulnerability (Deep & Dani, 2009; Stone et al., 2015; Vlajic et al., 2013).

Natural catastrophes have significantly influenced the global FSC in recent times. For instance, according to the worldwide disaster management database, storms from 2004 to 2014 were the leading cause of accidental fatalities (42.14%), after earthquakes (29.89%) (EM-DAT, 2023). A crisis like this reveals systemic flaws, measures resiliency, and puts trade rules and agreements up for review. In addition to these disturbances, a new disruption emerged called the COVID-19 epidemic, which has given practically several issues for almost all SCs, including unpredictable demand, changing consumer behavior, workforce shortage, poor visibility, and SC stakeholders' insolvency (EM-DAT, 2023; Kumar et al., 2022). The global pandemic has disrupted various sectors with the effects of precautions to prevent the spreading of the virus (e.g., strict mitigation laws, lockdowns, and commercial closures); the global pandemic has disrupted various sectors (Tang, 2006). However, FSCs are among the most damaged sectors since they meet one of the most fundamental human requirements and are also one of the fastest-growing global industries (Paul et al., 2021; Sharma et al., 2021).

A resilient FSC can build the adaptive capability to recover from disturbances of varying lengths, effects, and probabilities or to adapt to them (Paul et al., 2021; Tang, 2006; Xu et al., 2021). Because the resilience characteristic enables SCs to adjust to uncertain future occurrences and endure the detrimental impacts of unidentified disruptions (Kazancoglu et al., 2021; Zhu & Krikke, 2020). To increase the resilience of FSCs, various strategies have been developed, including increasing flexibility, building redundancy, using alternative sources of supply, enhancing visibility, increasing SC agility, leveraging relationships with SC partners, and sharing information (Abideen et al., 2021; Golan et al., 2020).

The food business, which continues to be the largest manufacturing sector in many developed and developing nations, has a pressing need for sustainable production and distribution (Li et al., 2014; Zhu & Krikke, 2020). Recent unforeseen crises that have threatened Supply Chain (SC) continuity and operations have especially emphasized the importance of SC sustainability and resilience (Hervani et al., 2022). Sustainable supply networks need resilience to continue operating in the face of unanticipated shocks (Michel-Villarreal, 2023). Because supply chain resilience (SCR) affects an organization's ability to maintain its economic, environmental, and social performance (Negri et al., 2021), and the resilience skills it provides (Mari et al., 2014), it can aid in the recovery from shocks and continue operating. Sustainability methods improve SCR by preserving ecological services, promoting sustainable behavior, cultivating community trust, and offering crisis remedies that may be altered via sustainability to lower risk (Sarkis, 2020). In this process, digital technology adoption can change the SCs' operations, goods, services, and business plans for FSC in gaining a competitive advantage; the SC partners respond more quickly, accurately, efficiently, and transparently and achieve sustainability for long-term survival.

In this context, the FSCs are moving towards abbreviating their SCs; developing smart, sustainable, and resilient SCs for the future; embracing digitization; increasing flexibility; strengthening traceability to handle interruption; and increasing efficiency (Sharma et al., 2021). However, a key consideration in this context is technology readiness, which refers to an organization's capacity to use emerging technologies (Dora et al., 2022; Paul & Chowdhury, 2021).

Agile, smart, resilient, and sustainable viewpoints may serve as the cornerstone of a viable SC, and these systems can help businesses protect themselves against long-term crises and disruptive occurrences by helping them make better decisions (Suryawanshi et al., 2021). Therefore, the main goal of this study is to make the FSC smart, sustainable, and resilient so that it can adjust to and react to risks and disruptive events. The disruptions and risks resulting from the disruptive events towards the FSC can be revealed by analyzing the causal interaction among the variables determined throughout the study. This study aimed to prepare an agenda for preparedness towards various disruptive events to build a smart, sustainable, and resilient FSC that is not easily affected by disturbances. To achieve this smart, sustainable, and resilient FSC objective, which tries to mitigate the negative consequences of disruptions and hazards in FSC, we examined how configurations that cause high FSC resilience and smartness can be configured. The accompanying research questions (RQs) were delineated below in this context.

*RQ1*. What are the key factors and configurations that contribute to high resilience, sustainability, and smartness in the FSC, enabling it to adjust and react effectively to disruptive events?

*RQ2*. How do smart technologies impact the resilience of FSC and its ability to withstand and recover from disruptive events?

Research on digital technologies' impact on SCR is growing, but there is a lack of understanding about the specific configurations and elements that lead to high resilience and smartness in the FSC. Current studies mainly focus on firm-level adoption, and the causal variables and connections between causes and effects are not well understood. More research is needed to explore configurations resulting in high resilience and intelligence and the role of smart technologies in achieving these goals. From the novelty perspective, this study's uniqueness resides in its comprehensive approach to how FSCs may proactively prepare for and handle disruptions by including technical preparedness, digital technology uptake, and agile, smart, and sustainable perspectives. Furthermore, the research aims to bridge an important gap by investigating the causal connections between factors, highlighting the configurations that significantly lead to high FSC resilience and smartness. The suggested research topics seek innovative insights into the deep relationships between result and causative variables, laying the groundwork for effective recovery management strategies adapted to the unique problems encountered by FSCs.

Following is the continuation of this article. The resilience in FSCs based on proposing conditions for improving resilience in FSCs and the importance of adopting digital technology to enhance resilience in FSCs are discussed in Section 2. Section 3 includes methodology. Sections 4 and 5 present implementation and discussions and implications, respectively. Finally, the conclusion is provided in the last section.

## 2 | LITERATURE REVIEW TOWARDS RESILIENCE IN THE FSC

With the disruptive effects of the COVID-19 pandemic, particularly exposing weaknesses in linked Global Value Chains (GVCs), Gölgeci et al. (2023) tried to reveal how GVCs can be reconfigured in extreme circumstances such as pandemics as well as how they can remain resilient in such case, by enhancing understanding of how they evolve as well as modifications in design and management. Similarly, Ekinci et al. (2022) sought to investigate the effects of the pandemic on energy-efficient Global Supply Chains (GSCs) and their resilience during trade between Turkey, China, and the EU by proposing ways for improving SCs resilience during crisis times. Mishra et al. (2022) attempted to examine SCR under an operational excellence approach, supported by a dynamic capability theory, in agri-food supply firms during disruptive events such as pandemics by addressing confronted difficulties, micro-level practices, and recommending theoretical frameworks. The pandemic has also brought attention to the importance of data-driven risk mitigation techniques for improving GSCs' security, resilience, and sustainability concerns; thus, Bechtsis et al. () tried to define key difficulties, deficiencies, and possibilities in SCM literature and offered an alternative structure for advancement in their paper.

