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RESEARCH ARTICLE

Research on the Resilience Enhancement Path of Technology-Based SMEs Using Dynamic Fuzzy Cognitive Maps–Organizational Context and the Employee Loyalty Perspective

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ABSTRACT Technology-based small and medium enterprises (SMEs) represent an important organizational aspect of technological innovation and economic growth. The complex and turbulent operating environment resulting from COVID-19 is a fatal threat to the survival and growth of technology-based SMEs. Based on the Wuli-Shili-Renli (WSR) methodology, this research uses dynamic fuzzy cognitive maps to analyze the mechanisms underlying the interactions among organizational context, employee loyalty and organizational resilience in the context of technology-based SMEs. The study also includes a sensitivity analysis, and the results of these analyses are mutually corroborated. The study finds that organizational context, employee loyalty and organizational resilience are correlated to varying degrees but also that organizational learning and sustained loyalty are weak, while normative organizational loyalty is relatively weak. This study enriches the research concerning organizational resilience and has practical value with regard to improving the organizational resilience of technology-based SMEs.

INDEX TERMS Technology-based SMEs, Wuli-Shili-Renli system approach, organizational resilience, organizational context, employee loyalty, dynamic fuzzy cognitive map.

I. INTRODUCTION

Technology-based small and medium enterprises (SMEs) are an important component of China's scientific and technological development and economic growth [1]. Such enterprises offer the advantages of effective growth, high technological content and great potential for development, and they represent the backbone of China's burgeoning modern industrial system. Globally, SMEs account for 95% of all enterprises. They employ 66% of workers worldwide and account for 55% of global production output. SMEs therefore play an irreplaceable role in the development of social and economic life, and the roles of technology-based SMEs as drivers and sources of national technological innovation are particularly important. However, compared with large enterprises, technology-based SMEs exhibit some inherent defects. On the one hand, they are small and difficult to finance [2], and they have limited resources [3]. On the other hand, technology-based enterprises are associated with high levels of investment and risk; therefore, technology-based SMEs face many adverse risk factors in their growth processes [4]. Moreover, a complex and turbulent operating environment poses a critical threat to the survival and growth of SMEs. Long-term and large-scale segregation may lead to the disruption of a production chain [5], which can have a particularly notable impact on technology-based SMEs

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due to their limited funds and urgent need for talent and intellectual resources. Accordingly, due to the impacts of the COVID-19 pandemic, technology-based SMEs are prone to failure in terms of their organizational functions due to a lack of key personnel and insufficient resources, which can have cascading effects, ultimately resulting in extensive economic losses. Therefore, technology-based SMEs should base their business on the concept of ''resilience'', thus allowing them to respond flexibly to risks and decreasing their recovery time after disruptions.

Continuous organizational improvement can enhance the long- and short-term resilience of SMEs [6]. Organizational context is a potential source of ''resilience'' [7] that can stimulate individual resilience and effectiveness [8], promote employee loyalty, and enhance organizational resilience. Organizational resilience is evidently influenced by factors at both the individual and organizational levels. However, little is known regarding how these different levels of analysis interact with one another [9]. Therefore, in this paper, we investigate the organizational functioning of technology-based SMEs in the context of the ongoing novel coronavirus pneumonia pandemic. Based on the Wuli-Shili-Renli (WSR) systems approach, we use dynamic fuzzy cognitive maps (DFCMs) to identify the key factors of organizational context, employee loyalty and organizational resilience, analyze the mechanisms underlying these factors, and propose countermeasures to enhance the resilience of technology-based SMEs and ensure sustainable development.

II. THEORETICAL ANALYSIS

A. ORGANIZATIONAL RESILIENCE

''Resilience'' is a concept that has been used widely in many fields. Organizational resilience has gradually attracted the attention of management scholars. Typically, resilience has been studied in terms of system capabilities or outcomes rather than processes [10], [11]. Specific performance, however, entails the ability to recover and progress. Organizational resilience refers to the ability to recover on multiple levels; both individuals [12] and organizations adapt to the shifting environments they face [13] to facilitate crisis management based on organizational resilience [14]. Stephanie [15] thus claims that resilience is the ability that allows these actors to deal effectively with emergencies, recover from crises and promote future success. Maria [16] also notes that organizational resilience refers to the ability to adapt to changes. However, resilience is a multidimensional construct, and no agreement regarding its measurement or the corresponding research methods has yet been reached. Relevant studies have therefore used direct measurement methods [17], [18], indirect measurement methods [19] and case study methods [20].

Kantur and Iseri-Say [21] divide organizational resilience into three dimensions: robustness, agility and integrity. Burnard [22] suggests that organizational resilience consists of readiness and fitness. Patriarca [23] divides organizational resilience into four dimensions: monitoring, response, prediction and learning. Finally, Yong [18] measures organizational resilience in terms of three aspects: adaptability, resilience and situational awareness. This study, however, divides organizational resilience into three dimensions based on the three stages of a crisis: planning, adaptability and recovery.

B. EMPLOYEE LOYALTY AND ORGANIZATIONAL RESILIENCE

Employee loyalty refers to the degree of loyalty that employees exhibit toward their organization and represents a positive psychological tendency that individuals form in the context of long-term employment. Hanson [24] was the first researcher to combine loyalty with the notion of organizational staff, highlighting the fact that employee loyalty has a significant coordinating effect on employee turnover intentions and opinions. Meyer and Allen [25] claim that employee loyalty refers to an employee's perception of his or her relationship with the organization to which he or she belongs. Some scholars claim that positive emotions [26], i.e., the positive emotions of employees [27], contribute to personal resilience, stimulate employee loyalty and enhance organizational resilience. Santoro [9] suggests that employee resilience helps improve organizational performance. Moreover, Mihus et al. [28] analyze the impact of the COVID-19 pandemic on employee loyalty and claim that only joint efforts on the part of employers and employees can promote effective enterprise operation.

Porter [29] develops a three-dimensional scale including value commitment, retention commitment and effort commitment. Meyer and Allen [25] measure employee loyalty in terms of the three dimensions of affective organizational loyalty (AOL), normative organizational loyalty (NOL) and continuance organizational loyalty (COL). Many empirical studies have demonstrated the high reliability and validity of this scale. For example, Hong et al. [30] use an organizational loyalty–implicit association test (OL–IAT) to measure implicit organizational loyalty and verify its predictive validity. Accordingly, following Meyer and Allen, this study measures employee loyalty in terms of AOL, NOL, and COL.

C. ORGANIZATIONAL CONTEXT AND ORGANIZATIONAL RESILIENCE

Organizational context is a potential source of resilience [7]. This term refers to the organizational structure and system that plays an external role in promoting or hindering organizational members and can stimulate individual resilience and efficiency [8] with the aim of developing organizational resilience. Organizations should thus focus on the cultivation of employee resilience in daily management to improve organizational resilience [31]. Scheuch [32] explores organizational resilience training in different organizational contexts and shows how a flexible organizational structure enables organizations to allocate resources more effectively and enhance organizational resilience [33]. In addition,

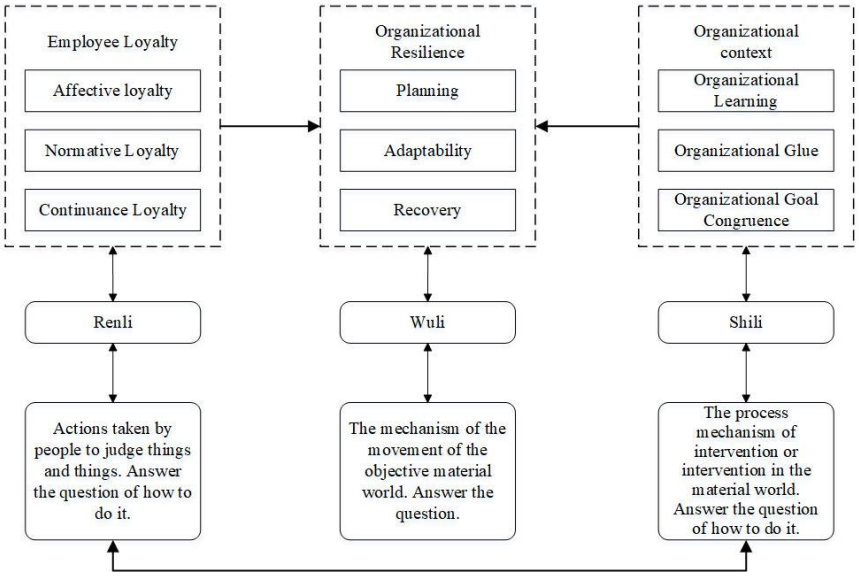

FIGURE 1. Theoretical model.

van den Berg [34] finds that an organization's structural empowerment is positively correlated with organizational resilience.

