Available online at www.ijournalse.org

Emerging Science Journal

(ISSN: 2610-9182)

Vol. 9, No. 5, October, 2025

Dynamic Capabilities and Technological Innovation for Firm Resilience: A Configurational Analysis

Jewel Rana [1], Md Zubair Ahmad [1], Md Nazmul Islam Jihad [1], Md. Rashed [2], Siddiqur Rahman [3], Mohammad Fakhrul Islam [4*]

[1] *School of Business, International American University, Los Angeles, United States.*

[2] *College of Business Administration, International University of Business Agriculture and Technology, Dhaka, Bangladesh.*

[3] *Department of Tourism and Hospitality Management, Daffodil International University, Dhaka, Bangladesh.*

[4] *Sustainability Competence Centre, Széchenyi István University, Győr, Hungary.*

Abstract

Firm resilience is essential to manage response and rapid recovery from disruptive events for a firm. Moreover, there is limited literature that investigates the combined effects of dynamic capability and technological innovation that are interrelated with firm resilience. This study used the dimensions of firm resilience, which were investigated with both necessary condition analysis (NCA) and fuzzy-set Qualitative Comparative Analysis (fsQCA) methods using survey questionnaires from 308 respondents operating in Bangladeshi corporate industries that are currently facing uncertainties due to unforeseen crises. NCA results showed that visibility, market position, and digitalization achieved firm resilience as these antecedents reached the full percentile to achieve an optimal level of outcome. On the contrary, the influence of reserve capacity and big data analytics was not empirically significant for achieving firm resilience. Moreover, fsQCA results appreciated NCA results and showed four solutions that are sufficient for achieving a high level of firm resilience. The study reveals the configurational effects of dynamic capabilities and technological innovation to achieve firm resilience. The results show the necessary effects of configurational relationships that lead to outcomes. The configurational method is applied to identify the combined effects of antecedents that help managers predict high levels of firm resilience in a turbulent environment.

Keywords:

Dynamic Capability View;
Technological Innovation;
Firm Resilience;
NCA;
fsQCA.

Article History:

Received:	05	April	2025
Revised:	19	September	2025
Accepted:	25	September	2025
Published:	01	October	2025

1- Introduction

Growing globalization and competition have transformed firm strategies and operations so much that internal capabilities and resources are no longer adequate to assure sustainable comparative benefit. In uncertain and volatile times, firms have recently encountered disruptive environments such as environmental shocks, natural calamities, and economic volatility [1]. In the extant literature, unforeseen events may arise within or outside of the firm and can allow various antecedents, including capability, resources, and strategies [2]. Moreover, the significance and extent of its effects on the firm can be shocking during disruptive events [3]. Firm resilience, which denotes a firm's capability to establish with its firm stakeholders and facilitate intimate long-standing associations, is derived from the sharing of missions, capabilities, and crises [4, 5]. Alternatively, Ambulkar et al. (2015) [6] see firm resilience as purposeful associations between organizational stakeholders that enhance their capability to efficiently facilitate internal and external resources to achieve organizational sustainability in response to disruptive events.

* **CONTACT**: fakhrul.mate.hu@gmail.com; fakhrul@stamford.university

DOI: http://dx.doi.org/10.28991/ESJ-2025-09-05-01

To survive in the long run during disruptive events, firms must be able to manage all these constraints of the unforeseen environment. Organizations must facilitate a resilient capability that allows them to sufficiently respond to disruptive conditions and manage an environment that could certainly comprehend a firm's survival [7, 8]. In this vein, resilience contrasts with related dynamic antecedents, including visibility, reserve capacity, and market position. Accordingly, visibility is defined as the capability of a firm to manage the operating resources and the circumstances to respond to risk management, thereby reducing uncertainty to achieve firm resilience [9]. Furthermore, reserve capacity holds the capability of managing resources and capabilities to cope with disruptive events [10, 11]. It facilitates agility and robustness that support organizational stability under unforeseen events [12, 13]. Furthermore, market position helps organizations to prepare, respond, and recover from turbulent environments [10, 14]. It relies on the availability of numerous capabilities and resources, enhancing proactive external funding to support reactive capability to overcome turbulent environments. In addition, technological innovation refers to generating new ideas and information using digital competencies that can help firms to be resilient in responding to disruptive events [15]. In this context, firm resilience is supported by related technological innovations, such as digitalization and big data analytics, to facilitate recovery from turbulent events [16]. Accordingly, digitalization refers to the combination of digital advancements (machine learning, blockchain, and IoT) into firms' operations to facilitate an operational activity of data-based decision-making [17-19]. Also, big data analytics has been focusing on the implementation of digital forecasting that affects firm operations, thereby broadly integrating decision-making and forecasting models [20].

Though the literature concerning firm resilience has slowly grown in recent times due to new technological advancements and various levels of disruptive events, the notion of a firm's resilience in a complex environment is still under-studied. Recent studies have taken many theoretical lenses to measure firm resilience, the most common of which is the capability context. Accordingly, resilience is regarded as the capability of a firm to adapt to the turbulent environment, respond to crises, and recover rapidly to its better or original condition [21, 22]. Enhancing resilience can facilitate manufacturing firms in better coping with disruptive events, eliminating volatility, and balancing business performance [23, 24]. Likewise, organizational robustness, the notion of firm resilience, proposes the response and recovery capability of manufacturing firms to unknown disruptions [21, 25, 26]. Some constructs, for instance, visibility, reserve capacity, agility, market position, digitalization, big data analytics, and collaboration, are increasingly considered by authors as capability antecedents that can achieve firm resilience [10, 27, 28]. To date, research has concentrated concern on organizational uncertainty [29], proactive capability [30], and reactive capability [31], but manufacturing firms' resilient strategies and technological innovation have been ignored. This is surprising since the firm resilience literature shows that balancing past shocks has developed in an investigated context of capability (citation) initiated in the context of a firm [32, 33]. Generally, there is abundant literature that implementation and effectiveness of firm resilience rely on the capability of dynamic resources [34] and technological innovation [35] to respond and recover from disruptive events. In this vein, it is still limited to what resilient firms perform and how firm resilience using the combinative effects of dynamic capability and technological innovation may be developed in theory and practice [36]. However, there is a need to examine if commonly employed resilience dimensions, for instance, dynamic capabilities and technological innovation, can be combined and employed in various necessary and sufficient configurations that predict achieving a high level of firm resilience. Therefore, the study has formulated a main research question that is: *How do dynamic capabilities and technological innovations combinedly achieve the practicality of firm resilience capabilities*? Considering the configurational context of this study, we conducted a survey instrument among various manufacturing firms in Bangladesh with a domain of manufacturing system information to examine their combined effects on resilience capabilities.

To answer the main questions, this study shows various implications and contributions by conducting a present study. This research examines how firm resilience is equally influenced by its dynamic capabilities and technological innovation-based constructs. More specifically, the study measured the influence of visibility, reserve capacity, market position, digitalization, and big data analytics on firm resilience in the Bangladeshi corporate sector. However, the result of this research contributes to extant literature besides being appropriate to the notion of a developing economy. Secondly, the study contributes to the integrated combination of NCA and fsQCA. Furthermore, while NCA evaluated the hypothetical paths, fsQCA showed complementary findings to the NCA results and produced sufficient solutions that led to high firm resilience. In the practical context, this research guides manufacturing firms in highlighting the dimensions of dynamic capability and technological innovation that contribute to successful firm resilience, besides offering sufficient causal conditions for attaining successful firm resilience.

2- Theoretical Framework and Concept Development

2-1- Dynamic Capability Theory

A firm was required to achieve a sustainable competitive advantage through inestimable, inimitable, and non-substitutable resources; it had to rely on a resource-based view (RBV) [37]. As originated from RBV, DCV has a remarkable ability to sense and respond early and effectively to market shifts with a proactive, deliberate orientation with the help of technological advancements and a new strategic framework to cultivate unique capabilities tailored to any specific need [38]. Unlike traditional methods, this framework is concerned with a firm's ability to anticipate continuous changes, integrate and seize opportunities by reconfiguring resources, and restructure to thrive in a competitive environment [39, 40]. DCV is particularly relevant in turbulent conditions, where survival depends on a firm's ability to anticipate changes, seize opportunities, and restructure its resources for sustained competitive advantage [40]. This process can be iterative and rooted in experiential knowledge, allowing firms to maintain strategic superiority.

In recent years, the concept of dynamic capabilities has gained prominence in increasingly volatile and complex situations of organizations. However, some researchers claim that dynamic capabilities have an issue with the obscurity of identifying specific components or processes that can suffer from conceptual challenges such as evasive nature, obscurity, and difficulties in measurement [41]. Its evasive nature shortens the macro- or micro-level advantages in real-time decision-making [42, 43]. Its shortcomings include obscurity, misunderstanding of operational dynamics, practical relevance, and difficulties in measurement. It has also been characterized as a 'black box' by Pavlou & El Sawy (2011) [44]. However, various researchers have also addressed these accusations. Researchers like Wang & Ahmed (2007) [45] and Barreto (2010) [46] have worked towards establishing a more cohesive theoretical foundation for dynamic capabilities, addressing the terminology gap for the conceptual challenge Pavlou & El Sawy (2011) [44] mentioned. Researchers also focused on understanding the specific processes and routines constituting dynamic capabilities, thereby providing a clearer pathway for organizations to implement them effectively regarding micro-foundations and evasive nature-based difficulties [47]. This approach towards examining micro-foundations helps clarify how dynamic capabilities can be operationalized in practice.