Against the disturbances caused by natural disasters, the FSC's resilience is on the spot. Under this motivation, the major motivation of Orengo Serra et al. (2022) was to put forward an FSC resilience model that discusses the post-disaster food product and its transport flow, with a focus on net food importer economies, by focusing on the adverse effects of critical infrastructure problems on the production, processing, transportation, and retail. In addition to that Gružauskas (2020) aimed to improve SCR, flexibility, and redundancy in FSCs in a sustainability context by leveraging cyber-physical systems to enable knowledge sharing and establishing an organizational structure that conceives resilience and identifies key food industry scenarios for validation. Another similar study by Kumar and Kumar Singh (2022) investigated the effects of the pandemic on Food and Beverage Services (Agri-food Supply Chain [AFSC]) and developed some measures that foster resilience by quantifying main consequences, determining correlations with corrective techniques, and prioritizing these efforts. Moreover, Wang et al. (2022) sought to explore customers' views regarding engaging in short food supply chains (SFSCs) via moral economy and personal relationships by verifying SFSCs and sustainability links, as well as researching governance and cultural components. It expanded triple bottom line concepts and investigated customer opinions towards SFSC activities. Gholami-Zanjani et al. (2021) developed a two-stage scenario-based mathematical model for developing a resilient FSC in the face of unpredictability in demand and epidemic interruptions.

There are a vast number of studies in the existing literature related to the resilience of the FSC in terms of smartness (I4.0 technologies) and sustainability concerns for risky times like pandemics or other disruptive events. For instance, Frederico et al. (2023) investigated the influence of technologies associated with I4.0 on the performance and resilience of SCs after the pandemic. It sheds light on how digital technology might improve responsiveness to unforeseen events, substantially contributing to SC management theory and practice. On the other side, Mohammed et al. (2023) proposed a novel technique for designing a sustainable and resilient two-tier SC network (S2TSCND), investigating the link between sustainability and resilience and proposing a comprehensive framework for identifying parameters, facilitators, and criteria for resilient development. Similarly, the purpose of Münch and Hartmann's (2023) research was to analyze the systemic character of SC systems and to fill a research gap by investigating the resilience skills created by organizations working in tangled SCs, as well as the influence of the COVID-19 epidemic on SCR. Furthermore, Sharma et al. (2021) also encouraged the utilization of Blockchain Technology (BC-T) to overcome interruptions, corruption, and threats caused by outbreaks, with an emphasis on establishing resilient FSCs. Frederico (2021) addressed leveraging the usage of SC 4.0 for the post-COVID-19 recovery process, by revealing its potential to improve robustness and the implementation of Industry 4.0 technologies.

The majority of the literature that has been published to date on the adoption of technology has been firm-level (Calabrese et al., 2022; Janssen et al., 2020; Paul & Chowdhury, 2021; Yang et al., 2015). Researchers and practitioners around the world are most concerned with technology adoption and usage (Paul & Chowdhury, 2021). Despite initial research being done to determine how digital technologies affect SCR (Aboelmaged, 2014; Lezoche et al., 2020; Michel-Villarreal et al., 2021), there is evidence that current supply networks are complicated, and this lack of understanding may limit risk awareness (Zouari et al., 2021) because company structures and tactics of today were created under the presumptions of a stable environment, which are irrelevant in the current chaotic, volatile, and highly unstable business environment (Bin Makhashen et al., 2020).

In addition to that, various publications in the existing literature also investigated smart and sustainable capabilities to deal with the vulnerable structure towards the disruptions caused by the pandemic and develop post-pandemic preparedness and recovery (Ivanov & Das, 2020; Kayikci et al., 2021; Kazancoglu et al., 2021; Ruel & El Baz, 2023). While some of the studies were focused on knowledge preparedness to overcome the challenges faced (Lopes et al., 2022; Orlando et al., 2022), some papers pointed out different strategies as risk management practices (El Baz & Ruel, 2021), the role of improvisation, anticipation, and data analytics capabilities (Munir et al., 2022), disruption management (Moosavi et al., 2022), the role of resource orchestration in supporting resilience (Queiroz et al., 2022), and so on. Apart from those studies, Kazancoglu et al. (2023) explored and evaluated several outsourcing ways to improve supply chain resilience (SCR) in firms to overcome the knowledge gap between existing understanding and GSC approaches to risk management from the perspective of resilience.

While previous studies have made great advances in understanding the resilience of FSCs during disruptive events, there is still a large study gap. Many studies focus on the impact of Industry 4.0 technologies and sustainability considerations on FSC resilience; however, there has been little investigation into the intricate relationships between technological readiness, digital technology adoption, and the overall smartness of FSCs in the context of resilience during disruptions. Moreover, the majority of the current studies in the field concentrate on disruptions caused by pandemics, neglecting other disruptive events. This represents a significant gap in the literature, as there is a lack of a broad study that addresses all types of disruptive events simultaneously. Considering this information, this study contributes to the literature by completely addressing the issues encountered by FSCs in the period following disruptive events such as natural disasters and global crises. It investigates the complicated dynamics of FSCs, highlighting the vulnerabilities unexpected to this sector, and presents a strategy framework for developing smart, sustainable, and resilient FSCs. The study attempts to give significant insights into critical characteristics and configurations that improve FSC resilience, sustainability, and smartness, allowing for better adaptation and reaction to disruptive events.

## 2.1 | Important intermediates of resilient FSCs

There are numerous intermediates of the food business that make up complex SC networks, and they are frequently reticent to contribute traceability data (Behnke & Janssen, 2020), which hinders digitalization, transparency, and supporting systems (Galvez et al., 2018; Nurgazina et al., 2021). A traceability system gives comprehensive awareness of the changing SC environment for component replacements (Ali et al., 2021). Due to its capacity to gather, update, and send information in real-time with no delay or error, traceability systems have come to be recognized as a crucial instrument for enhancing the relationship between SC performance and SC risk management (Razak et al., 2023; Ringsberg, 2014; Stranieri et al., 2017). To increase the transparency and visibility of the SCs, traceability is utilized to provide signs of the source, position, condition, composition, and so on across all manufacturing, processing, and distribution phases (Kelepouris et al., 2007; Razak et al., 2023; Timmer & Kaufmann, 2017).