Gupta [35] identifies task environment, structural characteristics and organizational culture as dimensions of organizational context measurement. Jiang Qinfeng [36] measures the organizational context of innovative SMEs in terms of three dimensions: external situation, industrial situation and development situation. Luo [37] and others measure organizational context in terms of organizational climate, commitment and trust, while Guohua [38] assesses organizational context based on the four dimensions of organizational trust climate, organizational rewards, leadership support and organizational regularization. Accordingly, this study uses OL, OG and project goal congruence (PGC) to measure organizational context.

D. EMPLOYEE LOYALTY AND ORGANIZATIONAL CONTEXT

Employee loyalty is an important factor associated with organizational success [39] and a key factor in the maintenance of organizational performance [40]. Organizational context (organizational culture, working environment, etc.) affects employee loyalty [41]. Thus, Robb [42] emphasizes the fact that the members of an organization regard themselves as an organizational economic task community, an essential element involved in the shaping of organizational resilience. Matzler and Renzl [43] note that organizational trust, especially trust between leaders and colleagues, can enhance employee loyalty. Ghoshal and Bartlet [44] study the interactions between organizational context and management behavior and suggest that organizational context is dynamic and affects the individual behaviors of organizational members. Nguyen et al. [45] note that the organizational environment and culture can enhance employee loyalty in SMEs. Finally, Aboobaker et al. [46] claim that identifying with organizational values is positively correlated with all dimensions of employee loyalty.

E. WSR METHODOLOGY

WSR methodology stems from Chinese culture and was created in 1994 by Gu Jifa, a system scientist, who integrated this methodology with the characteristics of Asian societies proposed by Zhichang [47]. WSR considers a research problem to be a whole that is composed of multiple elements and explores the relationships among these various elements.

In this context, the term physics refers to the mechanisms underlying the movement of matter and their definitions [48]. Affairs comprise the mechanisms that people use to intervene in physical processes and answer questions about them [49]. Finally, humanism is defined in terms of the actions taken by a person to answer questions regarding how to do something in accordance with his or her physical and logical judgments [50]. Accordingly, in this paper, physical factors inform the organizational resilience of technology-based SMEs during the COVID-19 pandemic. Governing factors include the impacts of technology-based SMEs on the COVID-19 pandemic via OL, OG and PGC. Human factors consist of the actions taken by the employees of technology-based SMEs based on their judgments of organizational context and resilience, which mainly take the form of AOL, COL, or NOL to their organization. This theoretical model is illustrated in Figure 1 below.

III. RESEARCH METHODS

A. THE DYNAMIC FUZZY COGNITIVE MAP AND ITS APPLICABILITY

1) THE DFCM

The temporal distribution of publications from 1990-2022 and some periodical characteristics of the critical evolution of this topic are illustrated in Figure 2. The research exhibits a steady quantity of organizational resilience

articles worldwide, which can be divided into three rough stages. In the first stage (preliminary), fewer than 10 articles per year were published from 1990-1999. In the second stage (rapid development), which exhibited a progression from 12 papers in 2000 to 116 papers in 2012, the study of organizational resilience developed rapidly. In the third stage (vigorous development), numerous articles on the topic of organizational resilience were published from 2013-2022. A dynamic fuzzy cognitive map (DFCM) is constructed by using a random neural network model to replace symbolic deduction with many computational processes, ultimately facilitating reasoning. This approach has been continuously deepened and extended by scholars from various countries, mainly in the forms of intuitionistic fuzzy cognitive maps [51], rough cognitive maps [52], fuzzy cognitive maps based on automatic control in time [53], dynamic grain cognitive maps [54], higher-order intuitionistic fuzzy cognitive maps based on variational pattern decomposition [55], and fuzzy gray cognitive maps based on gray clustering [56], which have been widely used in the social sciences [57], economics [58], energy science [59], ecology [60], healthcare [61], risk management [62], expert systems [63], education [64], and other fields.

Definition 1 of a DFCM evaluates the concept node $C_1, C_2, \ldots, C_i, \ldots, C_n$ of an FCM, assuming that the edge weight of directed graph $e_{i,j} \in [-1, 1]$, matrix $\mathrm{E} = (\mathrm{e_{i,j}})$, $\mathrm{e_{i,j}}$ is the weight of directed edge $\mathrm{C_i}, \mathrm{C_j}$, E, i.e., the adjacency matrix of an FCM, also known as the correlation matrix. Assuming that in the fuzzy cognitive map, $\mathrm{E} : (\mathrm{C_i}, \mathrm{C_j}) \rightarrow \varpi_{\mathrm{ij}}$ is a mapping, $\varpi_{\mathrm{ij}} \in \mathrm{E}$, $\mathrm{C_i}, \mathrm{C_j} \in \mathrm{C}$, and ϖ_{ij} denotes the degree of causal influence among concepts $\mathrm{C_i}, \mathrm{C_j}$, $\mathrm{E}(\mathrm{C} \times \mathrm{C}) = (\varpi_{\mathrm{ij}})_{\mathrm{n \times n}}$, which is also the adjacency matrix of the fuzzy cognitive map.

In a DFCM, concept nodes can affect the system state. The value of $\mathrm{W_{ij}}$ represents the influence of concept node $\mathrm{C_i}$ on concept node $\mathrm{C_j}$. $\mathrm{W_{ij}} > 0$ represents a positive connection between concept nodes. $\mathrm{W_{ij}} < 0$ represents a negative linkage between concept nodes $\mathrm{C_i}$ and $\mathrm{C_j}$. $\mathrm{W_{ij}} = 0$ indicates that there is no connection between these concepts.

2) APPLICABILITY OF THE DFCM

A DFCM improves an FCM by making concept nodes quantitative and dynamic and introduces a nonlinear dynamic function to the reasoning process to establish a dynamic causal relationship. This approach is able to overcome the limitations of traditional research methods by validating hypotheses that do not exist or potential relationships that are unverified. A DFCM is thus closer to a real environment, enables researchers to construct a virtual world that changes over time, and provides rich dynamic reasoning mechanisms. In organizational resilience research, because the formation process of organizational resilience is highly complex and nonlinear and involves multiple factors, it features fuzzy boundaries with respect to indirectness and resilience measurability. DFCM modeling and simulation methods can enable researchers to focus on the causal relationships between employee loyalty and organizational context with the help of research data and the use of a random neural network learning algorithm to support modeling and simulation with the aim of conducting a dynamic analysis of organizational context and employee loyalty. Therefore, a DFCM can facilitate the construction of improved organizational resilience incentive mechanisms.

3) PARAMETER DESIGN

If $\mathrm{C_i}$ represents the concept node of influencing factors in the network of employee loyalty, organizational context and organizational resilience in the context of technology-based SMEs, each concept node is represented by a set of numerical vectors V, and $\mathrm{V_i}$ represents the importance of the ith concept node. $\mathrm{W_{ij}}$ represents the correlation between concept node $\mathrm{C_i}$ and concept node $\mathrm{C_j}$; A(i) represents the state value of concept node i.