Dynamic capabilities highlight an organization's capacity to sense opportunities, seize them, and maintain competitiveness. Combined with supply chain resilience (SCR), DCV has gained perception capability, seizing capability, and competitiveness maintenance [38]. The perception capability is reflected in the emphasis on risk identification, prediction, and monitoring of market changes. Second, the seizing capability involves the rapid realignment of upstream and downstream supply chain resources to address emerging opportunities. Finally, the maintenance of competitiveness underscores swift recovery mechanisms and adaptive learning to enhance the robustness of the long-term supply chain. During the COVID-19 pandemic, organizations had to observe market fluctuations and reconfigure internal and external resources to adapt to these unprecedented challenges. This over-perception and maintenance technique reflect the DCV's emphasis on restructuring capabilities to remain competitive [40]. Organizations also need to learn to act quickly to capitalize on new opportunities created by the pandemic. The ability to seize opportunities in crisis has reinforced the importance of agility and innovation as central elements of dynamic capabilities [39].

The arrival of turbulent environments, for instance, COVID-19, political instability, and economic recession, has strengthened the technological innovation and capabilities of manufacturing firms [35, 48]. Technological innovations are employed in organizational operations to eliminate operational expenditures and production costs [48]. Moreover, they are substantial resources and capabilities that use current capabilities and are inadequate to help manufacturing firms stay competitive in a dynamic business [49]. The digital advancement and the growing shocks have accelerated the dynamism of the business operation and the extent of dynamic transformation, and manufacturing firms are depending on DCVs to combine and transform their capabilities and resources to achieve comparative benefit and firm-level resilience [50]. The significance of technological innovation like digitalization is more emphasized in combination with organizational systems to facilitate building dynamic capabilities that can adjust to the business model [51]. Firm resilience is derived as a DCV that addresses timely shock prediction, available resource utilization, and transformation of organizational capabilities and resources in disruptive events to achieve comparative benefit and sustainable effectiveness levels in turbulent environments.

2-2- Resilience as a DCV

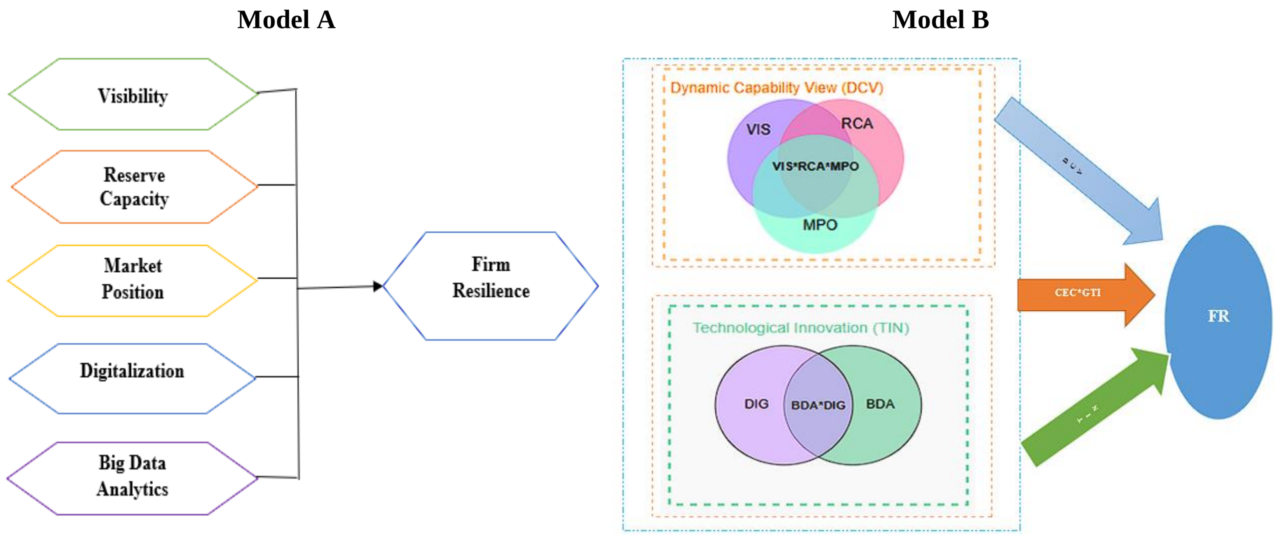
Resilience is a capability that reflects how firms or organizations and their members respond to uncertainty or volatile business environments [52]. Resilience also contributes to enhanced situational awareness of organizations, reducing organizational vulnerabilities to risks and restoring effectiveness following a disruption [32, 53, 54]. It also prioritizes innovation to cope with volatile situations and implement these factors [55, 56]. Firms that fail in innovations might not deliver the anticipated performance gains in a fluctuating and uncertain market. In such dynamic environments, innovations prioritizing resilience strengthen the existing supply chain, promoting ongoing performance enhancements during market irregularities. This leads to a more resilient supply chain capable of adapting to sudden changes while continuing the existing productivity [56].

Combined with dynamic capability, resilience enables organizations to adapt to different uncertainties and navigate changes in their business environment. However, managerial awareness of environmental dynamism can affect the relationship between the antecedents and outcomes of resilience using a dynamic capability framework [57]. This means that the effectiveness of these antecedents in fostering resilience can be manipulated by how well managers understand and respond to environmental dynamism. For instance, organizations with high managerial awareness will likely leverage their capabilities more effectively, leading to improved resilience outcomes. Forliano et al. (2023) [58]

examined this thought and confirmed that organizational resilience equipped with DCV can bring out more perspectives that can uplift a corporation's outcome. They further noted that policy changes, coupled with managerial awareness, can highlight the importance of implementing proactive strategies to navigate disruptive changes learned from uncertain incidents like COVID-19 and effectively leverage potential benefits according to consumer preferences. The configurational model is shown in Figure 1, where visibility, market share, and reserve capacity derive the dynamic capability view, and digitalization and big data analytics derive the dimension of technological innovation.

Furthermore, innovation is defined as the capability for the execution and advancement of unique information and ideas in a firm or the integration of innovative business models and production approaches to run the business in the competitive market [59]. Innovation is mainly considered a capability or ability that can facilitate a firm's resilience during and after unforeseen environments [60]. People often consider that a firm with technological innovation is more resilient, particularly to organizational crises or turbulent circumstances, than less inventive firms. During disruptive events, organizations in supply chain networks with the vigorous application of collaborative technological capacities are likely to employ more new insights from other organizations to associate with their technological invention to survive in the competitive market [61]. So, these partner firms consider and realize each other's issues and facilitate a combined solution as cooperative innovation functions relate the consumers and managers to ensure the same innovative workplace to manage disruptive events and achieve high levels of firm resilience [62]. However, firm innovation with technological adoption allows several opportunities, for instance, enhancing advancement in prediction, purchasing new products, planning innovations, monitoring sustainable operations, and advancing operational capabilities to achieve high firm resilience during turbulent conditions [28].

Figure 1 shows models A and B, where model A defines the NCA method and model B defines the fsQCA method. In model A, the study adopted five causal conditions, like VIS, RCA, MPO, DIG, and BDA, to test the proposed propositions. Mode B shows the combination of all causal conditions to identify multiple configurations to achieve the same outcome.



Note: VIS = Visibility, RCA = Reserve Capacity, MPO = Market Position, DIG = Digitalization, BDA = Big Data Analytics, FR = Firm Resilience.

Figure 1. Configurational research model

2-3- Propositions Development

2-3-1- Visibility

Visibility is the ability to understand the recent organizational structural domain [63, 64]. It allows firms to manage transparency beyond their firm performance [65]. The capability of visibility enables the operating role of internal assets and environments to manage risk management and validation and minimize uncertainties [12, 66]. To prevent uncertainty, visibility improves the capacity to predict unforeseen events using technology for covering and scanning to achieve resilient firms [67]. Moreover, visibility enhances knowledge accuracy and ascertains the valuation moment to combine capabilities to reduce turbulent environments [66]. Faruquee et al. (2023) [68] revealed that visibility into these capabilities facilitates planning and reconfiguring processes, resources, and associates' firms to predict and mitigate turbulent environments. While visibility might enhance capacity in many ways in firms, including reducing operating costs, investing time into organizational settings, and performance in response to disruptive events [69, 70]. Thus, enhanced responsiveness, improved decisions, and rapid action can be facilitated by achieving firm resilience during disruptive events. Therefore, the study has formulated the following proposition:

P1: Visibility is necessary condition to achieve high firm resilience.

2-3-2- Reserve Capacity

Reserve capacity is defined as the capability of extra resources deployed during turbulent circumstances, enhancing flexibility and associated response [71]. With a high adaptive divergence, reserve capacity becomes more productive, particularly when the reserve capacity elements respond rapidly to transforms and change uncertainties [14]. Adopting redundancy in resources and capacities is an efficient approach to reducing firm uncertainties [72]. Adding extra capability in inventory, services, production, and reserve capacity, unforeseen crises can be rapidly regenerated to achieve high firm resilience [73]. Sustainable firms prefer the application of reconfiguring resources, lessening the environmental effect of distributing resources in response to disruptive events [74]. The emerging economy process allows firms to generate proactive and reactive capabilities for rapid actions, reducing the requirement for additional resources and capabilities during turbulent environments [68, 74-77]. Thus, reserve capacity enhances unpredictable complex service, adjusts and manages during disruptive crises, lessens the potential for comprehensive threats, and achieves overall firm resilience. Therefore, the study has formulated the following proposition:

P2: Reserve capacity is necessary condition to achieve high firm resilience.

2-3-3- Market Position

A robust marketing position facilitates various capabilities to plan for, reconfigure to, and recover from turbulent environments because of economic stability, firm efficiency, and increased market stability to attain competitive advantage [10, 12, 14]. The market position depends on the availability of various capabilities and resources, enabling proactive and reactive investments and funding opportunities. A robust market position helps R&D capabilities and particular resources to manage customer intention [38, 65]. In addition, it thus generally focuses on planning, reactive, and recovery and is mainly supported by productivity as it allows a firm's economic growth, highlighting the continual context of DCVs [14]. Accordingly, Singh et al. (2024) [77] revealed that a robust market share allows large capitalization in organizational resilience so that associates remain in better associations with the consumers during and after disruptive events. Firms that adopt significant investment in achieving firm resilience more successfully respond to economic shocks because of their concentration on resource management, waste minimization, and appropriate actions. Therefore, the study has formulated the following proposition:

P3: Market position is necessary condition to achieve high firm resilience.