Other important conditions necessary for FSC to be smart, sustainable, and resilient are cooperation and collaboration (Ambulkar et al., 2015; Bottani et al., 2019; Bottani et al., 2020; Sharma et al., 2021). Companies may need to communicate important information and valuable knowledge and create cooperative initiatives to ease the production in SC (Brusset & Teller, 2017; Hohenstein et al., 2015). Collaboration is identified as the capacity of inter-organizational relations to organize and carry out SC operations to accomplish shared objectives (Scholten & Schilder, 2015). Collaboration among vendors and buyers boosts SC members' trust and improves their ability to respond to unexpected shifts in demand or unanticipated SC interruptions (Hobbs, 2020). Also, supply network participants must cooperate for digital technologies to be successfully implemented (Kaipia et al., 2013; Paul & Chowdhury, 2021; Sharma et al., 2021). Problems with food quality, security, transparency, and traceability may also be resolved using information exchange in the FSC (Durrant et al., 2021; Paul & Chowdhury, 2021).

Businesses' capacity to be resilient mostly relies on their agility and ability to respond to shocks (Ivanov, 2022; Kazancoglu et al., 2021). Agility can be considered a resilience tactic that helps organizations adjust swiftly to change (Christopher & Peck, 2004; Paul et al., 2021). Agility in SC refers to a strategic method to adapt an organization quickly to change, and velocity and visibility have a role in determining it (Sharma et al., 2021). As mentioned above, agility is mostly determined by visibility and velocity (Lohmer et al., 2020). Thereby, we can claim that the significance of achieving resilience through enhancing velocity, which is referred to as distance/time; visibility, which is referred to as the ability to see "end to end" in the pipeline; and agility, which is the ability to adapt quickly (Chenarides et al., 2021). Visibility is about knowing in real-time who, where, and how operating assets are moving through the SC (Johnson et al., 2013). As a result of improved visibility throughout the entire SC and the ability to track and trace products using the system, the SC is more resilient because real-time information is available (Lohmer et al., 2020; Priya Datta et al., 2007). Also, if managers try to increase their companies' visibility, clients are more likely to perceive their commitment to sustainability as genuine, which may foster productive commercial relationships (Sharma et al., 2023). On the other side, the term "velocity" describes how quickly an SC may respond and bounce back from an unforeseen disturbance (Johnson et al., 2013; Scholten & Schilder, 2015). Velocity relates to flexibility and adaptation since it is crucial to quickly adjust to changes (Christopher & Peck, 2004; Wieland & Wallenburg, 2013). Flexibility supports SCR by ensuring that resources can be relocated to change operations swiftly in case of interruption.

The ability of an SC to adapt its operations to deal with alterations in market conditions or any other unanticipated occurrence is referred to as flexibility (Jüttner & Maklan, 2011; Scholten & Schilder, 2015). Flexibility is based on the premise that choosing one distribution channel over another has a "real option" because of the economic environment's cyclicality and the high fixed costs involved (Chenarides et al., 2021). For food enterprises, adaptability and flexibility are crucial elements of a resilient SC (Hobbs, 2021). The capacity of an organization to adjust its operations to best respond to a disruption or opportunity is referred to as adaptability. FSCs' adaptability may be divided into two categories: flexibility in order fulfillment and flexibility in sourcing (Peck, 2006; Stone et al., 2015). Another crucial condition is redundancy, which refers to the presence of extra raw material capacity storage, manufacturing capacity, generation of power, and transportation that are not necessary for routine operations (Stone et al., 2015).

## 2.2 | Digital technology integration into FSC for smart, sustainable, and resilient FSCs

Emerging technology has the potential to mitigate the effects of disruptive events on FSC by managing food systems and enhancing quality and safety. Thereby, technology incorporation into food systems leads to increased productivity and resource efficiency (Ponomarov & Holcomb, 2009). Furthermore, the ability of a corporation to innovate is impacted by digitalization (Li et al., 2020), environmentally friendly (Li et al., 2021), adaptability to interruptions (Yang et al., 2019), and quick to change SC operations to fit the new circumstances (de Camargo Fiorini & Jabbour, 2017). Lack of digitization results in manual procedures and paperwork that are prone to human error (Rogerson & Parry, 2020), a lack of records, delayed tracing, and challenges with the retrieval of information and product sorting (Galvez et al., 2018; Nurgazina et al., 2021). Therefore, the FSC must be digitalized to reduce value chain risks and gain a sustainable competitive advantage (Bermeo-Almeida et al., 2018; Queiroz et al., 2020; Rejeb et al., 2021).

There is an exponential increase in digitalization in the food industry and FSCs due to the integration of technologies (Nurgazina et al., 2021; Queiroz et al., 2020). BC, cloud computing, and big data analytics (BDA) can all enhance FSC's traceability and visibility (Kayikci et al., 2022; Saurabh & Dey, 2021). Also, technologies like BC and artificial intelligence (AI) have all benefited tremendously from the use of their capabilities to address issues with the FSC relating to sustainability and traceability (Ponomarov & Holcomb, 2009). Moreover, AI offers cutting-edge technological solutions for producing and distributing food yields, minimizing food waste, and maintaining food safety (Kollia et al., 2021; Paul & Chowdhury, 2021).

For instance, IoT and CPS technologies are two sensor technologies that have been heavily included in FSCs to maintain monitoring logistics activities, tracking product quality and process control (Creydt & Fischer, 2019; Galvez et al., 2018). Sensors gather and preserve vital food data, including food location history and product life cycle, to enhance storage management and decrease product losses, contamination, and degradation (Aung & Chang, 2014; Creydt & Fischer, 2019; Galvez et al., 2018; Kamble et al., 2020; Nurgazina et al., 2021).

One of the cutting-edge technologies in the age of I4.0 is BT. The flexibility, stability, traceability, resilience, reduction of risk, sustainability, and affordability may all be lowered by BT (Behnke & Janssen, 2020; Hughes et al., 2019; Sharma et al., 2021). According to Subramanian et al. (2020), this innovative technology can also help to improve operating efficiency (Upadhyay, 2020). BT can enhance inventory management and replenishment, decrease the need for intermediaries, improve inventory reliability and security, promote better quality management, reduce unauthorized copying, influence new product conception and development, and lower the price of transactions of the SC (Cole et al., 2019).

Furthermore, BD is also claimed to have the ability to aid in the restoration following interruptions, such as the application of data analytics to raise visibility, boost forecast precision, and activate backup plans (Aboelmaged, 2014). In BD, once data have been saved in a single record, it can no longer be changed, and all duplicated copies are updated almost instantly verified updated records eliminate the need for intermediary verification and increase confidence between the partners (Kshetri, 2018), which results in eliminating redundancy, improved efficiency, and decreased costs (Sharma et al., 2021).