B. DATA COLLECTION AND COLLATION

1) RESEARCH SAMPLES

This study is conducted using a questionnaire that consists of three mature subscales: the Organizational Resilience Scale, the Employee Loyalty Scale and the Organizational Context Scale. A questionnaire survey was administered to technology-based SMEs located in Hebei Province, China. From February 2021 through April 2021, 520 questionnaires were distributed via the Association of Small and Medium-Sized Science and Technology Enterprises of Hebei Province. After eliminating invalid questionnaires, 393 valid questionnaires were obtained, for an effective rate of 75.58%. The distribution of the sample is shown in Table 1.

TABLE 1. Sample distribution.

Project		Number of people	Percent (%)
Gender	Men	212	53.94
	Woman	181	46.06
Age	20-30 years old	191	48.60
	31-40 years old	152	38.68
	41-50 years old	42	10.69
	More than 51 years old	8	2.04
Level of education	Higher vocational college	88	22.39
	Bachelor's degree	243	61.83
	Postgraduate degree	58	14.76
	Doctoral students	4	1.01
Work seniority	Within 1 year	69	17.56
	1-3 years	64	16.28
	4-6 years	99	25.19
	7-10 years	83	21.12
	More than 10 years	78	19.85
Your department	R&D department	131	33.33
	Production	70	17.81
	Marketing	67	17.05
	Finance	45	11.45
	Ministry of personnel	48	12.21
	Logistic command	32	8.14
Your position	Clerk	182	46.31
	Director	55	13.99

TABLE 2. Measurement scale composition: Results of the reliability and validity analysis.

WSR Dimension	Construct	Dimension	Terms	Source
Physics	Organizational Resilience	Planning	5	Lee. et al (2013);Patriarca (2018); Wangyong (2019)
		Adaptability	4	McManus (2017); Umoh (2014);
		Recovery	4	Larissa. et al. (2017); Kantur (2015); Wangyong (2019)
Affair	Organizational Context	Organizational Learning OL	4	Shaw & Perkins (1991); Lloria & Moreno-Luzon (2015); Knight (2000)
		Organizational Glue, OG	5	Cameron (2011); Egan(2004)
		Project Goal Congruence, PGC	4	Denison & Mishra (2000)
Humanity	Employee Loyalty	Affective Organizational Loyalty, AOL	4	Allen & Meyer (1990); Clugston, Howell & Dorfman (2000); Meyer, Allen & Smith (1993); O'Reilly & Chatman (1986); Porter, Steers, Mowday (1982)
		Continuance Organizational Loyalty, COL	4	Allen & Meyer (1990); Clugston, Howell & Dorfman (2000); Meyer, Allen & Smith (1993)
		Normative Organizational Loyalty, NOL	4	Allen & Meyer (1990); Clugston, Howell & Dorfman (2000); Meyer, Allen & Smith (1993)

2) MEASUREMENT SCALE

The measurements used in this paper are scored on a 5-point Likert scale. According to the physical-affair-human factors included in the theoretical framework, the measurement scale is based on three aspects of organizational resilience and organizational context. The specific sources used for the scale and the number of terms are shown in Table 2.

3) RELIABILITY AND VALIDITY ANALYSIS

The reliability and validity of the scale were tested according to the collected data. The Cronbach's α coefficients of each subscale are greater than 0.7, indicating that each subscale exhibits high internal consistency.

Thus, the scale is generally credible. In addition, the Bartlett sphericity test was passed at the level of 0.001, and the Kaiser-Meyer-Olkin (KMO) values of other subscales were greater than 0.7, thus meeting the statistical requirements and indicating the subscales' suitability for factor analysis. The results of the reliability and validity tests for each subscale are shown in Table 3.

TABLE 3. Results of the reliability and validity analysis.

Scale name	KMO	Bartlett	α Coefficient
Organizational Resilience	0.745	0.000	0.901
Planning	0.855	0.000	0.836
Adaptability	0.825	0.000	0.807
Recovery	0.796	0.000	0.799
Organizational Context	0.747	0.000	0.911
OL	0.783	0.000	0.773
OG	0.846	0.000	0.836
PGC	0.778	0.000	0.785
Employee Loyalty	0.689	0.000	0.813
AOL	0.767	0.000	0.786
COL	0.719	0.000	0.742
NOL	0.785	0.000	0.810

4) CONFIRMATORY FACTOR ANALYSIS

Using confirmatory factor analysis, the degree of fit exhibited by a model can be analyzed. The results of the confirmatory factor analysis for each subscale are shown in Table 4. Each subscale passed the P1 < 0.001 test and exhibited a significant difference from the perfect model, P2 > 0.05. In addition, the fit indexes of each subscale are good.

C. CONSTRUCTION OF THE DFCM

To construct the relationship matrix among concept nodes in the DFCM, the original data of the questionnaire are fuzzified. The specific methods used are as follows:

For any numerical vector V, the v_i fuzzy values of other elements in any numerical vector V can be calculated using Formula (1), $\theta_i = 4$. [65].

$$\chi V(v_i) = \frac{v_i(t) - \text{mean}(v_i) + \theta_i \cdot \text{stdDev}(v_i)}{2\theta_i \cdot \text{stdDev}(v_i)} \quad (1)$$

By integrating the fuzzy evaluation value of each concept node into the questionnaire, assuming that the importance remains consistent, the mean value can be calculated. This group of mean values is used as the initial value C^0 of the state of the concept node in the DFCM. The initial value of the concept node state is shown in Table 5.

In this study, we adjust 'chord similarity' to determine the correlation between two concept nodes. To overcome the problem that chord similarity is not sensitive to absolute values, we subtract a mean value from all dimensions, calculate the chord distance between concept nodes according to

TABLE 4. Confirmatory factor analysis results for each subscale.

Scale name	Chi-Square	Df	Chi-Square/df	P1	P2	GFI	AGFI	CFI	RMSEA	RMR
Organizational Resilience	159.155	74	2.151	***	0.000	0.947	0.925	0.967	0.054	0.033
Planning	5.29	5	1.058	***	0.382	0.995	0.985	1.000	0.012	0.015
Adaptability	18.027	5	3.605	***	0.030	0.982	0.946	0.977	0.082	0.029
Recovery	0.787	2	0.394	***	0.675	0.999	0.995	1.000	0.000	0.007
Organizational Context	167.630	62	2.704	***	0.000	0.936	0.906	0.956	0.066	0.036
OL	0.863	2	0.431	***	0.650	0.999	0.995	1.000	0.000	0.007
OG	13.969	5	2.794	***	0.016	0.986	0.959	0.987	0.068	0.022
PGC	1.323	2	0.661	***	0.516	0.998	0.991	1.000	0.000	0.010
Employee Loyalty	177.660	51	3.484	**	0.000	0.930	0.893	0.931	0.080	0.070
AOL	9.909	2	4.954	***	0.007	0.988	0.941	0.982	0.100	0.023
COL	0.119	2	0.059	***	0.942	1.000	0.999	1.000	0.00	0.004
NOL	6.291	2	3.146	***	0.043	0.992	0.962	0.992	0.074	0.022

*P<0.05, **P<0.01, ***P<0.001.

TABLE 5. Initial values of the concept node status.

Concept node	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
Status value	0.308	0.281	0.297	0.257	0.297	0.298	0.268	0.346	0.365

TABLE 6. Similarity matrix.

Concept node	Value vector chord								
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	1.000	.745	.715	.466	.664	.622	.444	.324	.359
C_2	.745	1.000	.771	.692	.720	.680	.649	.220	.211
C_3	.715	.771	1.000	.584	.742	.697	.573	.297	.294
C_4	.466	.692	.584	1.000	.688	.630	.726	.045	-.010
C_5	.664	.720	.742	.688	1.000	.800	.667	.365	.438
C_6	.622	.680	.697	.630	.800	1.000	.670	.397	.417
C_7	.444	.649	.573	.726	.667	.670	1.000	.194	.212
C_8	.324	.220	.297	.045	.365	.397	.194	1.000	.727
C_9	.359	.211	.294	-.010	.438	.417	.212	.727	1.000

Formula (2), and judge the correlation.

$$\text{similarity} = \cos\theta = \frac{\sum_{\substack{i=1\\j=1}}^{n} V_{ij} \cdot V_{(i+1)j}}{\sqrt{\sum_{\substack{i=1\\j=1}}^{n} (V_{ij})^2 \times \sqrt{\sum_{\substack{i=1\\j=1}}^{n} (V_{(i+1)j})^2}}} \tag{2}$$

Here, we seek to eliminate the systematic error of the cosine similarity algorithm by using blurred data to conduct a correlation analysis. A correlation coefficient ≥ 0.60 between concept nodes indicates a correlation; otherwise, it is irrelevant.