2-3-4- Digitalization

With technological advancement, digitalization services for firms and the analytical domains behind firm productivity have become the main competitive predictors in the digital era [78]. Particularly since the pandemic, environmental instability, and political turmoil—which caused state blockades and disruptions in supply chain processes—the need for telecommuting, paperless procedures, and firm restructuring has accelerated the adoption of digital operations and enabled firms to respond rapidly to disruptive events [79]. For example, the manufacturing sector has expanded its implementation of digital techniques and pioneered technological and operational solutions aligned with manufacturing process applications [80]. To achieve digitalization objectives, firms employ digital competencies and technologies, as well as other technological advancements, including digital culture, structure, and talent, to respond effectively to disruptive events [81–83]. Technological innovation, such as digitalization, has also attracted increased attention and research from both industry and academia, focusing on the adoption of digital solutions in firms and the business models enabled by firm digitalization [84–86]. Therefore, the study has formulated the following proposition:

P4: Digitalization is necessary condition to achieve high firm resilience.

2-3-5- Big Data Analytics

While employing big data analytics, it has been considered that this technological incorporation affects firm processes, initially integrating forecasting and decision-making processes during disruptive events [20]. BDAs allow firms with the devices and techniques to operational process, validate, and analyze large data sets to forecast turbulent environments [87]. Accordingly, BDAs have the technological capability to predict and manage the required information that efficiently enables firms to minimize unforeseen events and contribute to innovation. In this vein, it facilitates one of the significant abilities of organizations to create unique solutions, drive new business processes, and allow them to employ innovative capabilities [88]. Bouncken et al. (2021) [89] found that digitalized firms evolve technological innovation and digitalization in a sustainable association, thereby focusing on how BDAs can help innovations. This data-driven capability enables firms to explore new opportunities, reduce disruptive events, manage operational processes, and support innovations in business operations and processes [50]. Ultimately, this technological innovation supports the first to predict market conditions and target customers and focuses on consumer preferences and emerging innovations, thereby supporting a solid structure for innovative decision-making during turbulent environments [20, 50]. Therefore, the study has formulated the following proposition:

P5: Big data analytics is a necessary condition to achieve high firm resilience.

3- Research Methodology

3-1- Instrument Development

The survey instruments were designed and validated on purposive sampling techniques to identify the target participants with pertinent experience, assuring the population was suitable for measuring the variables. This technique enables us to address respondents who could share meaningful knowledge about all latent constructs within the study's domain. To ensure the survey instruments' validity, the study followed several validation techniques. The measurement validity was designed by a review of a couple of topic-matter professors, who affirmed that the measurements perfectly presented the variables. Moreover, the study established several techniques and analytical procedures to eliminate and measure potential common method bias (CMB), as followed by MacKenzie & Podsakoff (2012) [90]. Systematically, (a) survey variables were taken from relevant studies to ensure a robust measurement model; (b) respondent anonymity was strongly safeguarded to eliminate response biases; (c) the measurement items were carefully undertaken to connect with the contexts of the validated constructs, reducing ambiguous or leading questions. In addition, convergent and discriminant validity were also measured by analyzing correlations with measured variables, respectively.

To analyze the causal paths of dynamic capability and technological innovation with firm resilience, the study uses the survey technique for empirical validation after combining the extant theoretical concepts to investigate the proposed hypotheses. The survey technique is an accessible approach that depends on factual data and addresses the accumulation of qualitative and quantitative data, employing statistical methods to determine a quantitative application of the constructs. The survey questionnaires are mainly shared by email and online platforms, allowing data to be accumulated comparatively quickly and developing the appropriate data collection models for quantitative studies. In addition, the authors can make the survey questionnaire theme by having participants understand the research questions to collect the primary data to validate the research methods [91]. This approach not only allowed us to justify extant theories but also to integrate extant concepts with new research domains and classify them to explore the limitations of theories and enhance their application. Regarding the benefit of the survey approach, research in the domain of firm resilience has also continuously developed the survey approach into a quantitative method, which has broadly contributed to the application of the organization's related theories [92]. However, this research adopts a survey questionnaire method to identify the potential impact of dynamic capability and technological innovation on firm resilience based on the DCV theory, exploring the empirical associations between latent constructs and supplementing related theories to some extent.

3-2- Context and Data Collection

A survey questionnaire method was deployed in the study to investigate the validated research framework. The Bangladeshi manufacturing industry was mainly focused for several reasons. Firstly, Bangladesh is well known as a developing country in manufacturing goods and products, with its manufacturing industry accounting for nearly one-fourth of the national manufacturing output. During the political instability and pandemic, the manufacturing industry was massively affected by internal and external demand for disruptive events. Considering its items and contribution to the national economy and well-being, the sustainable implementation of the Bangladeshi manufacturing industry is crucial. In addition, the industry is presently undergoing technological innovation, where successful data-driven initiatives are fundamental [93]. Moreover, the data-driven process remains in its infancy, and most manufacturing firms, particularly small and medium ones, cannot provide clear insights or consider how technological innovation goals can be implemented [94]. However, we investigated how the manufacturing industry can prioritize proper guidance to employ digital competencies in their firms to overcome such disruptive events.

We used the survey questionnaire by employing the two-stage technique suggested by many researchers [95]. First, we conducted a pilot study with several experienced professionals from industry and academia to review the survey questionnaire and evaluate the usability of the scales for measuring the variables. The professionals contributed to refining our survey questionnaire in terms of item appropriateness; all of them were familiar with survey-based research. Insights into organizational practices supported selecting senior-level professionals as target respondents and primary data sources in this study, in line with the recommendations of Flynn et al. (2010) [96]. We collected primary data from May 2024 to August 2024, obtaining a total of 308 finalized questionnaires, which is sufficient for empirical analysis and represents an appropriate sample size for data analysis [97]. Participants were asked to indicate the extent to which their firms employed technologies in products and services and in their business operations. The demographic information of validated participants is presented in Table 1.

Table 1. Demographic characteristics

		Frequency	Percentage
Age	1	183	59.4
	2	123	39.9
	3	11	3.6
	4	4	1.3
	Total	308	100.0
Education	1	3	1.0
	2	12	3.9
	3	198	64.3
	4	92	29.9
	5	3	1.0
	Total	308	100.0
Position	1	11	3.6
	2	23	7.5
	3	89	28.9
	4	152	49.4
	5	33	10.7
	Total	308	100.0
Firm Life Cycle	1	21	6.8
	2	51	16.6
	3	120	39.0
	4	85	27.6
	5	31	10.1
	Total	308	100.0

3-3- Measures

The study employed the dimensions of the dynamic capability view and technological innovation to measure five variables using five Likert scales from 1 (strongly disagree) to 5 (strongly agree). The study measured firm resilience as a dependent variable from [6]. We deployed visibility using various items that had been measured in previous literature [14]. The items analyze the acquisition of significant stakeholder partners (VIS1), operations (VIS2), business intelligence (VIS3), and real-time flow (VIS4). We operationalized reserve capacity on the measurement scale [14] of items stock (RCA1), backup energy (RCA2), stock for raw materials (RCA3), recovery process (RCA4), strategic goals (RCA5), and growth patterns (RCA6). Market position was operationalized [14, 98] in this study using a measurement scale. The items are stakeholder satisfaction (MPO1), product differentiation (MPO2), buyer-supplier relation (MPO3), and preferred brand (MPO4). Digitalization was adapted from [51]. The measurement scales of digitalization were developed like digital product service (DIG1), operation process (DIG2), business model (DIG3), digital system (DIG4), digital capability (DIG5), and digital innovation (DIG6). Therefore, big data analytics was adapted from Chen et al. (2004) [95]. The measurement scale of big data analytics was collected from five items, including customer behavior analysis (BDA1), inventory planning (BDA2), process monitoring (BDA3), demand forecasting (BDA4), and human resource management (BDA5). Firm resilience was adapted from Ambulkar et al. (2015) [6]. The items of firm resilience were external disruption (FR1), new environments (FR2), rapid response (FR3), and situational awareness (FR4).

3-4- Statistical Approach

3-4-1- NCA Model

The quantitative approach does not focus on causal relationships or necessity logic, which is necessary to discover significant issues and influences in the data. However, NCA can fill this gap by identifying conditions as bottlenecks or prerequisites for an outcome. It evaluates whether a construct is needed for the outcome to happen, emphasizing its indispensability rather than its glorified influence [99]. NCA also provides a platform for theories that include necessary conditions by bridging the methodological gap of other quantitative approaches [99, 100]. By compiling these advantages, NCA offers a nuanced view of causality that traditional sufficiency-oriented methods often overlook.

A necessity logic is the idea that certain conditions must be present for an outcome to occur, even if they are insufficient to produce that outcome [101]. NCA begins its methodology by identifying potential necessary conditions within a dataset based on theoretical reasoning or a constructed research model to assess the relationship between independent (X) and dependent (Y) variables. The relationship between X and Y is evaluated using two fundamental techniques where necessary conditions can be identified based on some criteria. A condition is how much is required for the outcome, measured by the 'Effect Size' score, a fundamental criterion in identifying and interpreting necessary conditions mentioned earlier [102]. NCA also provides bottleneck analysis to determine how changes in necessary conditions affect the outcome. This methodological approach enhances the ability to analyze complex variations and scenarios where specific conditions can be observed earlier [103].