# 3 | METHODOLOGY

The traditional comparative techniques that John Stuart Mill theorized in 1843 are where the qualitative comparative analysis (QCA) stems from (Kan et al., 2016; Ragin, 2014). A method of analysis known as QCA (Ragin, 2000; Ragin, 2014), which combines quantitative and qualitative approaches, was initially restricted to tiny samples, but further advancements allowed for its usage in more extensive situations (Roig-Tierno et al., 2017).

The use of QCA, which employs Boolean logic, to establish the causal connections between variables relating to a specific result has been growing recently (Ragin, 2000; Ragin, 2009; Ragin & Fiss, 2008; Roig-Tierno et al., 2017; Vis, 2012; Woodside, 2016). According to Miles and Huberman (1994), the QCA is an effective analytical technique for cross-case analysis that concentrates on the complexity that distinguishes the instances under consideration. There are various advantages that QCA provides. For instance, QCA excels in identifying various causal condition configurations that are adequate for a given outcome. Even though it may be used with extremely high sample sizes, it was initially intended to be used with tiny sample sizes, which are far less than those needed for conventional regression analysis (Fainshmidt et al., 2020).

In this study, the *Fuzzy Set Qualitative Comparative Analysis (fsQCA) method, which is a type of QCA, was developed in 1987 by Charles Ragin, a social scientist (Ragin, 2014). The flowchart of the methodology is presented in Figure 1. The notion of clusters and linkages describes the relationship between causal circumstances and

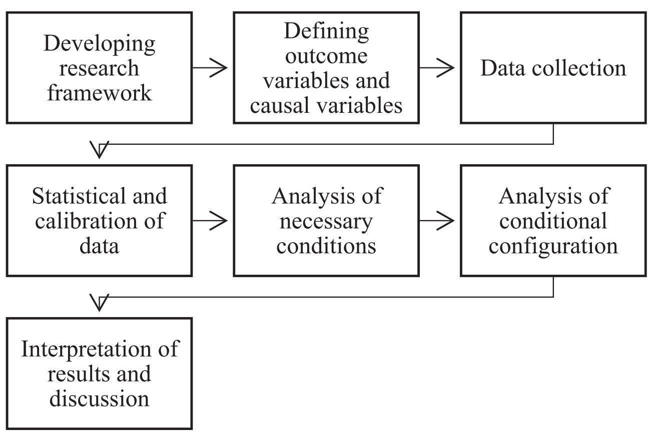


**FIGURE 1** Flowchart of the methodology.

outcomes in QCA (Rabadán et al., 2019). It blends quantitative research methods with qualitative research techniques such as comparative case studies. QCA is a theoretical method that explains the interaction between among variables and independent variables with the set theory approach (0/1). More recently, more studies have focused on fsQCA in business and management disciplines to overcome the limitations of symmetric statistical tools (Mena et al., 2022).

One of the advantages of the fsQCA method is that it examines asymmetric relationships and causal complexity by evaluating combinations of conditions (Beynon et al., 2020). According to Huarng and Yu (2017), the fsQCA technique has a relative advantage in illustrating the combinations of circumstances that result in the lack of an outcome, a positive outcome, and a negative outcome. QCA is a method used to analyze multiple cases in complex situations. For theory development, elaboration, and testing, the fsQCA is helpful for inductive and deductive reasoning (Greckhamer et al., 2018; Pappas & Woodside, 2021; Park et al., 2020). This method is also effective in examining the effect a change has on the output. Although qualitative data are used to derive these attributes, it is a quantitative analysis method. Cut-off values in fsQCA vary from full non-membership (0.05) to full membership (0.95), with 0.5 signifying the most uncertainty (Yin & Ran, 2022). For this investigation, fsQCA is ideal since it concentrates on the interactions between causal circumstances (Fiss et al., 2013; Ragin, 2000; Veríssimo, 2016). The implementation of the study is presented in the next section.

The use of fsQCA in this study contributes significant advantages since it addresses the inherent complexity of food systems. With FSCs consisting of dynamic and complicated networks of players, processes, and infrastructures, fsQCA enables the study of various causative circumstances and their combinations. This approach is well-suited to capture non-linear correlations, which are critical for understanding the subtle interactions in FSCs. By looking at elements like digital technology adoption, traceability provision, and cooperation enhancement, fsQCA allows us to uncover complex causal configurations that contribute to SCR, sustainability, and smartness. Furthermore, fsQCA takes into account contextual elements such as market dynamics and regulatory contexts, offering a thorough knowledge of how these aspects affect SC performance. This technique allows us to identify essential components, such as greater flexibility structures and IT capabilities, that are critical to attaining high levels of SCR, sustainability, and smartness.

## 4 | CASE STUDY

This section of this study mainly investigates implementing a case study in the Fast-Moving Consumer Goods (FMCG) industry related to examining and framing the smart, sustainable, and resilient FSC against disruptive events such as earthquakes and pandemics, in Turkey. Due to its inherent sensitivity to disruptive events such as earthquakes, floods, and epidemics, the FSC, notably within the FMCG business in Turkey, is a suitable target for this study. Because of the region's regular vulnerability to natural catastrophes, it needs creative and resilient solutions, making it an appealing backdrop for investigating SCR. The study's goal is to give insights into the issues faced by the FMCG SC in a disaster-prone setting, as well as practical solutions that may be used to improve resilience in comparable environments worldwide. Recent events in Turkey have highlighted the need to understand and increase the adaptive ability of food supply networks, making it a relevant and useful issue for this research.

As suggested above, Turkey was selected as the study's focal point owing to the country's distinct environment, which frequently experiences a variety of disturbances, including earthquakes and flood catastrophes, which call for the adoption of innovative and resilient solutions. Natural catastrophes are common in the nation due to their geographic position, and these occurrences may significantly negatively influence SCs, particularly those in the FMCG industry. Studying the Turkish environment will help researchers better understand the unique difficulties the FMCG SC faces in a disaster-prone area and come up with solutions to make it more resilient. The lessons learned from Turkey's experiences are an important foundation for recognizing the necessity for preemptive measures, readiness, and efficient reactions to disruptions, helping to build all-encompassing solutions that may be applied to other areas facing comparable problems.

