Antecedent Configuration Study of Organizational Resilience under Digital Transformation: Based on fsQCA Method

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Abstract. Digital technologies are continuously embedded in enterprise operations. While organizations improve information processing efficiency, they also face new uncertainties such as technology dependence, resource misallocation, and the superposition of external shocks. To explain the multiple formation paths of organizational resilience in the context of digital transformation, this paper constructs a digital empowerment-organizational adaptation-external collaboration configuration framework, incorporating digital infrastructure, data-driven capabilities, organizational agility, organizational learning capabilities, supply chain collaboration capabilities, and external knowledge acquisition capabilities into a unified analysis. Based on 218 structured simulated enterprise samples, fuzzy set qualitative comparative analysis is used to conduct necessary condition, sufficiency configuration, and robustness tests. The results show that none of the six single conditions constitutes a necessary condition for high organizational resilience; high organizational resilience has four equivalent paths: digital agility-driven, learning collaboration-driven, digital-organization dual-wheel drive, and internal and external collaboration-driven, with an overall solution consistency of 0.836 and a coverage of 0.854; the formation of low organizational resilience exhibits significant causal asymmetry. Digital capabilities can only be stably transformed into resilience advantages when matched with organizational responsiveness, learning mechanisms, or external collaboration. This research reveals the complementary and substitutive relationships between digital capabilities, internal organizational capabilities, and external network resources from a configurational perspective, providing an analytical basis for enterprises with different resource endowments to choose resilience enhancement paths.

Keywords. Digital transformation, organizational resilience, organizational agility, supply chain collaboration, fsQCA.

1. Introduction

Digital transformation has moved from partial technology application to the stage of simultaneous adjustment of organizational structure, decision-making process and value network. Cloud computing, data analysis and intelligent platforms have improved the speed at which enterprises perceive market changes and strengthened the real-time coupling between businesses. In the face of demand fluctuations, supply disruptions and emergencies, whether enterprises can maintain key functions, recover quickly and complete adaptive adjustments after the shock has gradually become an important dimension for measuring the quality of digital transformation. Browder et al. found in a longitudinal case study in a crisis situation that digital capabilities such as virtual collaboration, data-driven decision-making and decision support can improve the speed and flexibility of enterprise adaptation[1]; He et al. further pointed out that technology investment and transformation management in digital maturity will affect the formation of organizational resilience through different mechanisms[2]. It can be seen that there is a clear connection between digital investment and organizational resilience, but this connection is constrained by both internal organizational capabilities and external relationship structure.

Existing research mainly discusses the impact of digital transformation, innovation, and dynamic capabilities on organizational resilience along the net effect logic. Zhang et al. used PLS-SEM and fsQCA parallel analysis and found that digital transformation and exploratory and exploitative innovation can form multiple high-resilience paths [3]; Kwiotkowska further verified the combined effect of digital transformation, dynamic capabilities, and organizational agility in a sample of thermal

power companies [4]. Related results have promoted the research from single variable effects to complex causal relationships, but the antecedent conditions are still mostly concentrated within the enterprise. Digital transformation is expanding organizational boundaries, and the linkage between supply chain collaboration, cross-organizational knowledge acquisition, and internal learning is increasingly affecting the speed of crisis identification, resource allocation, and recovery. Simply testing the average effect of a certain condition is difficult to explain why companies with different resource endowments can obtain similar resilience results through differentiated paths.

This paper constructs a six-condition configuration framework from three dimensions: digital empowerment, organizational adaptation, and external collaboration. It uses fsQCA to identify the equivalent path of high organizational resilience and simultaneously analyzes the formation mechanism of low organizational resilience. The study focuses on answering two questions: First, how do digital infrastructure, data-driven capabilities, organizational agility, organizational learning, supply chain collaboration, and external knowledge acquisition complement or substitute for each other? Second, does the combination of antecedents of high resilience and low resilience have causal asymmetry?

2. Model Design

2.1. Analysis Framework

Resilience is best understood as what an organization does across a disruption, rather than as a capacity revealed only after it. Before a shock, the firm absorbs strain; during it, the firm preserves and restores critical activities; afterward, it adjusts routines in light of what occurred. Digital systems may help at each point by widening access to information and shortening cross-departmental communication, yet technical capability does not by itself determine the response. AlNuaimi et al. link organizational agility to the progress of digital transformation and show its mediating role between leadership and transformation [5]. Zhu and Li likewise indicate that data-derived insight becomes useful for ambidextrous digital transformation through resource orchestration and agile action [6]. On this basis, the framework treats digital infrastructure and data-driven capability as the digital-empowerment conditions, whereas organizational agility and organizational learning represent organizational adaptation.