3-4-2- fsQCA Model

fsQCA also identifies significant combinations of conditions that distinguish between core and peripheral elements within these configurations that produce particular outcomes [104, 105]. These lead fsQCA to construct the presumption that an outcome can emerge from multiple conditions, each contributing uniquely to achieving the overall outcome assumption [106, 107]. The fuzzy-set variant of QCA (fsQCA) offers a nuanced approach by calibrating data into various fuzzy membership scores [108]. It converts binary data into predefined percentile scores called membership scores, which generate three types of solutions: complex, intermediate, and parsimonious. Each solution provides different combinations, allowing researchers to explore various pathways to reach the same goal [109].

However, fsQCA requires a comprehensive sequence of steps, including proper case selection, thorough data collection, accurate calibration with precise membership scores, necessary-condition analysis, solution derivation, and interpretation [104]. These methodological stages ensure a detailed exploration of causal configurations, which are further elaborated in subsequent sections. Figure 2 shows the flowchart of the research methodology through which the objectives of this study were achieved.

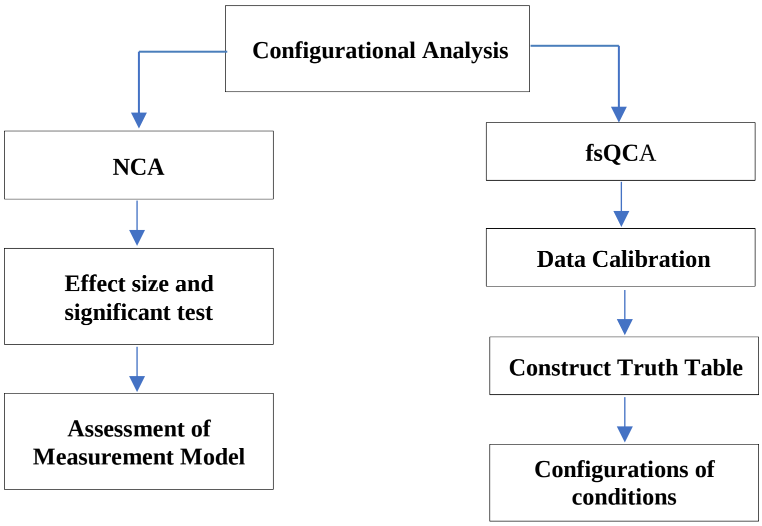


Figure 2. Flowchart of the research methodology

4- Data Analysis and Results

4-1- Measurements

Table 2 showcases measurement models satisfying every characteristic of the standard. We concentrated on Cronbach's Alpha (CA) and the Composite Reliability (CR) outcomes to confirm the validity and dependability of our interest. CA values ought to be above 0.7. All values of CA in Table 2 were greater than 0.7, which supported the assertion. Internal consistency dependability is analyzed by CR, which offers good construct reliability in all aspects. A value of CR between 0.7 to 0.9 indicates good reliability [110]. From Table 2, the values of CR were not only significant but also showed good reliability between our chosen constructs. Convergent validity is measured by Average Variation Extracted (AVE), which must exceed 0.5 [111], which confirms that each concept explains a significant portion of the variation in its indicators. Every score of AVE in Table 2 overruns the 0.5 limit. Before proceeding to the structural model, the measurement model's validity and reliability were assessed. The reliability of internal consistency was confirmed by CA values and CR scores, both of which reached the acceptable threshold of 0.70.

Table 2. Measurement results

Constructs	Cronbach's Alpha	Composite reliability (rho)	Average Variance Extracted (AVE)
Visibility	0.896	0.928	0.763
Reserve capacity	0.907	0.928	0.683
Market position	0.888	0.923	0.750
Big data analytics	0.800	0.870	0.626
Digitalization	0.929	0.944	0.739
Firm Resilience	0.908	0.935	0.783

4-2-NCA Results

According to Dul et al. (2020) [103], determining whether a condition is necessary or not relies on two critical standards. The first criterion requires the effect size to exceed the 0.1 threshold; an effect size below this level is deemed too negligible to hold practical significance. This ensures that the identified effect represents a meaningful relationship rather than a trivial one. Scores between 0.1 and 0.3 will be stated as a condition of generating a 'medium effect' on outcome, whereas scores between 0.3 and 0.5 will be considered as having a 'large effect' (Figure 3). The second criterion involves statistical validation using a permutation test. The p-value obtained from this test must be less than 0.05 to confirm that the observed effect size is unlikely due to random variation. This statistical threshold provides robust evidence for the necessity of the condition, reinforcing the reliability of findings in empirical analyses. Most selected constructs exceeded the minimum score of 0.1, except for big data analytics, presented in Table 3. However, the remaining constructs also have p-values less than a selected 0.05 significance threshold, which is statistically significant. This indicates that the observed necessity relationship is due to minimal random chance and increases the reliability of the findings [107]. Constructs with effect sizes ranging between 0.1 and 0.3 can be classified as having a 'medium effect,' highlighting their moderate influence on firm resilience [99].

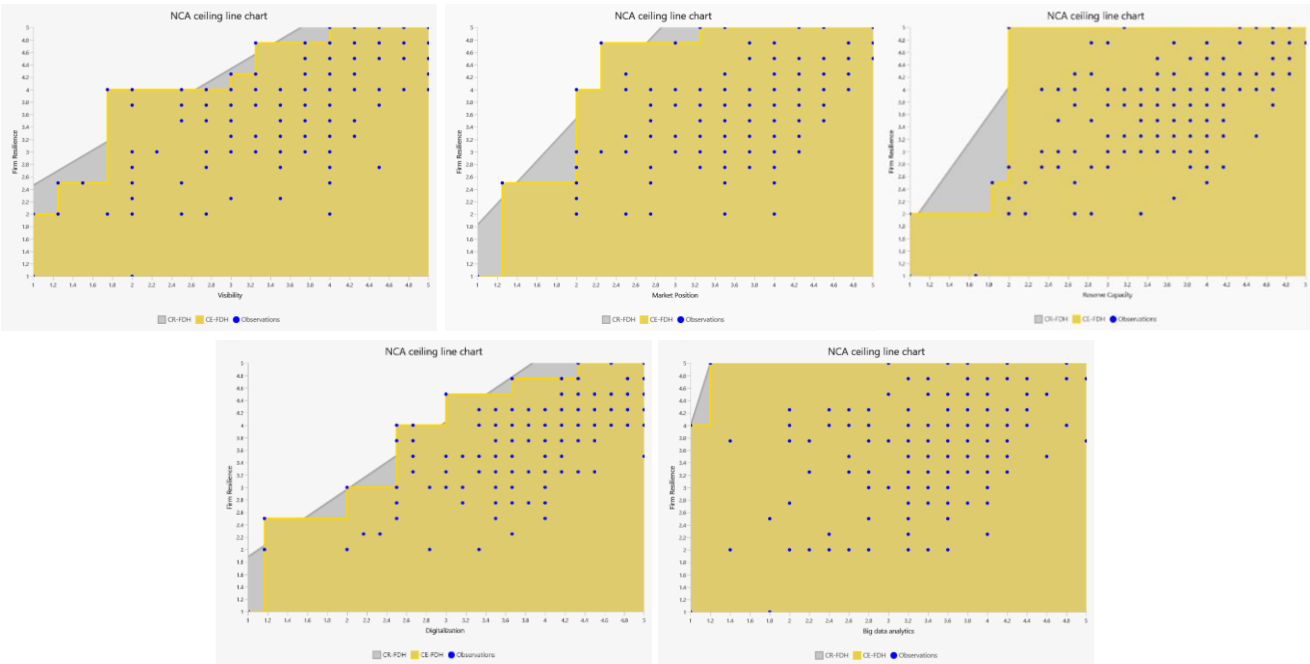


Figure 3. Effect size score of antecedents

Table 3 shows that visibility has a necessary effect on predicting firm resilience (p=0.000, P1 is supported). The effect size of visibility has a medium effect on firm resilience as an outcome variable. Reserve capacity has a significant and necessary effect on firm resilience. The result shows that there is a necessary relationship between visibility and firm resilience (p=0.002, P2 is supported). This relationship has a medium effect size between reserve capacity and firm resilience (0.182). The market position has a significant and necessary effect on firm resilience. The result shows that there is a relationship between market position and firm resilience. This relationship has a medium effect on predicting firm resilience (0.211). Big data analytics has a necessary effect on firm resilience (p=0.949, P4 is not supported). The effect size of BDA has a significant relationship with firm resilience (0.012). Digitalization has a necessary effect on firm resilience (p=0.000, P5 is supported). This relationship has a medium effect between firm resilience and digitalization (0.280).

Table 3. Results of hypotheses testing

Causal Conditions	Method	Accuracy	Effect Size	*P*-value
Visibility	CE-FDH	100%	0.227	0.000
	CR-FDH	100%	0.215	
Reserve capacity	CE-FDH	100%	0.182	0.002
	CR-FDH	100%	0.143	
Market position	CE-FDH	100%	0.211	0.000
	CR-FDH	100%	0.184	
Big data analytics	CE-FDH	100%	0.012	0.949
	CR-FDH	100%	0.006	
Digitalization	CE-FDH	100%	0.297	0.000
	CR-FDH	100%	0.280	

Note: General benchmark for effect size: $0 \leq d < 0.1$ ‘‘small effect,’’ $0.1 \leq d < 0.3$ ‘‘medium effect,’’ $0.3 \leq d < 0.5$ ‘‘large effect,’’ and $d \leq 0.5$ ‘‘very large effect.’’). * $p < 0.05$ level.