Collecting data from experts requires a methodical approach to verify the accuracy and reliability of the information gathered. Identifying precise and dependable experts from a vast pool necessitates careful consideration and an organized approach. To enhance the reliability and validity of this study, it is essential to identify the experts who have contributed to it. This can be achieved by seeking recommendations from reliable sources within professional associations. Professionals employed by companies that are acknowledged or endorsed by professional organizations have been reached to gather knowledge and expertise in the relevant field, hence ensuring the reliability of the obtained results. Subsequently, we employed specialized databases that compile a list of experts across diverse areas. These platforms frequently facilitated the identification of prospective applicants by furnishing details regarding the credentials, areas of knowledge, and affiliations of the specialists. Assessing the expertise, methods of communication, and compatibility of specialists with the research goals is a crucial procedure. The involvement of professionals from many departments within the SC proved to be highly valuable in conducting a thorough assessment of the research. Subsequently, following the selection of these prominent companies, the expert selection procedure was started. Individuals who possess expertise in your specific field or area of interest have been identified. The data collection procedure was explicitly defined with defined aims and objectives. The sample of this study includes well-known food companies, most specifically FMCG companies, operating in Turkey. The FMCG industry is significant given how strongly people relied on food products for everyday necessities throughout the disruptive events. The FMCG sector was selected for this study's implementation because of its importance in satisfying fundamental consumer requirements, the complexity and difficulties associated with its SC, susceptibility to disruptive events, and the development of digital technology within the industry. By addressing its unique complexity, reducing vulnerabilities, and investigating the effects of technology adoption, the research seeks to comprehend and improve the resilience and smartness of the FMCG SC. The study's focus on the FMCG industry is intended to provide insightful analysis and practical suggestions for enhancing the FMCG SC's effectiveness, responsiveness, and overall performance. This has allowed FMCG firms to grow their businesses, supply networks, and consumer bases. The earthquake, flood disasters, and epidemic have disrupted Turkey's SCs, making it challenging for businesses to procure raw materials and deliver goods. Therefore, businesses that can adjust to shifting market conditions and satisfy customer wants, or resilient businesses, are more likely to prosper in this industry. This is the rationale for the case study's application phase's selection of the FMCG industry. Based on such data, we conducted interviews for our research study with 20 managers from diverse companies and backgrounds who work in Turkey's food industry. They were selected from well-known FSC companies with at least 4 years of managerial experience. They were involved in different projects such as sustainability, digital technologies, risk, and operations management. These experts have participated in seminars and certification programs on these topics. The selected managers have in-depth knowledge and experience in the field and have the competence to lead the field, and creating another group from this group would have led to a lack of knowledge. This is presented as a group that well reflects the population in the field because the participants in our research work for businesses spread across different regions of Turkey; information was transferred and made available by phone, email, and so on, with the intention that they would provide us with feedback. It is crucial to ensure that the study's participants' selection is representative of the demographic that interests us. Therefore, it is crucial to select a variety of company employees who can offer a wide range of opinions and experiences to establish this representativeness. To ensure that our study and the results we will obtain are adequate in terms of generalizability and representativeness, we tried to choose different food companies from different regions of Turkey by considering different variables such as different positions, genders, years of experience, and backgrounds. After these stages, the variables and conditions are determined, and then raw data are collected to apply fsQCA. A questionnaire was created to facilitate discussion with experts. The objective of this study is to assess the factors that contribute to the forming of High SC Resilience Performance by examining the configuration conditions. The impact of specific factors on High SC Resilience Performance was evaluated by experts using a scale that ranges from 1 to 5. The objective was to determine the essential nature or non-necessity of these conditions for the occurrence of this outcome, as well as to identify the relative importance of different combinations of conditions. The method was applied by transforming raw data into fuzzy sets, and finally, the contradictions were resolved, and the findings were interpreted. The analysis was conducted by utilizing the fsQCA 3.0 software package.

Table 1 represents the outcome and causal variables. The output of this study (dependent variable) is V0: High SC Resilience Performance. "High SC resilience performance" refers to the ability of a system or entity to exhibit resilience or resistance to disruptive events,

**TABLE 1** Outcome and casual variables.

| Variable |
|---|
| Outcome variable: |
| V0: High SC Resilience Performance |
| Casual variables: |
| V1: Enhanced flexibility structure and adaptability skills in the SC |
| V2: Increased IT capability in the SC |
| V3: Providing redundancy in the SC |
| V4: Integrating digital technologies into the SC process |
| V5: Enhancing collaboration to deal with complexity in the SC |
| V6: Providing traceability and improving visibility in the SC process |

**TABLE 2** 5-point Likert scale that used in this study.

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

shocks, or challenges that may arise in the context of SC. It implies the capacity to withstand and recover from disruptions efficiently and effectively, minimizing the negative impact on the overall SC operations. The concept of High SC Resilience Performance is associated with various condition variables. The conditions for this variable (argument/input) are V1: Enhanced flexibility structure and adaptability skills; V2: Increased IT capability; V3: Providing redundancy; V4: Integrating digital technologies into the process; V5: Enhancing collaboration to deal with complexity; V6: Providing traceability and improving visibility in the process. V0 = f (V1, V2, V3, V4, V5, V6). According to Woodside (2013), the original scales are set in a fuzzy cluster scale.

Model: V0 = f (V1, V2, V3, V4, V5, V6).

Raw data were gathered during the data collecting procedure using a 1–5 Likert scale, as shown in Table 2. These evaluations are carried out with the Board of Directors' agreement. Twenty managers who are FSC stakeholders are included in the study. Details of experts are presented in Table 3.

Table 4 shows the statistical parameters and calibration parameters for fsQCA. The highest deviation among the answers was seen in "Providing redundancy in the SC" and "Providing traceability and improving visibility in the SC process." In contrast, the lowest deviation was seen in "increased IT capability in the SC." Table 4 shows a greater variability for increased IT capability in the SC factor provided within the relevant measures across cases. At the same time, there is a high variable for providing redundancy in the SC, providing traceability, and improving visibility in the SC process factors. It shows that there was no missing value for the 20 cases.

Table 4 depicts an examination of the criteria required for food firms' SCR performance. After creating the fuzzy set for each variable, the method was applied, and the two main sub-outputs of the method, necessity analysis and sufficiency analysis, were made. Necessity analysis identifies the indispensable inputs (independent variables) for the output (the dependent variable) to be realized. If inputs are required, the desired result cannot be achieved without these inputs (Kordel & Wolniak, 2021).