By using SPSS 19.0 software to conduct chord distance correlation analysis, we obtain the relationship matrix for SMEs' organizational context, individual loyalty and organizational resilience, which is shown in Table 6.

Additionally, the hyperbolic tangent function is selected as the threshold function for the resilience improvement model of technology-based SMEs, as shown in Formula (3).

$$f(x) = \tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}} \tag{3}$$

TABLE 7. Concept node state value table.

Concept node	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
Initialization value	0.308	0.281	0.297	0.257	0.297	0.298	0.268	0.346	0.365
Steady state value	0.979	0.982	0.982	0.969	0.986	0.985	0.975	0.941	0.942

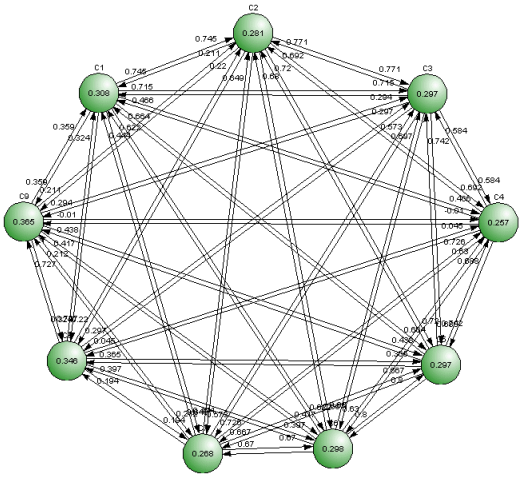

FIGURE 2. Construction of the DFCM model.

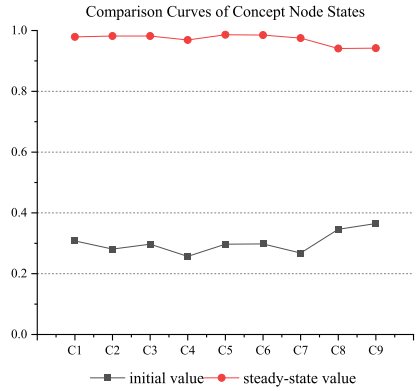

FIGURE 3. Curves of the initial and steady values.

When the initial state vector $C_i(t)$ of the concept node and the topological structure correlation matrix W_{ij} are clarified, the dynamic evolution of the model is mainly converted by using the transformation function f(x) to obtain the state vector

$C_i(t+1)$ of each concept node at time $t+1$ until the state result reaches the final stable state.

$$C_j(t+1) = f\left(C_j(t) + \sum_{i=1, i\neq j}^{n} W_{ij} \times C_i(t)\right) \quad (4)$$

Here, FCM Analyst 1.0 software is used to construct the FCM model, and the state curve and data value of the concept node of the model, which are iteratively updated over time, are the output. The DFCM is thus constructed, as shown in Figure 2.

IV. SIMULATION RESULTS AND TEST OF UNITS

A. STATE ANALYSIS

The initial value of the concept node is input into the FCM. After 10 iterations, the FCM reasoning model system reaches the equilibrium state, and each concept node obtains the steady-state value according to the equilibrium state. The state value of the concept node is shown in Table 7.

According to the data shown in Table 7, the initial value and steady-state value curves are obtained, as shown in Figure 3.

1) ORGANIZATIONAL RESILIENCE

The order of the initial value is planning ability C_1 > recovery ability C_3 > adaptability C_2, and the order of the steady-state value after iteration is adaptability C_2 = recovery ability C_3 > planning ability C_1.

2) ORGANIZATIONAL CONTEXT

The order of the initial value is $OLC_4 = PGCC_6 > OGC_5$, and the order of the steady-state value after pipe iteration is $OGC_5 > PGCC_6 > OL\ C_4$.

3) EMPLOYEE LOYALTY

The order of the initial value is $NOLC_9 > COLC_8 > AOLC_7$, and the order of the steady value after management iteration is $AOLC_7 > NOLC_9 >$ sustained loyalty C_8.

B. THE EVOLUTIONARY MECHANISM UNDERLYING ORGANIZATIONAL CONTEXT, EMPLOYEE LOYALTY AND ORGANIZATIONAL RESILIENCE

1) THE MECHANISM UNDERLYING THE INFLUENCE OF ORGANIZATIONAL CONTEXT ON ORGANIZATIONAL RESILIENCE

When the initial values of the concept nodes of OLC_4, OGC_5 and $PGCC_6$ are set to −1 (range), −0.5 (poor), 0.5 (good), and 1.0 (excellent), the initial values of other nodes are set to 0.

By simulating the causal reasoning and iterative operation operative between concept nodes, for example, P $(C_1/C_4 = -1.0) = -0.871$, P $(C_1/C_4 = -0.5) = -0.757$, P $(C_1/C_4 = 0.5) = 0.757$, and P $(C_1/C_4 = 1.0) = 0.871$. The initial values of the other concept nodes are set in a similar manner, and the mechanism underlying the influence of organizational context on organizational resilience is ultimately obtained, as shown in Table 8.

Table 8 shows that when the value of organizational context concept node C_4 is −1.0, −0.5, 0.5, and 1.0, the values of planning ability node C_1 in organizational resilience are −0.871, − 0.757, 0.757, and 0.871, respectively. When the value of C_4 gradually increases, the value of C_1 also gradually