Table 4. Descriptive Statistics and Calibration

Construct	Descriptive statistics					Fuzzy set calibration		
	Mean	Std.	Min	Max	N	Fully-Out	Cross-over	Fully-In
Visibility	3.494	0.855	1.000	5.000	308	2.000	3.750	4.250
Reserve capacity	3.508	0.817	1.000	5.000	308	2.000	3.833	4.333
Market position	3.503	0.819	1.000	5.000	308	2.000	3.750	4.250
Big data analytics	3.392	0.750	1.000	5.000	308	2.000	3.600	4.200
Digitalization	3.663	0.849	1.000	5.000	308	2.000	4.000	4.500
Firm Resilience	3.566	0.816	1.000	5.000	308	2.000	4.000	4.250

4-2-1- Bottleneck Analysis

Moving on, NCA’s bottleneck analysis is given in Table 5, showing how a specific condition or a combination of constructs catalyzes achieving a desired outcome. The designation "NN" within the bottleneck table indicates that X's inadequacy does not constrain Y, indicating the needlessness of X (Figure 4). A low level (less than 30%) of firm resilience can be achieved by employing just two of our selected constructs, market position and digitalization, with the same amount of 0.649% for each. If we want to get a medium level (up to 50%), we must use all our constructs except big data analytics in a different combination. We can use 1.623% of visibility, 1.299% of reserve capacity, and digitalization with 0.974% of market position to get moderate firm resilience. If we increase the contribution of all the constructs and include big data analytics, we can get the full level of outcome of firm resilience. To achieve our full potential, as shown in Figure 4, we need 51.623% of visibility, 1.299% of reserve capacity, 26.299% of market position, 0.649% of big data analytics, and a massive amount of 80.844% of digitalization.

Table 5. Bottleneck analysis

Firm Resilience	Visibility	Reserve capacity	Market position	Big data analytics	Digitalization
0.00%	NN	NN	NN	NN	NN
10.00%	NN	NN	0.649	NN	0.649
20.00%	NN	NN	0.649	NN	0.649
30.00%	0.649	0.974	0.649	NN	0.649
40.00%	1.623	1.299	0.974	NN	1.299
50.00%	1.623	1.299	0.974	NN	1.299
60.00%	1.623	1.299	0.974	NN	13.312
70.00%	1.623	1.299	0.974	NN	13.312
80.00%	21.104	1.299	14.286	0.649	17.532
90.00%	29.221	1.299	14.286	0.649	30.519
100.00%	51.623	1.299	26.299	0.649	80.844

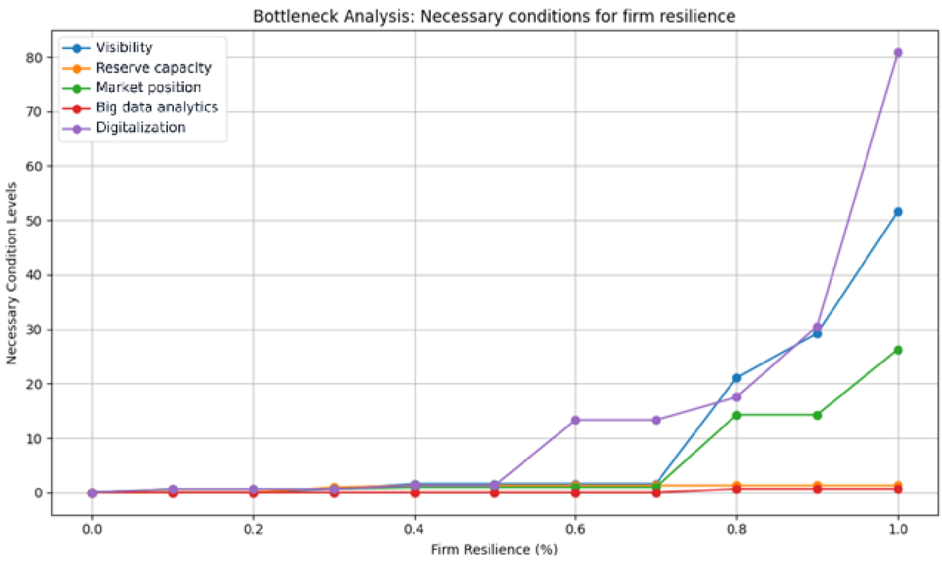


Figure 4. Bottleneck analysis

4-3- fsQCA Results

4-3-1- Calibration Process

The measurement statistic from Table 2 is used for the construct's reliability and validity. According to Jr. et al. (2017) [112], the composite reliability and Cronbach's Alpha values must surpass the minimum of 0.7, and the scores for AVE must exceed 0.5. Every construct has exceeded the threshold value by far margins, providing evidence of robust validity and reliability of the given data, which will also help fsQCA analysis. However, the given data need to be calibrated into different fuzzy set membership scores because of fsQCA's binary operation. We have used (Table 4) three different percentiles: 90th for fully out, 10th for fully in, and 50th for crossover points for properly calibrating the five-point Likert scale data with the help of fsQCA 4.1 software [113].

4-3-2- Necessary Condition Analysis

To identify the presence or absence of specific conditions, we must conduct a necessary-conditions analysis to determine whether a construct is required for achieving the possible outcome [107]. For a construct to be classified as always necessary, it must achieve a consistency score above 0.9, while a score between 0.8 and 0.9 represents an "almost always necessary" condition, with coverage required to exceed 0.75 [114, 115]. However, Table 6 shows that no constructs exceeded the minimum value of 0.8 except for digitalization (Figure 5). Although the values are close to the threshold, we must proceed to the next step—sufficiency analysis—to examine the contribution of our selected constructs (Figure 6).

Table 6. NCA results by fsQCA

Configurational Constructs	High firm resilience		~ Low firm resilience	
	Consistency	Coverage	Consistency	Coverage
Visibility	0.709	0.886	0.881	0.700
~ Visibility	0.558	0.575	0.465	0.447
Reserve capacity	0.763	0.860	0.839	0.732
~ Reserve capacity	0.565	0.641	0.588	0.510
Market position	0.708	0.869	0.861	0.695
~ Market position	0.578	0.606	0.512	0.483
Big data analytics	0.696	0.814	0.800	0.668
~ Big data analytics	0.588	0.643	0.576	0.518
Digitalization	0.837	0.916	0.901	0.810
~ Digitalization	0.560	0.654	0.615	0.518

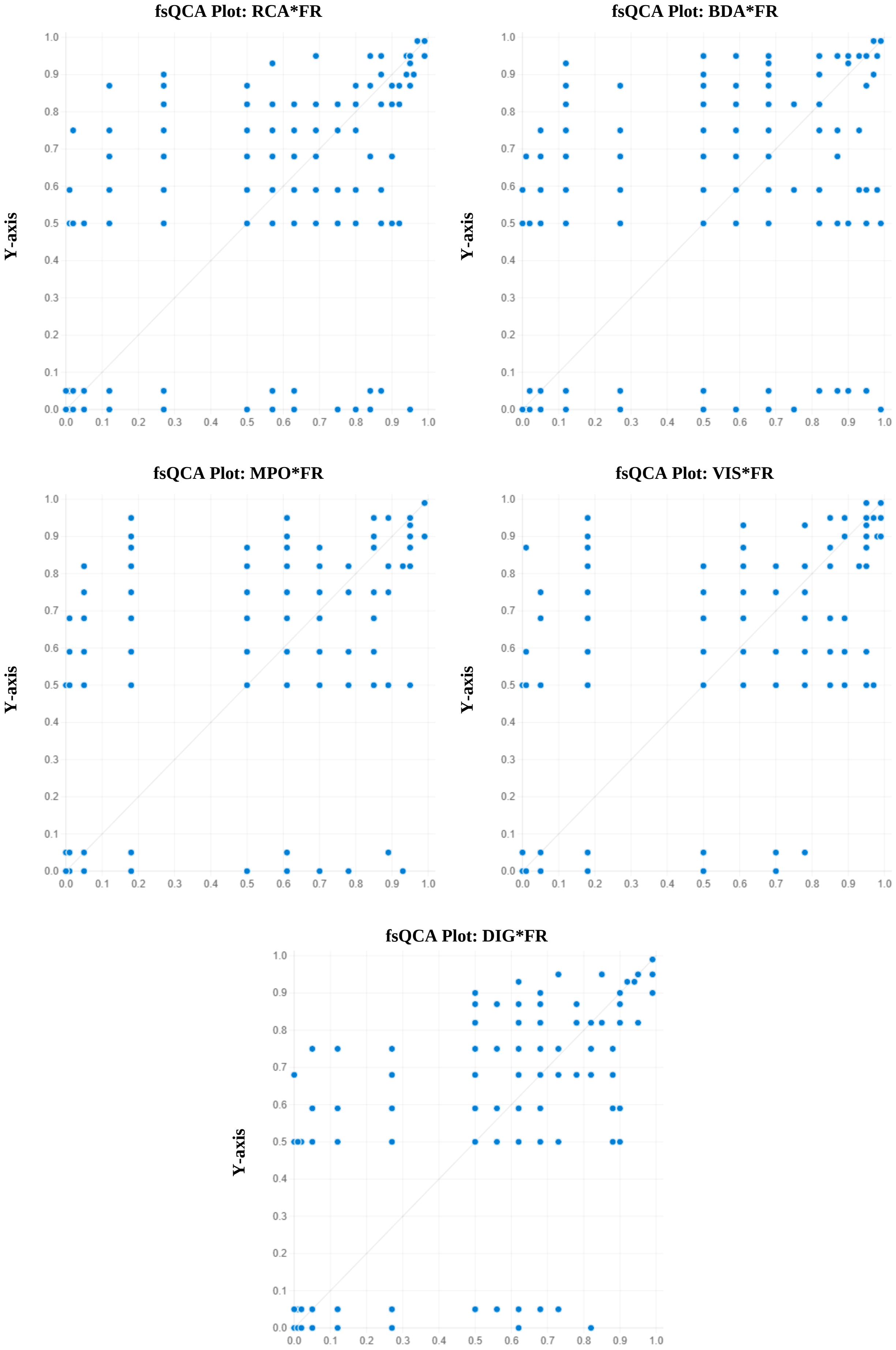


Figure 5. Configuration's plot using coverage and consistency score for high level of firm resilience

4-3-3- Sufficient Analysis

The study found four sufficient configurations for predicting high firm resilience. The proposed configurations are identified based on the analysis of the truth table algorithm, where we can find three solutions, including intermediate, parsimonious, and complex solutions. The study identified the best configurations based on the combination of intermediate and parsimonious solutions. The findings suggest that when a causal condition is present in both intermediate and parsimonious solutions, we can consider it as a core condition; when the causal condition is only present at intermediate, we can consider it as a peripheral condition [109]. Tables 7 and 8 show the symbol of core and peripheral conditions using small and large black circles.