TABLE 3 Details of participants.

| Experts | Position | Work experience (years) | Experts | Position | Work experience (years) |
|---|---|---|---|---|---|
| 1 | SC manager | 10 | 11 | Information technology manager | 7 |
| 2 | Total quality manager | 7 | 12 | Information technology deputy general manager | 9 |
| 3 | Sustainability manager | 5 | 13 | Operations manager | 5 |
| 4 | Information technology manager | 4 | 14 | SC deputy general manager | 10 |
| 5 | Information technology deputy general manager | 12 | 15 | SC deputy general manager | 9 |
| 6 | Operations deputy general manager | 9 | 16 | Total quality deputy general manager | 7 |
| 7 | Total quality manager | 4 | 17 | Sustainability manager | 5 |
| 8 | Total quality deputy general manager | 9 | 18 | Operations manager | 6 |
| 9 | SC deputy general manager | 7 | 19 | Operations deputy general manager | 7 |
| 10 | Operations deputy general manager | 11 | 20 | SC deputy general manager | 4 |

TABLE 4 Statistical and calibration parameters for FsQCA.

| Variable | Mean | SD | Minimum | Maximum | *N* cases | Missing |
|---|---|---|---|---|---|---|
| V0 | 0.71 | 0.27 | 0.18 | 0.95 | 20 | 0 |
| V1 | 0.72 | 0.28 | 0.18 | 0.95 | 20 | 0 |
| V2 | 0.81 | 0.21 | 0.18 | 0.95 | 20 | 0 |
| V3 | 0.63 | 0.33 | 0.18 | 0.95 | 20 | 0 |
| V4 | 0.79 | 0.22 | 0.18 | 0.95 | 20 | 0 |
| V5 | 0.70 | 0.28 | 0.18 | 0.95 | 20 | 0 |
| V6 | 0.64 | 0.33 | 0.05 | 0.95 | 20 | 0 |

TABLE 5 Analysis of necessary conditions for food companies' SC resilience performance.

| | Consistency | Coverage |
|---|---|---|
| V1 | 0.836286[a] | 0.821155 |
| ∼V1 | 0.353650 | 0.886323 |
| V2 | 0.936215[a] | 0.820497 |
| ∼V2 | 0.231042 | 0.835897 |
| V3 | 0.713678 | 0.796677 |
| ∼V3 | 0.430900 | 0.826087 |
| V4 | 0.885897[a] | 0.790139 |
| ∼V4 | 0.250886 | 0.846890 |
| V5 | 0.858965[a] | 0.862633 |
| ∼V5 | 0.330971 | 0.784874 |
| V6 | 0.736357 | 0.809821 |
| ∼V6 | 0.440113 | 0.866109 |

[a]Indicates that a consistency value of 0.80 is provided for the requirement conditions.

First, the requirement analysis studied the essential circumstances for getting the outcome: strong resilience performance in the FSCs. Ragin (2000) recommends thresholds of 0.80 for causal inputs/factors that are "almost always" necessary or sufficient.

According to Table 5, In achieving high resilience performance in Fast Supply Chains (FSCs), the following conditions are crucial: V1: Enhanced flexibility, structure, and adaptability skills in the SC; V2: Increased IT capability within the SC; V4: Integration of digital technologies into SC processes; and V5: Enhancement of collaboration to address complexity in SC conditions. However, it was found that the remaining conditions, V3: Providing redundancy in the SC, and V6: Providing traceability and improving visibility in the SC process, did not exhibit strong correlations. Providing redundancy in the SC, traceability, and improved visibility in the SC process are not strong enough conditions to provision smart, sustainable, and resilient FSCs in the context of disruptive events. However, enhanced flexibility, structure, and adaptability skills in the SC, increased IT capability in the SC, integration of digital technologies into the SC process, and enhanced collaboration to deal with complexity in the SC conditions are all necessary for achieving high resilience performance in FSCs.

The core study comprises determining configurations that are adequate for the existence and lack of SCR, although no one element is enough for either conclusion. Then, different causal groups leading to V0 are determined by adequacy analysis.

Table 6 shows the models predicting SCR performance in food companies. According to the configuration table, black circles are used to show the condition (●), whereas white circles show the absence of the condition (○). The coverage value of the model is high (0.69), and the solution consistency is more than the minimal value (0.8) set by Ragin.

**TABLE 6** Models predicting SC resilience performance in food companies.

| Configuration no. | V1 | V2 | V3 | V4 | V5 | V6 | Coverage | | Consistency |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Raw | Unique | |
| M1:V1[a]V2[a] ∼ V3[a]V4 | ● | ● | ● | ● | ○ | ○ | 0.362863 | 0.022679 | 0.842105 |
| M2:V1[a]V2[a]V4[a]V5 | ● | ● | ○ | ● | ● | ○ | 0.672573 | 0.332388 | 1 |
| M3: V1[a]V2[a] ∼ V3[a]V4[a]V6 | ● | ● | ● | ● | ○ | ● | 0.362863 | 0.136074 | 0.842105 |
| Solution coverage: 0.695252<br>Solution consistency: 0.910864 | | | | | | | | | |

[a]Frequency cut-off: 1, consistency cut-off: 0.817664.

Based on Table 6, three different configurations have been identified. Configuration 2 (coverage 67%) circumstances are more likely to lead to improved resilience performance in FSCs: V1: Enhanced flexibility structure and adaptability skills in the SC, V2: Increased IT capability in the SC, V4: Integrating digital technologies into SC process, V5: Enhancing collaboration to deal with complexity in the SC. The reliability of this configuration is 1, suggesting that organizations with the described circumstances perform better in terms of resilience. Depending on the configuration, it can be said that enhanced flexibility structure and adaptability skills in the SC, increased IT capability in the SC, and integration of digital technologies into the SC process are the key to the SC. Although V6, providing traceability and improving visibility in the SC process, is encountered in the one configuration, V3, providing redundancy in the SC condition, was never encountered in the configuration. Table 6 shows that to improve resilience performance in the FSCs, the following conditions must be achieved: improved flexibility structure and adaptability skills in the SC; increased IT capability in the SC; integration of digital technologies into the SC process; and improving collaboration to deal with complexity in the SC.

## 5 | DISCUSSION

Even though there have been several studies on the smartness and resilience of FSCs in dealing with disruptive events, sustainability integration is still lacking in the existing literature. Mandal et al. (2023) investigated resilient FSC in establishing the necessary circumstances for food security and safety throughout unstable times by integrating Industry 5.0 technologies, which is a novel approach. Chowdhury et al. (2024) focused on establishing a dynamic capacity view (DCV) to explore and succeed in resilience solutions to offset the disruptive impacts of severe events for more sustainable tourist SCs. Joshi et al. (2023) investigated the lowering of food waste and the security of the AFSC using technological advances to develop resilient FSC in emerging economies; unlike other studies in the literature, the present study incorporates sustainability, resilience, and technology integration to deal with the disruptive effects of dangerous occurrences.