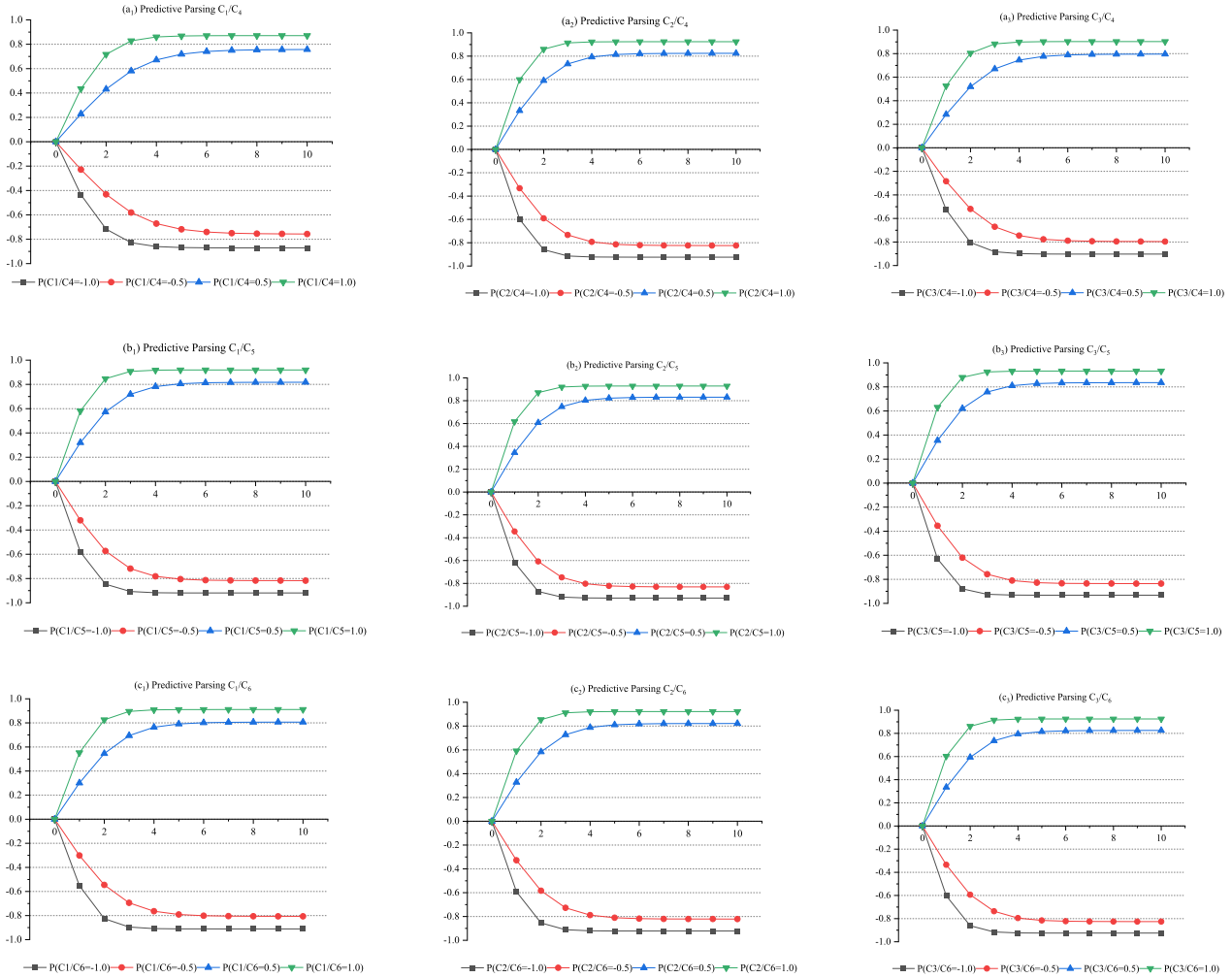

FIGURE 4. Influence mechanism of organizational context on organizational resilience.

TABLE 8. Influence mechanisms of organizational context on organizational resilience.

Concept node			P(C/i= -1.0)	P(C/i= -0.5)	P(C/i= 0.5)	P(C/i= 1.0)
Organizational context	C4	C1	-0.871	-0.757	0.757	0.871
		C2	-0.924	-0.824	0.824	0.924
		C3	-0.903	-0.796	0.796	0.903
	C5	C1	-0.919	-0.818	0.818	0.919
		C2	-0.929	-0.831	0.831	0.929
		C3	-0.932	-0.836	0.836	0.932
	C6	C1	-0.911	-0.807	0.807	0.911
		C2	-0.922	-0.822	0.822	0.922
		C3	-0.925	-0.826	0.826	0.925

increases, thus indicating that the two values change in the same direction, i.e., C_1 and C_4 exhibit a positive causal relationship. Meanwhile, regarding the data, the range of C_1 is [-1,1], indicating that for C_1, the stable values, ranging from poor to good degree of planning ability, are -0.871, -0.757, 0.871, 0.871, respectively. The change in the C_1 value from the initial state to the stable state is very obvious, indicating that the correlation is strong. The other nodes are similar.

Figure 4 illustrates the mechanism underlying the influence of the organizational context concept node on the organizational resilience concept node. The slope of each curve shown in the figure allows us to make a preliminary judgment regarding the degree of influence of the latent variable (organizational context) on organizational resilience. The larger the slope is, the stronger the correlation. Figure 4 shows that each curve enters a stable state at t = 4.

By comparing the slope of the curve across the four time periods 0-1, 1-2, 2-3, and 3-4, $P(C_1/C_5 = 1.0) > P(C_1/C_6 = 1.0) > P(C_1/C_4 = 1.0)$. The influence of organizational context on organizational resilience (planning ability C_1), ranging from large to small, is $OGC_5 > PGCC_6 > OLC_4$. By comparing the curves of P (C/i = a) (C = C1, C2, C3) (i = C4, C5, C6) (a = 0.5, −0.5, −1.0), the influence of organizational context on organizational resilience (adaptability C_2, recovery ability C_3) exhibits an order of $OGC_5 > OLC_4 > PGCC_6$.

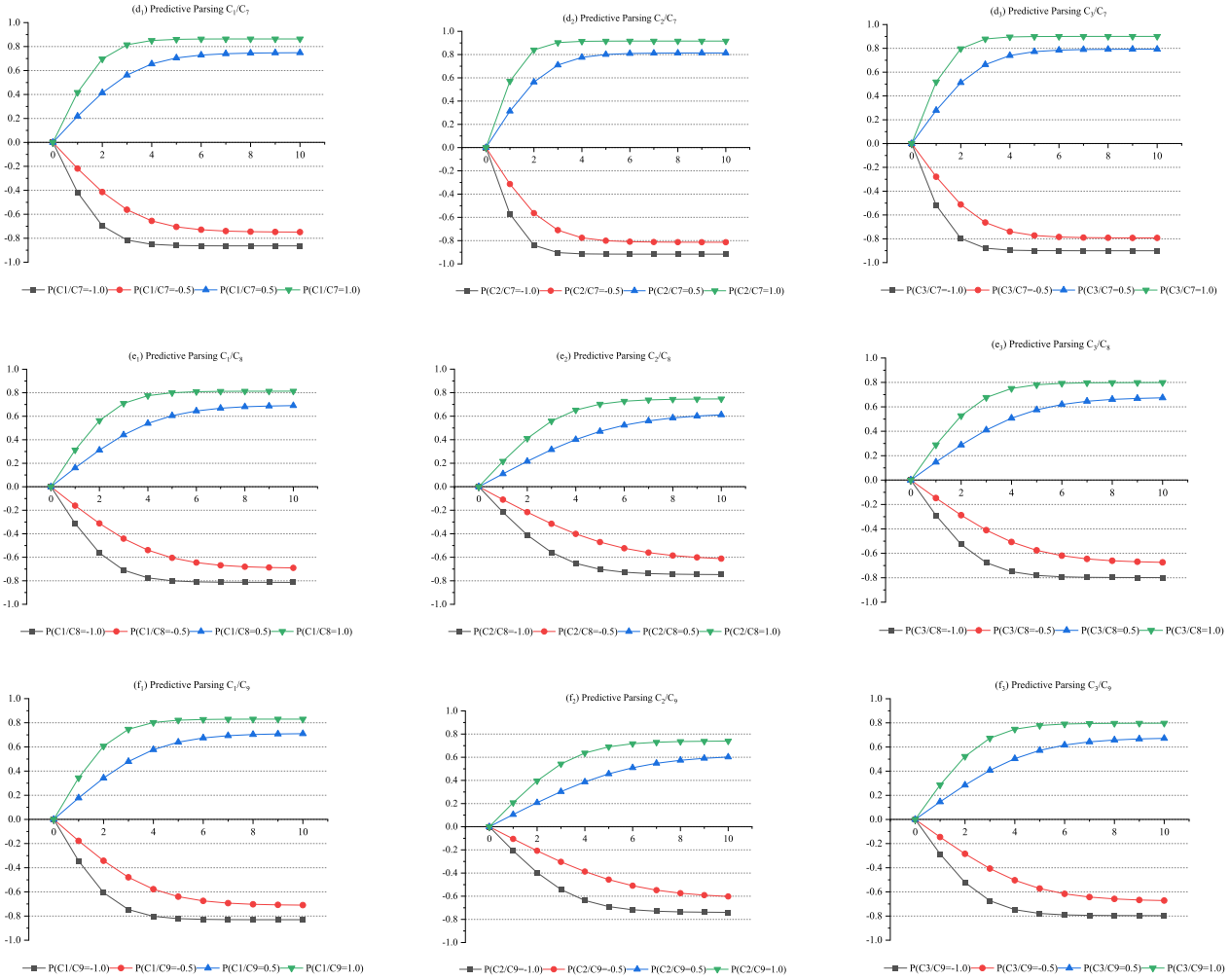

FIGURE 5. The influence mechanism of employee loyalty on organizational resilience.