Table 7. Configuration for high levels of firm resilience

Configurational Constructs	Solutions for a high level of firm resilience			
	S1	S2	S3	S4
Visibility	●		●	⊗
Reserve capacity				
Market position	⊗	⊗		●
Big data analytics				
Digitalization		●	●	⊗
Raw Coverage	0.359	0.472	0.643	0.317
Unique Coverage	0.013	0.039	0.008	0.006
Consistency	0.900	0.906	0.951	0.875
Overall Solution Coverage	0.948			
Overall Solution Consistency	0.800			

Note: Black circle (●) indicates the presence of a condition, and Negation circle (⊗) indicates its absence. Large circles indicate core conditions; small ones, peripheral conditions. Blank spaces indicate "don't care".

Table 8. Configuration for Low levels of firm resilience

Configurational Constructs	Solutions for a low level of firm resilience				
	S5	S6	S7	S8	S9
Visibility	⊗			⊗	●
Reserve capacity		⊗	●	●	⊗
Market position					
Big data analytics		●			
Digitalization	⊗		⊗		●
Raw Coverage	0.825	0.488	0.541	0.519	0.349
Unique Coverage	0.014	0.001	0.017	0.009	0.007
Consistency	0.868	0.831	0.884	0.840	0.824
Overall Solution Coverage	0.959				
Overall Solution Consistency	0.659				

Note: Black circle (●) indicate the presence of a condition, and Negation circle (⊗) indicate its absence. Large circles indicate core conditions; small ones, peripheral conditions. Blank spaces indicate "don't care".

Tables 7 and 8 represent fsQCA's truth table by employing the analysis of sufficient conditions consisting of both raw coverage and consistency values with their prominent solutions. Truth tables are constructed with 2^k rows, where k represents the number of causal conditions. Each row corresponds to an obvious logical configuration of these conditions, identifying almost all the possible scenarios [116]. Table 7 informs us about the possible combinations of solutions for a high level of firm resilience primary measures based on the construct's raw coverage and consistency score (Figure 6). A construct's raw coverage evaluates the comprehensive influence on the outcome, whereas consistency measures how a subset of relationships are observed within the data, examining which cases follow a hypothesized pathway [117].

As raw coverage is considered a practical indicator for the real-life use case scenarios and applicability of the identified configurations, we will prioritize those solutions with the highest raw coverage scores [100, 116]. By comparing all the solutions, we have found that the third solution for a high level of firm resilience has the highest raw coverage score of 0.643. This solution also holds the highest consistency score of 0.951, crowning it as the best solution for our study. It informs us that the core presence of visibility and digitalization can bring out the full potential of firm resilience. Reserve capacity, market position, and big data analytics are not significant constructs for achieving high levels of firm resilience. The finding of S1 shows that a high level of visibility and a low level of market position are sufficient conditions for achieving high levels of firm resilience. The second solution in Table 7 has the second-highest raw coverage score of 0.472, with a satisfying consistency score of 0.906. This solution advises the absence of market position, but the presence of digitalization as the core condition can uplift firm resilience. This result implies that a high level of digitalization and a low level of market position are sufficient constructs for achieving a high level of firm resilience. Moreover, visibility, reserve capacity, and big data analytics are irrelevant constructs for achieving a high level of firm resilience. The rest of the solutions can be discarded, as their raw coverage value is too low to be considered.

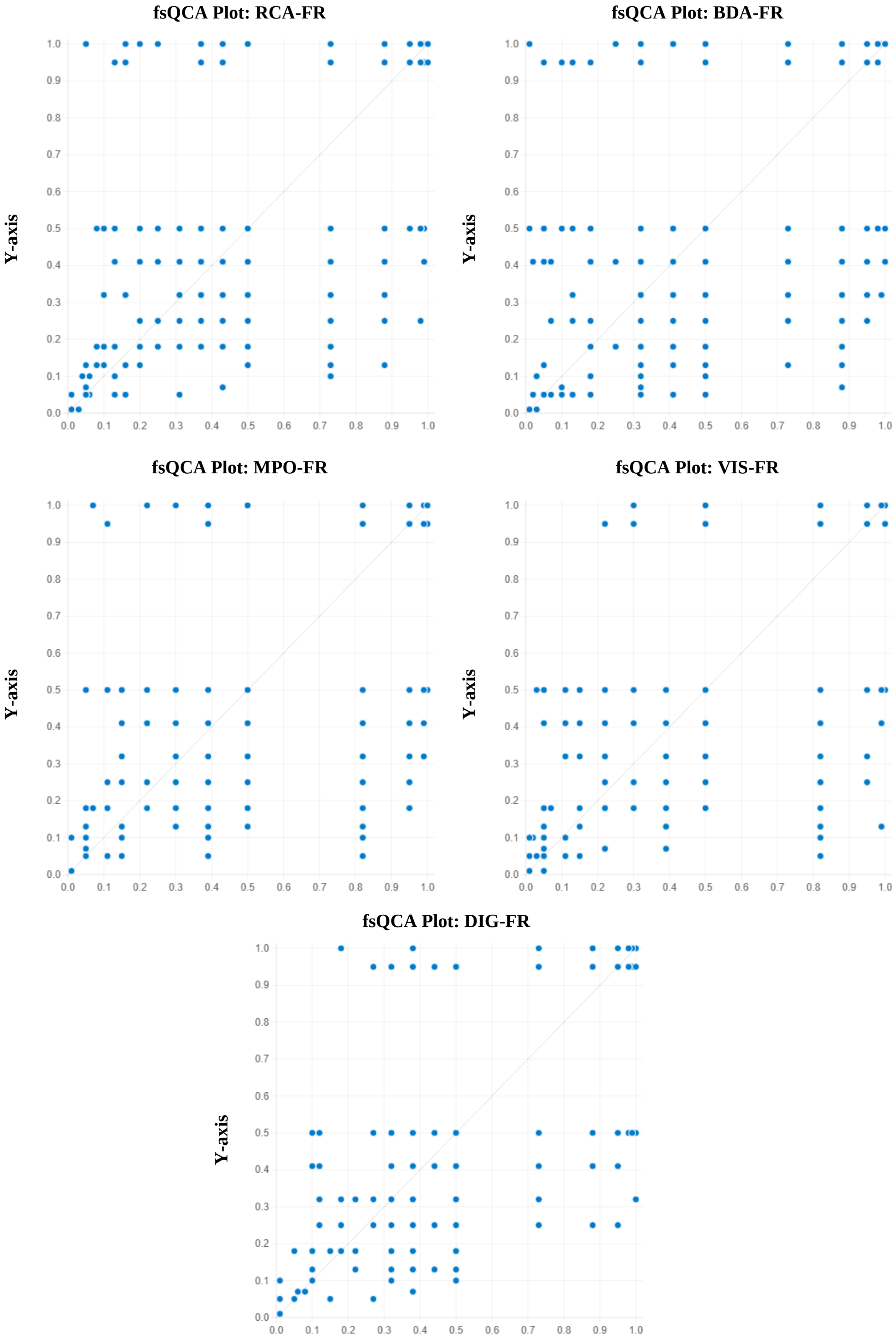


Figure 6. Configuration's plot using coverage and consistency score for low level of firm resilience

Table 8 represents the solution that can lower the potential of firm resilience. These solutions will also be evaluated by comparing both consistency and raw coverage. By following the table, the S5 solution of Table 8 has the highest raw coverage and consistency scores of 0.825 and 0.868, respectively. This solution warns us that the absence of visibility and digitalization will drawback the potential for firm resilience. Reserve capacity, market position, and big data analytics are not significant for achieving low levels of firm resilience. Consistent with S6, low levels of reserve capacity and high levels of big data analytics are sufficient conditions for achieving low levels of firm resilience. Visibility, market position, and digitalization are irrelevant conditions for achieving low levels of firm resilience. In solution 7, high levels of reserve capacity and low levels of digitalization are relevant conditions for achieving low levels of firm resilience. Visibility, market position, and big data analytics are not sufficient conditions for achieving firm resilience. Consistent with solution 8, low levels of visibility and high levels of reserve capacity are sufficient conditions for achieving low levels of firm resilience. Surprisingly, market position, big data analytics, and digitalization are not sufficient conditions for achieving low levels of firm resilience. Following this, the seventh and eighth solutions have the second-most raw coverage values of 0.541 and 0.519, respectively, with satisfactory consistency scores of 0.884 and 0.840 (Figure 7). Both solutions agree that the parsimonious presence of reserve capacity can decrease firm resilience, combined with either digitalization or visibility. In solution 9, high levels of visibility, low levels of reserve capacity, and high levels of digitalization are sufficient conditions for achieving low levels of firm resilience. Conversely, market position and big data analytics are not sufficient conditions for achieving low levels of firm resilience.