Digital operations have increased enterprises' reliance on supply chain partners and external knowledge networks. Awad and Martín-Rojas verified the positive correlation between digital transformation, organizational learning, innovation and organizational resilience[7]; Li et al. found that the depth of digital technology deployment can enhance corporate resilience through supply chain coordination[8]; Lin et al. explained from the perspective of resource orchestration that the matching between digital-driven business capabilities and supply chain governance can enhance supply chain resilience[9]. In addition, boundary-crossing knowledge search can connect external knowledge and innovation results through organizational resilience[10]. Accordingly, this paper incorporates supply chain collaboration capabilities and external knowledge acquisition capabilities into the external collaboration dimension. Figure 1 shows the research roadmap.

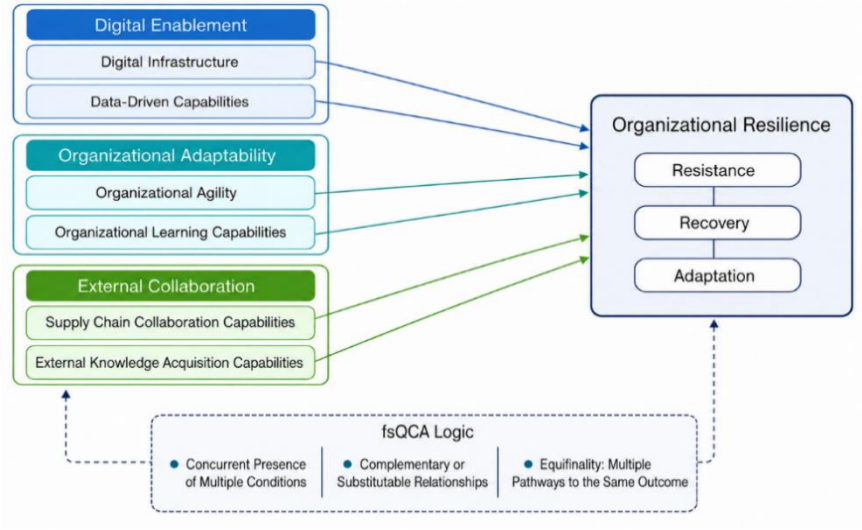


Fig. 1 Research Roadmap.

The six conditions do not have a predetermined linear hierarchy. Digital infrastructure provides the foundation for connectivity and process standardization; data-driven capabilities transform scattered data into decision-making information; organizational agility corresponds to rapid adjustment; organizational learning corresponds to experience updates; supply chain collaboration and external knowledge acquisition extend resilient resources beyond organizational boundaries. The conditions can be complementary or substitutive: sufficient external collaboration can compensate for some internal resource deficiencies; mature internal digital and learning capabilities can reduce reliance on immediate external knowledge input. fsQCA is suitable for identifying multi-condition concurrency and multi-path equivalence relationships.

2.2. Variable Measurement and Sample Design

Digital Infrastructure (DI) captures whether core systems are connected, cloud or platform tools are available, and business activities are digitally linked. Data-Driven Capability (DC) concerns the firm's ability to gather, combine, and interpret data for decisions. Organizational Agility (OA) is assessed through decision speed, operational adjustment, and resource redeployment; Organizational Learning Capability (OL) through knowledge sharing, post-event review, and the absorption of new knowledge. The two outward-facing conditions are Supply Chain Collaboration Capability (SC), covering information exchange, joint planning, and coordinated emergency action, and External Knowledge Acquisition Capability (KA), covering purposeful learning from customers, suppliers, universities, research institutions, and industry networks. Organizational Resilience (OR) is measured through continuity under pressure, recovery speed, and subsequent adaptation. Three five-point Likert items are used for each construct; Table 1 sets out the measurement domains.

Table 1. Constructs and measurement design.