Combining Table 8 with the P (C/i $= -1.0$) column, according to a comparison with the absolute value of the number in the table, $|$ P ($C_1/C_6 = -1.0$) $| > |$ P ($C_1/C_6 = -1.0 | > |$ P ($C_1/C_4 = -1.0 |$), thus indicating that when P (C/i $= -1.0$), the influence of organizational context latent variables on organizational resilience, from large to small, is as follows: $C_5 > C_6 > C_4$. The ranking of concept nodes in terms of absolute value can also be consistent with the slope judgment shown in Figure 4.

In summary, by analyzing the mechanism underlying the influence of organizational context on organizational resilience, the following conclusions can be obtained:

① There is a strong positive correlation between organizational context (OL $\mathbf{C_4}$, OG $\mathbf{C_5}$, PGC $\mathbf{C_6}$) and organizational resilience (planning ability $\mathbf{C_1}$, adaptive ability $\mathbf{C_2}$, recovery ability $\mathbf{C_3}$);

② The influence of organizational context on organizational resilience (planning ability $\mathbf{C_1}$) is ranked as follows: OG$\mathbf{C_5}$ > PGC$\mathbf{C_6}$ > OL$\mathbf{C_4}$; the influence of organizational context on organizational resilience (adaptability $\mathbf{C_2}$, recovery ability $\mathbf{C_3}$), ranked from largest to smallest, is as follows: OG$\mathbf{C_5}$ > OL$\mathbf{C_4}$ > PGC$\mathbf{C_6}$.

2) THE MECHANISM UNDERLYING THE INFLUENCE OF EMPLOYEE LOYALTY ON ORGANIZATIONAL RESILIENCE

Similarly, the mechanism underlying the impact of employee loyalty on organizational resilience can be obtained, as shown in Table 9 and Figure 5.

When the initial values of the AOL$\mathbf{C_7}$, COL$\mathbf{C_8}$ and NOL $\mathbf{C_9}$ concept nodes are set to the four state values of -1 (very poor), -0.5 (poor), 0.5 (better), and 1.0 (very good), the initial values of the other nodes are set to 0, P($\mathbf{C_1/C_7} = -1.0$) $= -0.864$, P($\mathbf{C_1/C_7} = -0.5$) $= -0.748$, P($\mathbf{C_1/C_7} = 0.5$) $= 0.748$, and P($\mathbf{C_1/C_7} = 1.0$) $= 0.864$ by simulating causal reasoning and iterative operations among the concept nodes. Similarly, the initial values listed above are set for each of the other concept nodes, and the final mechanism underlying the impact of employee loyalty on organizational resilience is thus obtained, as shown in Table 9.

Table 9 shows that when the employee loyalty concept node $\mathbf{C_7}$ takes the values -1.0, -0.5, 0.5, and 1.0, the values of planning capability node $\mathbf{C_1}$ in organizational resilience are -0.864, -0.748, 0.748, and 0.864, respectively. As the value of $\mathbf{C_7}$ gradually increases, the value of $\mathbf{C_1}$ also

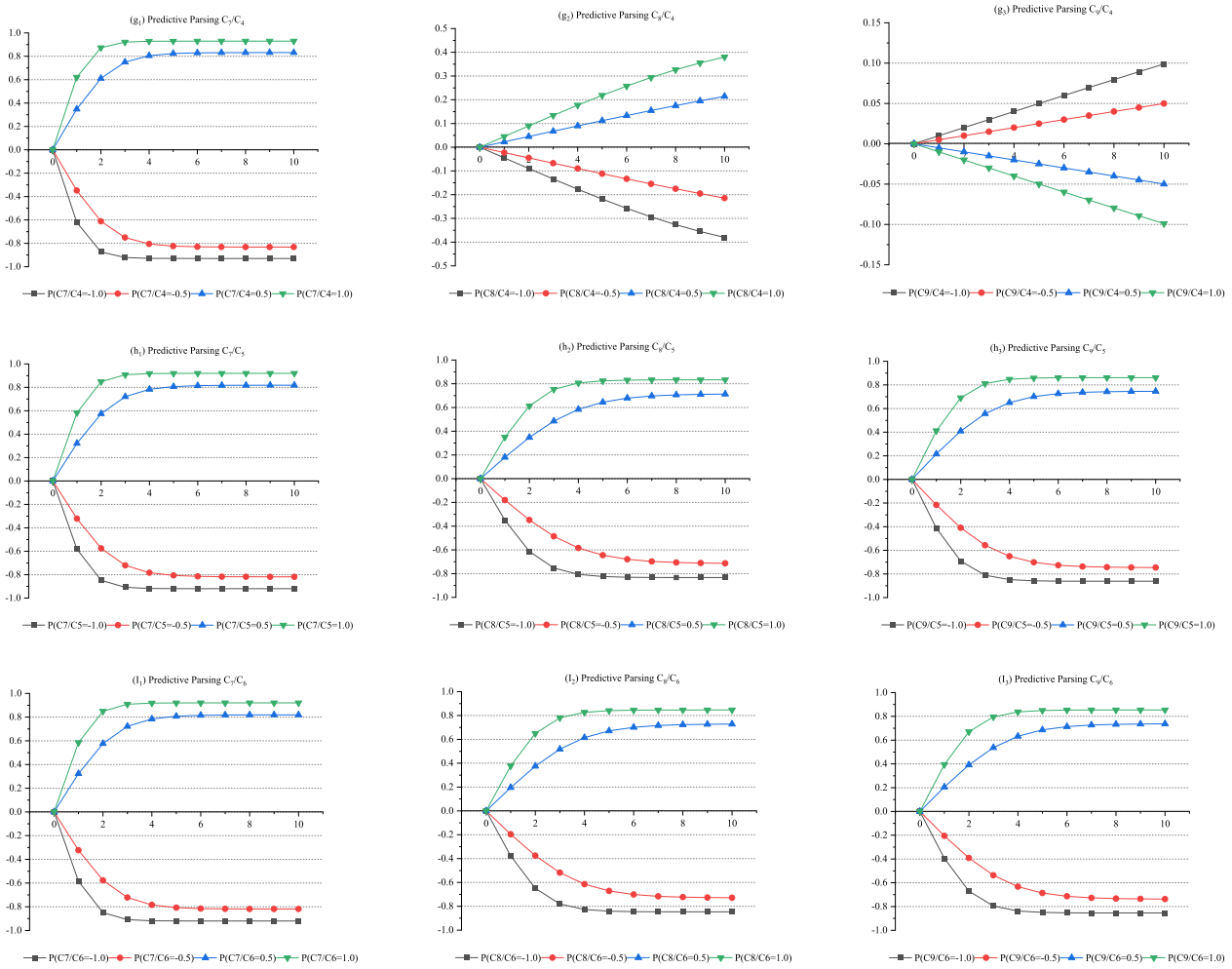

FIGURE 6. Influence mechanism of organizational context on employee loyalty.

gradually increases, thus indicating that the two values change in the same direction and that there is a positive causal relationship between $\mathbf{C_1}$ and $\mathbf{C_7}$. Meanwhile, regarding the values shown in the data, the value range of $\boldsymbol{C_1}$ is $[-1,1]$, thus highlighting the degree of $\boldsymbol{C_1}$, ranging from poor to good planning ability, in which context the stable values are -0.864, -0.748, 0.748, 0.864, respectively. Thus, the change in the $\boldsymbol{C_1}$ value from initial to stable is very obvious, thereby indicating the corresponding strong correlation. The same conclusion applies to the other nodes.

As shown in Figure 5, each curve enters a steady state at t = 4. Comparing the magnitudes of the slopes of the curves across the four time periods 0-1, 1-2, 2-3, and 3-4, P $(C_1/C_7 = 1.0) >$ P$(C_1/C_9 = 1.0) >$ P$(C_1/C_8 = 1.0)$. The impact of employee loyalty on organizational resilience (planning capability C_1), ranked from largest to smallest, is as follows: AOL C_7 > NOL C_9 > COL C_8.Comparing the curves of P(C/i = a)(C = C1,C2,C3)(i = C7,C8,C9) (a = 0.5, 0.5, 1.0) once again, the impact of employee loyalty on organizational resilience (Adaptability C_2, Recovery C_3), ranked from largest to smallest, is as follows: AOL C_7 > COL C_8 > NOL C_9.