Based on the primary findings of comparable research in the available literature, the essential resilient tactics and noteworthy components are listed below. For instance, the results of Zhao et al. (2022) suggest that contractual limitations and frequent communication are critical to establishing agri-food SC resilience in (AFSCR) France and Argentina. The study also implies that by bringing all stakeholders together, AFSCR may be improved by strengthening the weakest link, such as farmers, and improving collaborative efforts. Scholten and Schilder (2015) stated that collaborative activities such as information sharing and communication improve SCR by boosting visibility, velocity, and flexibility. It identifies these elements' processes and interdependencies inside the SC network. According to Michel-Villarreal et al.'s (2021) findings, SFSCs include five essential SCR capabilities: flexibility, redundancy, cooperation, visibility, and agility. Another study by Yang et al. (2021) suggested that the use of various digital technologies can directly impact SCR performance, and they presented that digitalization has the potential to be extremely beneficial in supporting resilience in the FSCs. Digital technology is significant in providing forecast accuracy, emergency plan activation, and data analytics to enhance visibility in the SC. There are complex interactions between digital technologies and SC flexibility. Lin and Yi (2022) suggested in their results that company innovation in the digital context is driven by a mix of elements at three levels: technological, organizational, and environmental. These elements combine to provide three effective digital innovation paths: technology-driven, organizational-led, and holistic collaboration. For resilient SC, recovery and increasing adaptive capacities require technological competence (Gaudenzi et al. 2023).

On the other side, the results of this study indicate that V1: Enhanced flexibility structure and adaptability skills in the SC, V2: Increased IT capability in the SC, V4: Integrating digital technologies into the SC process, and V5: Enhanced collaboration to deal with complexity in the SC are necessary conditions to provide better resilience performance in the FSCs. Initially, the key to creating a resilient SC that can endure interruptions and sustain the continuity of operations is to boost the SC's structure and adaptive abilities. These competencies allow businesses to react swiftly and successfully to changes in the business environment, such as SC interruptions, consumer demand shifts, or market circumstances. Additionally, they assist businesses in improving risk management, raising customer satisfaction, and lowering the expenses related to downtime, lost productivity, and reputational harm. Investments in these areas are anticipated to result in greater company performance, including better risk management, higher levels of client satisfaction, and cost savings.

Secondly, building a resilient SC that can survive interruptions and ensure the continuity of operations requires increased IT capabilities and information exchange throughout the SC. This includes increased agility, higher efficiency, and improved visibility and cooperation. Investments in these areas are expected to result in greater company performance, including better visibility, improved cooperation, higher agility, and improved efficiency. Accordingly, building a robust SC that can survive interruptions and sustain operational continuity requires the use of digital technology. Lastly, by focusing on collaboration to deal with SC complexity, companies may enhance risk management, speed up reaction times, enhance decision making, increase flexibility, and boost customer satisfaction by working with SC partners.

In light of this information, this study's primary contribution and uniqueness are found in several areas. In the first place, the study focuses primarily on the FSC setting, which is a crucial and quickly expanding business but has particular vulnerabilities and difficulties compared to other SCs, and this study considers FSCs in terms of resilience during the crisis times. The paper fills a critical absence in the literature that frequently ignores this sector's unique complexity and dynamics by integrating and discussing the resilience and smartness of the FSC. Second, the research attempts to create a thorough disruption preparation plan for the FSC in case of crisis and risk management, taking into account a variety of disruptive situations such as earthquakes, terrorist attacks, pandemics, natural catastrophes, and economic crises. On the methodology side, the fsQCA methodology recognizes the necessity for preventative actions to lessen the negative effects of disruptions and tries to offer useful information for policymakers and decision-makers when developing strategies and laws to improve the FSC's preparation. The study also examines the essential settings and elements that make the FSC highly resilient and intelligent. This research explores the underlying causative factors and their interactions beyond merely evaluating technological adoption. The work deepens our understanding of creating a robust and intelligent FSC. It advances our understanding of SC management by examining the intricate relationships between results and causative variables. Finally, the paper acknowledges the potential influence of smart technologies on FSC resilience, including AI, robots, and BC. It investigates how these cutting-edge technologies might improve organizational capability, visibility, traceability, and other FSC-related features.

## 6 | IMPLICATIONS

This section presents academic and practical implications that can be inferred from the results are presented. As an academic implication, a holistic approach should encourage organizational engagement and cooperation among SC partners due to the inclusion of all FSC stakeholders. Thus, this study provides collaborative research combining the findings of various disciplines to develop holistic solutions for smart, sustainable, and resilient FSCs. Developing resilience strategies to enhance awareness of the increased resilience of FSCs is critical to providing diversification, redundancy, and flexibility in SC. Such methodologies that observe the configuration of the affecting factors are required to assess and mitigate risks in FSCs during disruptive events.

Based on the policymakers' implications, businesses should develop a strategic plan to enhance flexibility and adaptability skills in the SC to deal effectively with unpredictable environments and achieve a high level of resilience. To increase adaptability skills, businesses should develop short-term, mid-term, and long-term action plans. Effective planning can enhance flexibility by providing different perspectives for changing conditions. Policymakers should encourage businesses to develop risk plans to increase flexibility in the SC. If necessary, the government should apply sanctions to enforce these measures. Various aid initiatives have been implemented by governments to improve FSCs and mitigate the socio-economic consequences of the epidemic such as assisting farmers, offering subsidies for food distribution networks, implementing regulations to enhance market accessibility, and providing incentives that promote local food production and resilience. According to the results of this study, V3: Providing redundancy in the SC did not emerge as an important factor encountered to create smart, sustainable, and resilient food SC in disruptive events in any configuration. In this context, it can be suggested that companies should carefully consider each stage in their SCs and create an optimized, efficient, and sustainable SC strategy, rather than adding unnecessary redundancy.