Dimension	Construct	Code	Representative measurement focus	Source
Digital empowerment	Digital infrastructure	DI	System connection; cloud/platform coverage; process digitization	[1],[2]
Digital empowerment	Data-driven capability	DC	Data integration; analytics; decision support	[1],[6]
Organizational adaptation	Organizational agility	OA	Decision speed; cross-unit response; resource reallocation	[4],[5]
Organizational adaptation	Organizational learning	OL	Knowledge sharing; review; absorption and renewal	[7]
External collaboration	Supply chain coordination	SC	Information sharing; joint planning; disruption response	[8],[9]
External collaboration	External knowledge acquisition	KA	Customers; suppliers; universities; industry networks	[10]
Outcome	Organizational resilience	OR	Resistance; recovery; adaptive adjustment	[1],[2]

The questions referenced established constructs from recent research on digital transformation and resilience, and were adjusted to fit the business context. DI focuses on system connectivity and digital platform coverage; DC focuses on data interpretation and decision-making; OA focuses on cross-departmental response and resource reallocation; OL focuses on review, sharing, and absorption; SC focuses on upstream and downstream information synchronization and joint handling; KA focuses on knowledge search outside organizational boundaries; and OR corresponds to business maintenance during shocks, recovery after shocks, and process adaptation, respectively. Each construct maintains clear measurement boundaries.

Since a publicly verifiable enterprise micro-questionnaire database has not yet been established at this research stage, this paper uses structured simulation samples to verify the configuration identification logic. 218 enterprise cases were constructed based on high, medium, and low combinations of the six antecedents, and random perturbations were added to each construct item. The random seed was fixed at 20260821, allowing for repeated generation of analysis results.

2.3. fsQCA Model and Variable Calibration

Here, organizational resilience is modeled as a set outcome produced by combinations of the six antecedent sets. Equation (1) states the relationship in compact form:

$$Y = f(DI, DC, OA, OL, SC, KA) \tag{1}$$

In equation (1), Y represents the organizational resilience set, and DI, DC, OA, OL, SC, and KA represent digital infrastructure, data-driven capability, organizational agility, organizational learning capability, supply chain collaboration capability, and external knowledge acquisition capability, respectively. fsQCA requires converting the original scores into set membership degrees between 0 and 1. This paper adopts the direct calibration approach, using the 95th, 50th, and 5th percentiles of the sample as anchor points for complete membership, crossover points, and complete non-membership, respectively. To accommodate distributions with unequal distances on both sides, the standardized distance is segmented and then mapped to membership degrees using the Logistic function:

$$z_i = \begin{cases} \frac{x_i - c}{a_H - c}, & x_i \geq c \\ \frac{x_i - c}{c - a_L}, & x_i < c \end{cases} \tag{2}$$

$$m_i = \frac{1}{1+\exp(-kz_i)}, \quad k = \ln(19) \tag{3}$$

In equations (2) to (3), x_i is the original score of case i, a_H, c and a_L represent the anchor points of complete membership, intersection, and non-membership, respectively; z_i is the segmented standardized distance; m_i is the calibrated set membership degree; $k = \ln(19)$, therefore, when the standardized distances are 1 and −1, the membership degrees are approximately 0.95 and 0.05, respectively. The anchor points of each variable are shown in Table 2.

Table 2. Calibration anchors for fuzzy-set membership.

Set	Full membership (95%)	Crossover (50%)	Full non-membership (5%)
DI	4.667	3.000	1.667
DC	4.667	3.333	1.667
OA	4.667	3.000	2.000
OL	4.667	3.000	1.667
SC	4.667	3.000	1.667
KA	4.667	3.000	1.667
OR	5.000	3.667	1.667

Necessary condition consistency, sufficiency consistency, and original coverage are calculated according to Equations 4-6, respectively.

$$C_N = \frac{\sum_{i=1}^{n} \min(X_i, Y_i)}{\sum_{i=1}^{n} Y_i} \quad (4)$$

$$C_S = \frac{\sum_{i=1}^{n} \min(X_i, Y_i)}{\sum_{i=1}^{n} X_i} \quad (5)$$

$$C_{cov} = \frac{\sum_{i=1}^{n} \min(X_i, Y_i)}{\sum_{i=1}^{n} Y_i} \quad (6)$$

Where X_i represents the membership degree of case i in the condition or configuration set, Y_i represents its membership degree in the result set, n is the number of cases, and $\min(\cdot)$ represents taking the smaller value of the membership degrees of the two sets; C_N represents necessity consistency, C_S represents sufficiency consistency, and C_{cov} represents the original coverage. Necessity consistency is considered a possible necessary condition only when it reaches 0.90 or higher; the case frequency threshold for configuration analysis is set to 3, and the consistency threshold is set to 0.80.