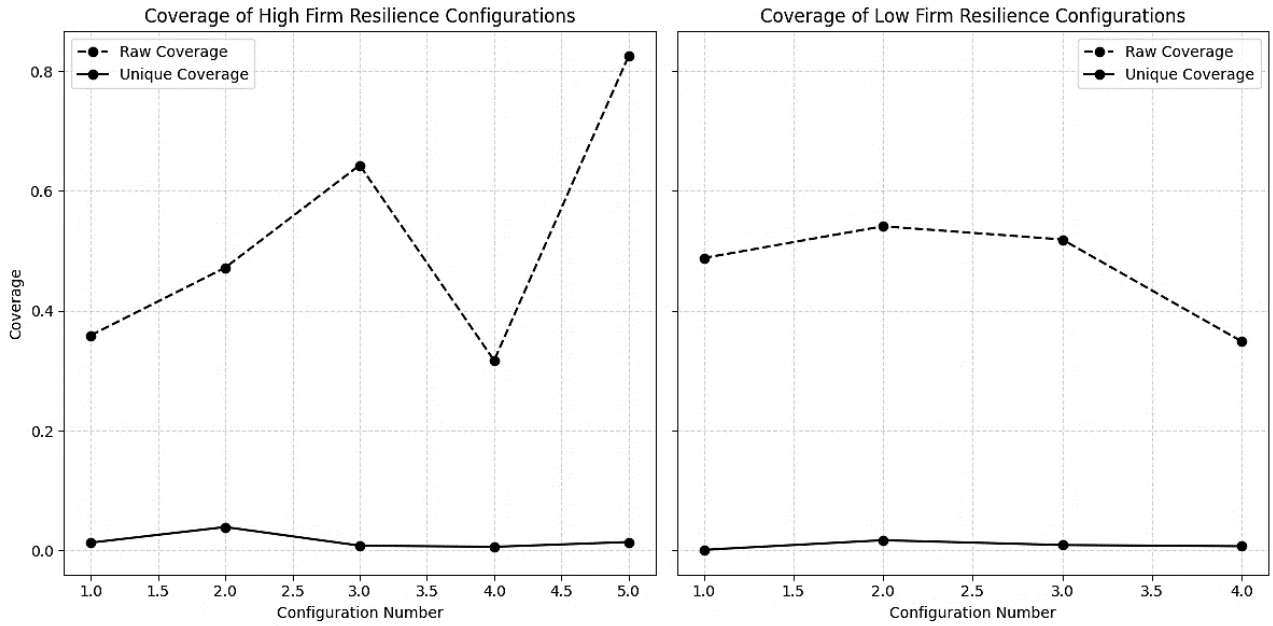


Figure 7. Coverage of high and low firm resilience configurations

5- Discussion

5-1- Relationship of Dynamic Capability View and Firm Resilience

This research contributes to the significance of the contemporaneous consolidation of firm resilience and technological innovation [56]. While firm resilience and dynamic capability are simultaneously discussed, recent studies do not provide an overview of a clear frame of their relationship. Some literature claims dynamic capability and firm resilience are conflicting concepts, whereas some consider their simultaneous contribution across each other [36]. This implies a contradiction in understanding the relationship between these two notions. The studies presume that confusion exists between the aim of firm resilience and dynamic capability, which are built upon a limited concept. In accordance with this literature, firm resilience ascertains building capabilities, whereas dynamic capability emphasizes building technological advancements that lead to achieving a high level of sustainable firm resilience during disruptive events. Moreover, the contributions of firm resilience and technological innovation are numerous and go beyond just capabilities and resources [118]. However, this research acknowledges the implication of a holistic justification of the relationship between firm resilience and DCV based on empirical validation. For the empirical validation, the study employed NCA and fsQCA models to analyze the proposed hypotheses. The results of this study will be discussed using NCA and fsQCA analysis in the following several contexts.

First, visibility has a necessary effect on firm resilience. This result is consistent with the prior literature obtained by various studies [14, 68]. In the domain of organizational transparency, the integration of visibility enables manufacturing organizations to manage risk mitigation plans and minimize uncertainties. To reduce uncertainties, visibility allows firms to assume disruptions using present capabilities and resources to achieve resilient firms [67]. Second, reserve capacity has a necessary effect on predicting firm resilience. This result is aligned with recent studies by Chowdhury & Quaddus (2017) [14] and Nair et al. (2024) [73]. Reserve capacity emphasizes the availability of additional resources and capabilities employed during disruptive events, enabling flexible operation and mitigating strategies [71]. Reserve capacity assures uninterrupted operation, adjusting and managing during uncertainties, eliminating the potential for broader shocks, and enabling overall firm resilience [119-121]. Finally, market position has a necessary effect on achieving firm resilience. This result is consistent with Namdar et al. (2021) [75], Hohenstein et al. (2015) [10], and Chowdhury & Quaddus (2017) [14]. This result implies that a strong market position can result in understanding advantages from the capabilities and resources across a wide base. The fsQCA results show that visibility is a sufficient condition in S1 and S3 to achieve a high level of firm resilience. Market position is an absent condition in S1 and S2 for achieving a high level of firm resilience. Surprisingly, market position is a sufficient condition in S4 for predicting a high level of firm resilience.

This research explores the association between firm resilience and the dynamic capability view and investigates a positive relationship between them. It implies estimated scales to analyze firm resilience and dynamic capability that assure a meaningful contribution to achieving a sustainable advantage during crises. The findings of this study counteract numerous studies in the extant literature that presume competing contributions between firm resilience and dynamic capability [122]. Simultaneously, this research affirms studies highlighting the significant relationship between technological innovation and firm resilience. The findings are related to the research by Xi et al. [123], which presents a positive effect of dynamic capability to achieve firm resilience during disruptive events. While Chowdhury & Quaddus (2017) [14] took various measures, including flexibility, financial strength, redundancy, market position, and visibility as dynamic capabilities of firm resilience, this research takes a survey scale originated by Ambulkar et al. (2015) [6] that claims a firm's adaptability, survival, and rapid response to achieve firm resilience. Such a theoretical concept of firm resilience permits us to explore the relationship based on a holistic understanding of the firm resilience scale. Therefore, the empirical estimation claims that firm resilience and dynamic capability share a positive relationship when their overall influence is justified to achieve sustainable advantage during turbulent events.

5-2- Relationship of Technological Innovation and Firm Resilience

Current literature highlights the role of technological innovation in shaping firms' awareness of their surroundings and enabling them to adapt their operational practices to respond to unforeseen crises in market environments [124]. The findings indicate that these attributes allow firms to achieve resilience by developing resources and capabilities that help them respond to disruptive events. Although limited literature explores this feasible relationship, this research empirically examines it within the firm context [125]. This study is one of the early investigations that reveals the mechanism through which technological innovation influences firm resilience. The results of this study will be assessed using NCA and fsQCA analyses across several aspects.

Consistent with P4, digitalization has a necessary effect on predicting firm resilience. This result is aligned with Sharma et al. (2024) [51], Chakraborty et al. (2021) [80], and Ardolino et al. (2022) [79]. This implies that digital technologies can be more useful for acquiring information from vendors and customers, and the findings can help manufacturing organizations to develop better operational development and growth, meet the varied and diversified requirements of customers, and achieve firm resilience [126]. Firms with a resilient business framework can remain on track with digitalization transformation and enhance their digital competencies. While their rivals are approaching to adjust to technological crises in the business, firms with technological innovation can influence digital competencies as a capacity to modify their functions, services, and products [127]. In addition, technological advancements allow firms to keep track of their products and services across sustainability and adjust changes in their operation [128]. Furthermore, big data analytics has a necessary effect on building firm resilience (P5). This result is consistent with Chen et al. (2004) [95] and Dubey et al. (2020) [50]. The BDA allows manufacturing firms to extend new opportunities, eliminate shocks, manage production costs, and help innovation in the dynamic business environment [50]. In fsQCA analysis, digitalization is significant as a core condition in S2 and S3, predicting high levels of firm resilience. Surprisingly, big data analytics is not significant as a core or peripheral condition for achieving firm performance.

Exact studies on technological advancements claim several contributions to firm resilience in achieving sustainable organizational performance [129]. This research argues for the scope of technological adaptation in building resilience and sustainability and empirically explores their relationships in the firm-level context. Technological advancements such as capability, invention, speed, strategic decision-making, and international connectivity have led to high firm resilience during turbulent circumstances [130]. Within the firm context, organizations support technological digitalization to produce sustainable products, evaluate sustainable productivity, and disseminate sustainable impacts throughout operations to reduce adverse effects on the business and the environment [131]. In fostering firm resilience, technological innovation enhances proactive capabilities for managing unforeseen crises through analytical validation and real-time monitoring, allowing reduced process time. Efficient decision-making and real-time monitoring of capabilities significantly improve the speed of response during the reconfiguring stage following turbulent circumstances [132].

5-3- Combinative Discussion

The findings reflect the strategy of various Bangladeshi organizations that balance resilience by equipping capabilities and resources (e.g., raw materials for manufacturing firms) and assuring fundamental transparency, a useful technique that provides constraints on technological investment. The findings also reflect that small, medium, and larger organizations or manufacturing-centered firms (e.g., textiles, leather, and pharmaceuticals) that maximize digital platforms and market effectiveness by acquisition stay low because of infrastructure disparities. The findings show that big data analytics is reported as a non-significant role due to its limited presence in NCA and fsQCA methods. This implies the cultural and structural realities in developing countries, like South Asian-based manufacturing organizations, in recent times. An emerging country like Bangladesh, with a manufacturing view captured by labor-related and SME industries like garments and leather, faces crucial difficulties in adopting BDA, including constraints on financial capabilities and resources and technological gaps. On the other hand, DIG is a necessary condition and sufficient configuration in S2 and S3. This implies the increasing significance of digital advancement in developing countries like Bangladesh, Bhutan, and Sri Lanka, where digital advancement has developed digital penetration in manufacturing organizations. Configuration 3 suggests that even manufacturing organizations with limited reserve capacity, market position, and big data analytics can build resilience strategies by integrating visibility and digitalization (e.g., employing digital channels). This configuration is specifically significant for manufacturing firms, which can deploy the process of transparency for digital channels to reduce disruptive events. Reserve capacity is a critical construct for achieving firm resilience due to high effect sizes and is supported by the proposition in the NCA analysis. For developing countries, where technical and economic capabilities and resources are scarce, the findings suggest prioritizing investment in digitalization instances, such as digital channels for controlling (e.g., AI-based logistic operations) and visibility (e.g., communication and openness for monitoring). These interventions cultivate significant resilience advantages in resource-limited operations and environments.