Increased IT capability and information sharing in the SC are key indicators for enhancing resilience in the FSCs. Thus, to enable IT alignment, suitable infrastructure must be developed to integrate stakeholders, improve collaboration, and ensure accurate data in the SC. Policymakers should develop policies and strategies that enable investments in IT and digital technologies. Integrating digital technologies into SC processes is a necessary condition for achieving high resilience performance in the FSCs. For example, BT integration into the SCs can help quickly identify and isolate contaminated products, decreasing the impact of foodborne illnesses or contamination outbreaks during a disaster time. Besides, data analytics and predictive modeling in the SCs can aid optimize inventory management, ensuring adequate stock levels without excessive wastage. By forecasting demand patterns, SC actors can improve and allocate resources and adjust production. In response to the dynamic characteristics of consumer demand and disruptions in the SC, retailers have employed complex analytics and machine learning algorithms to enhance pricing strategies and improve the accuracy of demand forecasting. With digital technologies, businesses should provide traceability and increase their ability to adapt to conditions created by complex and uncertain environments. FSCs consist of multiple stakeholders and possess complex natures; therefore, suitable policies should be developed to enhance collaboration and increase traceability to address the complexity of the SC. SC managers have adopted agile and flexible approaches to changing demand patterns and logistics restrictions caused by COVID-19 disruptions such as optimizing inventory levels, diversifying sourcing strategies, and creating alternative transportation routes to ensure a persistent flow of vital food products. Based on the results, factor V6, Providing traceability and improving visibility in the SC process, did not find a strong correlation with smart, sustainable, and resilient FSCs in the context of disruptive events. Traceability and visibility processes can frequently be considered resource-intensive. Complex SCs, such as FSCs, can sometimes further complicate business processes, depending on the ability to utilize available resources effectively. Therefore, greater traceability and visibility in SCs require data-sharing capability. This can bring risks to the organization in terms of data security. The complexity of the SC can negatively impact management and operational processes. Therefore, considering the risks of traceability for the company, in some cases, it may be more effective and sustainable to provide traceability only at certain critical stages or products. The SC strategy must be designed considering the objectives and requirements of the organization. For instance, establishing multi-tiered sourcing strategies includes diversifying suppliers across different geographic regions and production systems to provide reduced vulnerability to localized disruptions and SC bottlenecks, ensuring the endurance of the SC process in the face of unexpected situations. With the implementation of quarantine and social distancing measures, there has been a significant increase in online shopping for groceries and food delivery services. Food retailers and restaurants have rapidly increased e-commerce capabilities, expanded online ordering platforms, and implemented efficient delivery logistics to meet growing demand while minimizing physical interactions. Besides, to address the growing demand for online food purchases and optimize the efficiency of order processing, retailers and logistics providers have the opportunity to create several strategies. The small automated warehouses can enhance the effectiveness and adaptability of e-commerce SCs by facilitating accelerated order processing and last-mile delivery.

Businesses should develop action plans and policies to improve SC flexibility, sustainability, and agility to cope with risky environments such as earthquakes. To solve the difficulties of food sustainability and resilience, key business players who are becoming more significant in the dynamics of food systems (Davis et al., 2021; Macfadyen et al., 2015) can organize without the assistance of governments (Cattau et al., 2016; Howard, 2021; Mohan, 2017). Integrating digital technologies with the SC is critical to increase traceability and, thus, quickly identify these risks and develop effective and permanent policies. Digital technologies also increase transparency and traceability among SC stakeholders and thus ensure that harmonious decisions are taken among stakeholders. To achieve this, developing collaborative SC platforms that enable real-time data sharing among stakeholders can enhance agility and responsiveness during disruptions. These platforms enable coordination, visibility, and decision making across the SC network and deal with the problem by increasing adaptation to the changing conditions. In risky environments such as earthquakes, the role of many stakeholders, such as non-governmental organizations, government agencies, government, and volunteers, is very critical. Determining the needs correctly and taking quick action with an accurate resilience plan has become necessary by integrating the SC processes with traceable and digital technologies. Developing alternative distribution channels, such as direct-to-consumer models rather than business-to-consumer or community-supported agriculture programs, can provide flexibility and resilience during these disruption times.

## 7 | CONCLUSION

Food commodities are distributed smoothly even during large-scale interruptions because of the development of resilience implementations in FSC. Thus, complexity and globalization are frequently linked to increased SC risk. While the FSC is getting more intricate and multi-tiered, it must operate in a global context accessible to market elements like the labor force and logistical resources.

This research mainly examines the influences of FSC resilience performance by investigating the numerous and complex linkages between outcome and causal variables. Thus, this study is conducted in food firms in Turkey. The fsQCA has been applied for the analysis of the study. Firstly, SCR performance conditions have been determined—V1: Enhanced flexibility structure and adaptability skills in the SC, V2: Increased IT capability and V3: Providing redundancy in the SC, V4: Integrating digital technologies into SC process, V5: Enhancing collaboration to deal with complexity in the SC, V6: Providing traceability and improving visibility in the SC process. It can be inferred from the results of this study that enhanced flexibility structure and adaptability skills in the SC, increased IT capability, and integration of digital technologies into the SC process are the critical variables for providing high SCR in the FSCs.

This study's key contribution to the literature is its detailed examination of how proactive use of digital technology and an emphasis on sustainability and resilience considerations might revolutionize FSCs. The study identified critical components, such as expanded flexibility adaptation abilities. It increased IT competence, as needed, for attaining high SCR, sustainability, and smartness by using fsQCA on data from the food sector in Turkey. The study fills gaps in our understanding of the causal relationships between these parameters, providing useful insights for policymakers and managers in enhancing FSC performance in the face of disruptions. In addition to this study's theoretical contribution is its new integration of theoretical frameworks relating to SCR, sustainability, and digital technology adoption in the context of FSCs. The research elucidates the intricate causal relationships between variables using fsQCA, presenting a deeper understanding of how enhanced flexibility, adaptability, and increased IT capability contribute to high resilience, sustainability, and smartness in the FSC. This theoretical framework not only contributes to the current literature by combining multiple theoretical viewpoints but also lays the foundation for future research to devise effective methods for resilient and sustainable FSCs in the face of disruptions.

As a limitation of this investigation, the data are mostly obtained from food companies' managers; thus, it cannot be generalized to other sectors. Different causality variables can add to enhance the clarity of the model. As a future study, primary data can be integrated into secondary data to provide a more comprehensive picture of the links. Also, this study can be expanded by applying factor analysis and structural equation modeling to provide better insight into the analysis. Besides, this study can be merged with the system thinking approaches to investigate causal relationships between variables.

## CONFLICT OF INTEREST STATEMENT

Authors have no conflict of interest to declare.

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**How to cite this article:** Sezer, M. D., Kazancoglu, Y., Mangla, S. K., & Lafçı, Ç. (2024). Smart, sustainable, and resilient food supply chains in disruptive events context. *Business Strategy and the Environment*, 1–16. https://doi.org/10.1002/bse.3801