3. Configuration Analysis and Results

3.1. Reliability, Validity, and Necessary Condition Analysis

Table 3 provides the scale diagnostics and descriptive results. Internal consistency is high across the seven constructs: Cronbach's α ranges from 0.889 to 0.942, composite reliability (CR) from 0.932 to 0.963, and average variance extracted (AVE) from 0.819 to 0.896. The factorability checks point in the same direction (KMO = 0.885; Bartlett's $\chi^2 = 3694.301$, df = 210, $p < 0.001$). At the descriptive level, OR has a mean of 3.401; the corresponding means for DI, DC, and OA are 3.110, 3.315, and 3.173. The distributions do not show a pronounced pile-up at either end of the scales.

Table 3. Reliability, convergent validity and descriptive statistics.

Construct	Cronbach's α	CR	AVE	Mean	SD
DI	0.889	0.932	0.819	3.110	0.902
DC	0.912	0.945	0.851	3.315	0.973
OA	0.898	0.936	0.831	3.173	0.890
OL	0.898	0.937	0.831	3.101	0.924
SC	0.911	0.944	0.850	3.057	0.984
KA	0.912	0.945	0.851	3.041	0.935
OR	0.942	0.963	0.896	3.401	1.127

Table 4 makes clear why no antecedent is treated as necessary. Consistency for the presence of a condition falls between 0.698 and 0.823, while consistency for its absence lies between 0.428 and 0.561; every value is below the 0.90 benchmark. DC comes closest (0.823), but even this value leaves too many high-resilience cases outside the set to support a necessity claim. The evidence therefore favors conjunctural explanation: resilience is associated with particular combinations of capabilities rather than with a condition that must appear in every case.

Table 4. Necessity analysis for high organizational resilience.

Condition	Presence consistency	Absence consistency	Necessary?
DI	0.716	0.554	No
DC	0.823	0.428	No
OA	0.790	0.471	No
OL	0.732	0.533	No
SC	0.698	0.539	No
KA	0.702	0.561	No

3.2. Configuration Paths for High Organizational Resilience

The minimized truth table contains four sufficient configurations for high organizational resilience (Table 5). Taken together, they cover 0.854 of the outcome set at a solution consistency of 0.836. H1 combines DI, DC, and OA with the absence of SC (consistency = 0.870; raw coverage = 0.447). In substantive terms, this is an internally coordinated route: connected systems supply current information, analytical capability interprets it, and agility turns that interpretation into rapid resource shifts. Strong performance along this chain can sustain critical operations even where supply chain collaboration is comparatively weak.

Table 5. Configurations for high organizational resilience.

Path	Configuration	Consistency	Raw coverage	Unique coverage	Path type
H1	DI*DC*OA*~SC	0.870	0.447	0.075	Digital-agility driven
H2	~DI*OL*SC*KA	0.829	0.357	0.151	Learning-collaboration driven
H3	DI*DC*OA*OL*~KA	0.904	0.421	0.056	Digital-organization dual driven
H4	DC*~OL*SC*KA	0.836	0.378	0.142	Internal-external collaboration
Solution	—	0.836	0.854	—	—

H2 follows a different logic. It joins the absence of DI with OL, SC, and KA and reaches a consistency of 0.829. A firm with a relatively modest digital base can therefore reach the outcome when learning routines are reinforced by coordination with supply chain partners and by systematic acquisition of outside knowledge. H3, by contrast, is an internal-capability configuration: DI, DC, OA, and OL are present, while KA is absent. Its consistency is 0.904, the highest among the four solutions. In these cases, digital connectivity, analysis, agile response, and learning form a sufficiently tight internal loop that immediate external knowledge input is less central.

The H4 internal and external collaborative driving model is formed by the presence of DC, SC, and KA, accompanied by the absence of OL, with a consistency of 0.836. In this path, data-driven capabilities are responsible for identifying anomalies and supporting decision-making, while supply chain collaboration and external knowledge acquisition are responsible for expanding resource boundaries, forming external compensation when internal learning mechanisms are relatively insufficient. All four paths collectively demonstrate that the contribution of digital transformation to organizational resilience has a clear configurable attribute. Enterprises can form different models, such as internal capability-led, external network compensation, or a synergy of both; no single path is universally dominant.