5-4- Theoretical Implications

This research contributes to the business models of firm resilience literature. Firstly, this research merges and comprehends the dynamic capability view and firm resilience notions. The dynamic capability view facilitates a framework for a holistic understanding of a firm's efforts across its disruptive events and attaining comparative benefit [133]. It shows a viewpoint to establish capabilities that facilitate firms to address disruptive events and transformations in the business model. These dynamic capabilities allow firms to achieve comparative benefits by reconfiguring and adapting capabilities and resources to attain sustainable resilience. As firm resilience broadly relies on responding, adjusting, and reconfiguring resources, it allows for adjusting and responding to the internal resources and capabilities notion of dynamic capabilities. In addition, attaining the comparative benefit under dynamic capability allows for the necessity of firm resilience. However, this research contributes to enhanced firm resilience to align features of enhanced comparative benefit. In addition, this research integrates capabilities, highlighting various insights to establish dynamic capabilities. The current implementation of dynamic capability in a disruptive management notion asserts the application of technological innovations and strategic insights as DCVs separately. Moreover, the second-order capabilities and innovations under dynamic capability (flexibility, redundancy, market position, visibility) permit authors to examine the first-order capabilities that collectively work across variance-based capabilities. As a result, such digital advancements and dynamic capabilities collectively can facilitate the firm's absorptive, adaptive, and reconfiguring capabilities to achieve sustainable competitive advantage during disruptive events. Technological innovation allows firms to establish capabilities that help them remain resilient and adaptable regarding the transforming business model. In this vein, technological innovation facilitates firms' absorptive and adaptive capabilities, which help build comparative benefits to achieve firm resilience.

Furthermore, while the NCA model shows that a causal connection might remain between predictors of interest, it is difficult to explore the complexities that remain in business operations. Complexity theory, moreover, observes that a configuration of causal conditions results in a setting producing combinations that would not happen when these causal conditions are reported in isolation. Simultaneously, these results report supplementary assistance for complexity theory, thereby featuring the implicit limitations of the NCA approach, such as the symmetric model. This research ascertains the exact literature that integrates NCA and fsQCA methods by focusing on the similarities and differences between both models [134, 135]. Additionally, while the symmetric method claims findings that can be comprehensive, the asymmetric method does not boast of such dynamic capabilities and technological innovations because it claims complex and comprehensive configurations that are related to complexity theory. Therefore, it is claimed that scholars explore their data before employing a model so that when the fsQCA method exists in the dataset, the asymmetric method is the most significant, as a symmetric model cannot explore these associations.

5-5- Practical Implication

The findings show practical contributions for policymakers, as they not only represent the order in which causal conditions should be considered to achieve firm resilience, but also identify additional relationships through which firm resilience can be attained during disruptive events. In addition, policymakers are advised that not all causal capabilities must be significantly present to achieve successful firm resilience. A simultaneous advancement of these causal conditions is also not necessary, as various configurations of these capabilities can yield the same results for firm resilience. Thus, when policymakers aim to enhance firm resilience, they should ensure improvements in the performance of concepts related to visibility, reserve capacity, market position, big data analytics, and digitalization. The findings report four different configurations that managers can employ. Since most organizations face certain disruptions in resources and capabilities, firm managers should prioritize the most effective configuration that achieves high levels of firm resilience during turbulent environments.

Furthermore, this research suggests that policymakers establish resilient business operations to overcome the constraints and uncertainties. The findings suggest that managers should leverage strong technological innovation (digitalization), like digital channels, automation, and operational information, to develop transparency and communication. This implies that managers can predict disruptions using digital platforms to communicate with partners or stakeholders, even with constraints, market strength, or digital capabilities that can balance disruptive events to achieve high resilience. Another configuration (S2) suggests that managers can prioritize market strength to enhance technological advancements; investing in market dominance and transforming new technologies can help organizations withstand turbulent environments. Firms should employ resilient operating and reconfiguring resources and capabilities that can adjust to disruptive conditions rapidly during the disruptive conditions. Also, the dynamic capability view claims that firms depend on the number of capabilities available to them in response to disruptive events. Thus, managers should measure their capabilities' solutions and produce the causal condition that assesses the maximization of their capabilities for attaining high firm resilience. Likewise, too many organizations must employ capabilities to attain a high level of visibility and digitalization and low levels of reserve capacity, market position, and big data analytics to lead to particular outcomes (solution S3). Other organizations must not see visibility and digitalization as a significant construct at all but instead may see the implication of capabilities to achieve high levels of reserve capacity, market position, and big data analytics as much more necessary for digital advancement to achieve a high level of firm resilience during disruptive events (solution S4).

5-6- Limitations and Future Research Directions

Being one of the latest efforts to explore the causal conditions of dynamic capability and technological innovation on firm resilience at the sub-predictor scale, this study is not without limitations and opportunities for future research. First, this research is based on the dimensions of dynamic capability and technological innovation. Future studies may explore other capability dimensions, such as absorptive, adaptive, and reconfiguring capabilities, to achieve firm resilience during pre-disruption, during-disruption, and post-disruption phases. Second, this research cannot be generalized to other sectors because the data were collected from individual participants within organizations in the corporate industry in Bangladesh. This research deployed PLS-SEM and fsQCA. Future work may integrate necessary condition analysis (NCA) with fsQCA and/or NCA alone. Moreover, since the application of these models is diverse, such integrations should consider how NCA supplements PLS-SEM and how the NCA model supplements the fsQCA method. Therefore, this study can be extended in future research by conducting a systematic review to examine the validated associations. Various moderators can also significantly enhance the theoretical framework in future studies.

6- Declarations

6-1- Author Contributions

Conceptualization, J.R, M.R., and M.F.I; methodology, M.R., M.F.I, M.N.I.J.; software, M.R, M.F.I., and M.Z.A.; validation, M.Z.A., and M.R., and M.N.I.J.; formal analysis, M.F.I., M.R. S.R., and J.R.; investigation, J.R., M.Z.A., M.N.I.J and S.R.; resources, S.R., M.Z.A., and S.R.; data curation, J.R., M.Z.A and S.R.; writing—original draft preparation, J.R., M.R., M.F.I. and M.Z.A.; writing—review and editing, M.N.I.J, S.R., and M.Z.A.; visualization, M.N.I.J., J.R., and M.R.; supervision, M.F.I., and M.R.; project administration, M.F.I and M.R.; funding acquisition, M.F.I. All authors have read and agreed to the published version of the manuscript.

6-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6-3- Funding

The authors received no financial support for the research, authorship, but the open access fee publication of this article is funded by the Sustainability Competence Centre, Széchenyi István University, Győr, Hungary.

6-4- Institutional Review Board Statement

Not applicable.

6-5- Informed Consent Statement

Participants involved in our research were provided with clear and comprehensive information regarding the purpose, procedures, and potential risks involved. Importantly, their participation was entirely voluntary, and informed consent was obtained before their involvement.

6-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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Appendix I. The Adapted Items of Previous Literature

Visibility (VIS) assessed through the prior literatures on [14].

VIS 1: We share information with supply chain partners

VIS 2: We track information on different operations

VIS 3: We have business intelligence to gather information

VIS 4: We have real-time flow of information throughout the project

Reserve Capacity (RCA) assessed through the prior literatures on [14].

RCA 1: We maintain reserve capacity for machinery, parts, and logistical supports of the project

RCA 2: We have backup energy/utility source

RCA 3: We have buffer stock for raw material of the project

RCA 4: We have adequate recovery process

RCA 5: We pursue a robust strategic growth model

RCA 6: We can balance endogenous and exogenous growth patterns

Market Position (MPO) assessed through the prior literatures on [14, 98].

MPO 1: We organize presentations for our stakeholder's satisfaction

MPO 2: We participate in educational programs regarding product differentiation.

MPO 3: Our employees' behavior is identical to our buyer-supplier relation values.

MPO 4: Our Customer has preferred brand toward our products and services.

Big data analytics (BDA) assessed through the prior literatures on [51].

BDA 1: Our organization is in the process of implementing or implemented BDA

BDA 2: Our organization is capable of parallel computing to address voluminous data.

BDA 3: Real-time access to data and information has helped organizations in better decision-making.

BDA 4: Our system is capable of handling semi-structured and unstructured data.

BDA 5: Truthfulness and accuracy of data have helped our organization.

Digitalization (DIG) assessed through the prior literatures on [95].

DIG 1: Our organization is using digital technologies (such as analytics, social media, mobile and embedded devices) to understand our customers better

DIG 2: Our organization markets and sell our products through digital channels

DIG 3: Our organization uses digital channels to provide customer services

DIG 4: Our organizations's core processes are automated

DIG 5: Our organization has an integrated view of key operational and customer information

DIG 6: Our organization uses digital technologies to increase the performance or added value of our existing products and services

Firm Resilience (FR) assessed through the prior literatures on

Kindly evaluate your level of consent with the following questions (5 presented strongly agree and 1 strongly disagree)

FR 1: Our organization can survive the changes brought by any external disruption

FR 2: Our organization adapts to the new circumstance due to external disruptions easily

FR 3: Our organization can quickly respond to any disruption easily

FR 4: Our organization is able to maintain high situational awareness at all times