TABLE 9. Influence mechanism of employee loyalty on organizational resilience.

Concept node			P(C/i= -1.0)	P(C/i= -0.5)	P(C/i= 0.5)	P(C/i= 1.0)
Employee Loyalty	C7	C1	-0.864	-0.748	0.748	0.864
		C2	-0.916	-0.814	0.814	0.916
		C3	-0.900	-0.793	0.793	0.900
	C8	C1	-0.814	-0.691	0.691	0.814
		C2	-0.747	-0.611	0.611	0.747
		C3	-0.799	-0.674	0.674	0.799
	C9	C1	-0.830	-0.710	0.710	0.830
		C2	-0.739	-0.602	0.602	0.739
		C3	-0.797	-0.672	0.672	0.797

By combining Table 9 with column P(C/i $= -1.0$) to compare the magnitude of the absolute values of the numbers shown in the table, we can obtain $|$P$(C_1/C_7 = -1.0)|>|$P$(C_1/C_9 = -1.0)|>|$P$(C_1/C_8 = -1.0)|$, thus indicating that when P(C/i = -1.0), the degree of influence of the latent variables of the organizational context on organizational resilience, ranked from largest to smallest, is as follows: C_7 > C_9 > C_8. The concept nodes also allow us to reach a conclusion similar to those obtained through the slope judgment illustrated in Figure 5.

TABLE 10. Influence mechanism of organizational resilience on employee loyalty.

Concept node			P(C/i= -1.0)	P(C/i= -0.5)	P(C/i= 0.5)	P(C/i= 1.0)
Organizational context	C4	C7	-0.930	-0.832	0.832	0.930
		C8	-0.380	-0.214	0.214	0.380
		C9	0.099	0.050	-0.050	0.099
	C5	C7	-0.920	-0.818	0.818	0.920
		C8	-0.833	-0.713	0.713	0.833
		C9	-0.862	-0.746	0.746	0.862
	C6	C7	-0.920	-0.819	0.819	0.920
		C8	-0.846	-0.728	0.728	0.846
		C9	-0.854	-0.737	0.737	0.854

In summary, based on an analysis of the mechanism underlying the influence of employee loyalty on organizational resilience, the following conclusions can be obtained:

① Employee loyalty (AOL C_7, COL C_8, and NOL C_9) has a strong positive correlation with organizational resilience (planning ability C_1, adaptability C_2, and recovery ability C_3);

② The impact of employee loyalty on organizational resilience (planning ability C_1) is ranked as follows: AOL C_7 > NOL C_9 > COL C_8; the impact of employee loyalty on organizational resilience (adaptability C_2 and recovery ability C_3) is ranked as follows: AOL C_7 > COL C_8 > NOL C_9.

3) THE MECHANISM UNDERLYING THE INFLUENCE OF ORGANIZATIONAL CONTEXT ON EMPLOYEE LOYALTY

Similarly, the mechanism underlying the influence of organizational context on employee resilience is obtained, as shown in Figure 6 in Table 10.

When the initial values of OL $\mathbf{C_4}$, OG $\mathbf{C_5}$ and PGC $\mathbf{C_6}$ concept nodes are set to the four state values of -1 (very poor), -0.5 (poor), 0.5 (better), and 1.0 (excellent), the initial values of the other nodes are set to 0. By simulating causal reasoning and iterative operations among concept nodes, P($\mathbf{C_7/C_4}$ = −1.0)= -0.930, P($\mathbf{C_7/C_4}$ = −0.5)= −0.832, P($\mathbf{C_7/C_4}$ = 0.5)= 0.832, and P($\mathbf{C_7/C_4}$ = 1.0)= 0.930. Accordingly, the mechanism underlying the influence of organizational context on employee resilience is obtained, as shown in Table 10.

Table 10 shows that when the organizational context concept nodes $\mathbf{C_4}$ take the values of −1.0, −0.5, 0.5, and 1.0, the values of AOL $\mathbf{C_7}$ in the context of employee loyalty are −0.930, −0.832, 0.832, and 0.930, and as the value of $\mathbf{C_4}$ gradually increases, the value of $\mathbf{C_7}$ also gradually increases. This finding indicates that these two values change in the same direction; thus, there is a positive causal relationship between $\mathbf{C_4}$ and $\mathbf{C_7}$. Meanwhile, regarding the data values, the value domain of $\mathbf{C_7}$ is [−1,1], thus indicating that the degree of AOL $\mathbf{C_7}$ ranges from poor to good. The stable values of −0.930, −0.832, 0.832, and 0.930 show that the value of $\mathbf{C_7}$ exhibits a very obvious change from the initial state to the stable state, thus indicating a strong correlation. However, although the concept nodes OL $\mathbf{C_4}$ and COL $\mathbf{C_8}$ are correlated, this correlation is not strong, and OL $\mathbf{C_4}$ and NOL $\mathbf{C_9}$ are not linearly correlated.

As Figure 6 illustrates, with the exceptions of plots g2 and g3, every curve enters a steady state at t = 4. Comparing the magnitudes of the slopes of the curves across the four time periods 0-1, 1-2, 2-3, and 3-4, P(C_7/C_4 = 1.0) > P(C_7/C_5 = 1.0) = P(C_7/C_6 = 1.0). The influence of organizational context on employee loyalty (AOL C_7) is ranked from largest to smallest as follows: OL C_4 > OG C_5 = PGC C_6. According to a further comparison of the curves of P(C/i = a)(C = C4,C5,C6)(i = C7,C8,C9) (a = 0.5, 0.5, 1.0), the organizational context has a large to small impact on employees' COL C_8, such that PGC C_6 > OG C_5.

The organizational context has a large to small impact on NOL C_9, such that OG C_5 > PGC C_6. In addition, plots g2 and g3 do not converge, thus indicating that concept nodes C_4 are weakly and not linearly correlated with concept nodes C_8 and C_9, respectively.

By combining the P(C/i = −1.0) column shown in Table 10 with a comparison of the magnitude of the absolute values of the numbers shown in the table, we obtain | P(C_7/C_4 = −1.0)|>|P(C_7/C_5 = −1.0|=|P(C_7/C_6 = −1.0|, thus indicating that when P(C/i = −1.0), the degree of influence of the latent variables of the organizational context on employee loyalty, ranked from largest to smallest, is as follows: C_4 > C_5 = C_6. From the concept nodes, we can obtain a conclusion similar to those obtained through the slope judgment illustrated in Figure 6.

Based on Table 10 and Figure 6, the mechanism underlying the influence of organizational context on employee loyalty is analyzed, and the following conclusions are obtained:

① Organizational context (OGC_5, $PGCC_6$) has a strong positive correlation with employee loyalty, OLC_4 has a strong positive correlation with $AOLC_7$, OLC_4 has a weak correlation with $COLC_8$, and there are no linear correlations with $NOLC_9$;

② The influence of organizational context on employee loyalty ($AOLC_7$) is as follows: OLC_4 > OGC_5 = $PGCC_6$. The influence of organizational context on employees' COL, ranging from large to small, is $PGCC_6$ > OGC_5, and the influence of organizational context on NOL, ranging from large to small, is OGC_5 > $PGCC_6$.

C. SENSITIVITY ANALYSIS

Sensitivity analysis seeks to identify sensitive factors that affect the target results as well as risk prevention measures. This paper analyzes the single-factor sensitivity of each concept node of organizational context and employee loyalty to organizational resilience. The simulation shows that when the initial value of the concept node is 0.5, organizational resilience is the strongest.

Therefore, assuming that C_4 = 0.5, C_5 = 0.5, C_6 = 0.5, C_7 = 0.5, C_8 = 0.5, and C_9 = 0.5 are the states when the percentage of change is 0, the value of each concept node of organizational resilience in the steady state can be obtained. Thus, the organizational context and employee loyalty concept nodes are changed by ±20% and ±40%, respectively, and the corresponding steady-state value of organizational

TABLE 11. Sensitivity analysis of planning ability.