Path comparison shows that DC appears in H1, H3, and H4, playing a strong pivotal role, but its necessity consistency is below 0.90. OA is concentrated in H1 and H3, dominated by internal digital capabilities, while SC and KA appear together in H2 and H4, dominated by external collaboration. Two types of resilience logic can be summarized: internal closed loops rely on information acquisition, rapid decision-making, and resource reallocation; external networks rely on knowledge input, partner collaboration, and resource compensation. OL exists in H2 and H3 but is missing in H4, indicating that the learning ability effect depends on its matching with digital capabilities and external resources.

3.3. Comparison of Non-High Organizational Resilience, Mechanisms, and Robustness

Inverting the result set yields three main non-high resilience paths. L1 is where DC and OA are both missing, with a consistency of 0.884 and a coverage of 0.651; L2 is where OL, SC, and KA are all missing, with a consistency of 0.897; L3 is where DI, DC, and OL are all missing, with a consistency of 0.955. The overall consistency of the three paths is 0.849, and the coverage is 0.774. A simple inverse of the high-resilience configuration cannot fully explain the non-high-resilience

aspect; causal asymmetry is quite evident. Especially when data-driven approaches and agile responses are insufficiently synchronized, even enterprises with some digital infrastructure are prone to exhibiting low resilience because information cannot be translated into rapid action.

Robustness was examined by moving the calibration anchors for full membership and full non-membership from the 95th and 5th percentiles to the 90th and 10th percentiles. Recalibration changes the numerical estimates slightly, but not the interpretation of the solution. The four paths retain the same core conditions and directions; their consistency values lie between 0.819 and 0.898. Solution consistency is 0.838 and solution coverage is 0.843, compared with 0.836 and 0.854 in the baseline analysis. Table 6 reports the path-level comparison.

Table 6. Robustness test under alternative calibration anchors.

Path	Base consistency	Robust consistency	Base raw coverage	Robust raw coverage	Direction stable
H1	0.870	0.861	0.447	0.415	Yes
H2	0.829	0.819	0.357	0.297	Yes
H3	0.904	0.898	0.421	0.377	Yes
H4	0.836	0.822	0.378	0.316	Yes
Solution	0.836	0.838	0.854	0.843	Yes

4. Conclusion

This paper constructs an antecedent configuration framework for organizational resilience from three dimensions: digital empowerment, organizational adaptation, and external collaboration. Analysis shows that digital infrastructure, data-driven capabilities, organizational agility, organizational learning, supply chain collaboration, and external knowledge acquisition cannot individually constitute the necessary conditions for high organizational resilience; however, digital agility-driven, learning collaboration-driven, digital-organization dual-wheel drive, and internal and external collaboration-driven approaches can all lead to high organizational resilience. The resilience value of digital capabilities depends on their compatibility with organizational response, learning mechanisms, and external networks.

The configuration results further reveal a clear substitution relationship. Enterprises with relatively weak digital infrastructure can compensate for insufficient technological resources through organizational learning, supply chain collaboration, and external knowledge acquisition; enterprises with insufficient internal learning capabilities can compensate by leveraging data capabilities and external collaboration; while enterprises with strong digital infrastructure, data-driven approaches, and agile learning rely more on internal closed-loop systems for risk identification and recovery. In management practice, enterprises should choose capability combinations based on their own weaknesses, avoiding substituting simply increasing investment in digital technology for organizational mechanism building. Theoretically, this research expands the explanation of organizational resilience from single technological investment to a configuration relationship involving the combined effects of technology, organization, and network, revealing the equivalence between high-resilience paths and the asymmetry between high and low resilience. In practice, enterprises with mature digital infrastructure and high-quality internal data can prioritize improving agile decision-making and knowledge review mechanisms; enterprises with limited digital resources should strengthen supply chain information sharing, joint emergency response, and external knowledge search to compensate for internal capability constraints with network resources. When formulating digital project budgets, enterprises should also simultaneously assess the degree of process authorization, cross-departmental collaboration, and partner connectivity to ensure that technological investment is consistent with organizational mechanisms.

The study's principal constraint is the use of structured simulation rather than observations from operating firms. Because the data-generating procedure is fixed and reproducible, the analysis is useful for checking the calibration and configuration-identification workflow; it cannot, however,

establish how widely these configurations occur in practice. A next step is to repeat the analysis with cross-industry questionnaires, annual-report measures, or multi-period panel data, and then test whether the paths differ by industry, firm size, or digital maturity. If repeated observations become available, dynamic QCA could also trace whether firms move between configurations as shocks unfold and learning accumulates.

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