Concept node		Percentage change (%)					
		-40	-20	0	20	40	Average change % (±)
Organizational context	C4	0.9957166941	0.9961001020	0.9964490067	0.9967665446	0.9970555618	0.0000167
	C5	0.9953611895	0.9959416033	0.9964490067	0.9968926750	0.9972806836	0.0000240
	C6	0.9954390025	0.9959757571	0.9964490067	0.9968663398	0.9972344214	0.0000224
Employee Loyalty	C7	0.9957544622	0.9961173241	0.9964490067	0.9967522163	0.9970294200	0.0000159
	C8	0.9959546485	0.9962099251	0.9964490067	0.9966729312	0.9968826688	0.0000116
	C9	0.9958972624	0.9961831483	0.9964490067	0.9966962549	0.9969262080	0.0000129

TABLE 12. Sensitivity analysis of adaptability.

Concept node		Percentage change (%)					
		-40	-20	0	20	40	Average change % (±)
Organizational Context	C4	0.9966975827	0.9971262666	0.9974990941	0.9978233940	0.9981055213	0.0000176
	C5	0.9966602005	0.9971100583	0.9974990941	0.9978355885	0.9981266805	0.0000183
	C6	0.9967134746	0.9971331850	0.9974990941	0.9978181467	0.9980963798	0.0000173
Employee Loyalty	C7	0.9967541739	0.9971509803	0.9974990941	0.9978045324	0.9980725591	0.0000165
	C8	0.9972680944	0.9973861549	0.9974990941	0.9976071358	0.9977104940	0.0000055
	C9	0.9972779518	0.9973908740	0.9974990941	0.9976028093	0.9977022084	0.0000053

TABLE 13. Sensitivity analysis of recovery.

Concept node		Percentage change (%)					
		-40	-20	0	20	40	Average change % (±)
Organizational context	C4	0.9967898541	0.9971452520	0.9974611533	0.9977419788	0.9979916480	0.0000150
	C5	0.9965793453	0.9970531949	0.9974611533	0.9978124478	0.9981149968	0.0000192
	C6	0.9966406751	0.9970797132	0.9974611533	0.9977926053	0.9980806607	0.0000180
Employee Loyalty	C7	0.9968040156	0.9971515525	0.9974611533	0.9977369888	0.9979827649	0.0000147
	C8	0.9971395122	0.9973051465	0.9974611533	0.9976080962	0.9977465056	0.0000076
	C9	0.9971429575	0.9973067695	0.9974611533	0.9976066555	0.9977437906	0.0000075

resilience is obtained by simulation. The resilience sensitivity analysis is shown in Tables 11, 12 and 13.

Table 11 shows that the sensitivity of planning ability C_1 to organizational context, ranging from strong to weak, is $OGC_5 > PGCC_6 > OLC_4$. The sensitivity of planning ability to employee loyalty, ranging from strong to weak, is $AOLC_7 > NOLC_9 > COLC_8$.

Table 12 shows that the sensitivity of adaptability C_2 to organizational context, ranging from strong to weak, is $OGC_5 > OLC_4 > PGC\ C_6$. The sensitivity of adaptability C_2 to employee loyalty, ranging from strong to weak, is $AOLC_7 > COLC_8 > NOLC_9$.

Table 13 shows that the sensitivity of recovery C_3 to the organizational context, ranging from strong to weak, is $OG\ C_5 > PGC\ C_6 > OL\ C_4$. The sensitivity of resilience to employee loyalty, ranging from strong to weak, is $AOL\ C_7 > COL\ C_8 > NOL\ C_9$.

The results of the sensitivity analysis and prediction analysis discussed above are consistent; however, the angles, processes and methods of those analyses differ. Accordingly,

for the DFCM, different methods of analysis are selected based on different perspectives, and the results are mutually verified to improve the reliability of the research results.

V. RESEARCH CONCLUSION

A. CONCLUSIONS AND DISCUSSION

In accordance with the WSR model, this paper utilizes a DFCM to analyze the relationships among organizational context, employee loyalty and organizational resilience and their underlying mechanisms and sensitivity factors in the context of technology-based SMEs. The conclusions are as follows:

Regarding organizational resilience, during the initial stage, planning ability is more important for technology-based SMEs.

Over time, their adaptability and their ability to avoid risks and recover from crises become more important. This change follows the developmental processes of technology-based SMEs in the context of dealing with risks and crises (before, during and after). Moreover, planning ability has a positive impact not only on the resilience of technology-based SMEs but also on the sustainable development of society and the economy. Maintaining business continuity in the context of an emergency [66] and continuing to grow under conditions of adversity are particularly important. Therefore, to improve the resilience of technology-based SMEs, we should focus on their early planning ability, their adaptability in emergencies, and their ability to recover and develop after a crisis.

Regarding organizational context, there is a strong positive correlation between organizational context and organizational resilience. PGC and OL ability are initially more important for technology-based SMEs, but OG subsequently becomes more important with regard to guaranteeing the organizational resilience of technology-based SMEs. OL enables SMEs to acquire knowledge continuously in dynamic and complex environments and promotes the dissemination and application of such knowledge [67], thereby helping SMEs cope with external changes by enhancing their organizational resilience [42]. Furthermore, if employees' goals are highly consistent with organizational goals, positive emotions and organizational trust serve as positive factors that shape organizational resilience [42]. During organizational development or in a crisis situation, organizational relations that are based on cohesive internal emotional intimacy and the coordination of organizational members' external behaviors are more important with respect to organizational resilience [68]. As the principal members of the global knowledge-based and technology-intensive economy, technology-based SMEs must first develop a learning organization. Accordingly, we should not only rely on continuous knowledge accumulation and new skill development to enhance the vitality of innovation but also establish a systematic and complete learning and training mechanism while constantly adjusting its training content to improve the overall learning ability of members of the organization. Second, employee goals should be consistent with organizational goals. When employees fully support their organization's objectives, they tend to exhibit a strong sense of responsibility during crises and to seek to overcome setbacks alongside their organizations, thus enhancing organizational resilience. Third, OG should be enhanced. Goal consistency can improve internal happiness and devotion within an organization by effectively stimulating the enthusiasm and passion of organization members and enterprises.

Regarding employee loyalty, there is a strong positive correlation between employee loyalty (AOL $\mathbf{C_7}$, COL $\mathbf{C_8}$, NOL $\mathbf{C_9}$) and organizational resilience (planning ability $\mathbf{C_1}$, adaptability $\mathbf{C_2}$, recovery $\mathbf{C_3}$). During the initial stage, employees' NOL to their SME plays a major role. Over time, employees' AOL to their SME becomes more important for maintaining organizational resilience. This change is mainly due to the fact that one's emotional life plays an important role in one's social life [27]. Positive employees help share and transmit positive emotions among organizational members, thus promoting organizational resilience [69].

The most important component of technology-based SMEs is the generation of highly educated employees who can make notable achievements and exhibit a developed consciousness of self-realization. Such knowledge workers should be given more work autonomy and encouraged to participate in organizational decision-making. Moreover, by meeting their self-achievement needs, an SME can help its employees sustain an organizational identity, stimulate their AOL, promote employees' spontaneous concern for organizational growth and prosperity, and thereby enhance organizational resilience.

Regarding organizational context and employee loyalty, organizational context (OG $\mathbf{C_5}$, PGC$\mathbf{C_6}$) has a strong positive correlation with employee loyalty. OL$\mathbf{C_4}$ has a strong positive correlation with AOL$\mathbf{C_7}$ but a weak correlation with COL$\mathbf{C_8}$ and no linear correlation with NOL$\mathbf{C_9}$. These findings are similar to those reported by Yuanyuan [70] and suggest that OL can promote employee AOL. However, our findings indicate that OL is not related to NOL. These mixed results may be due to our subjects; the flow rates of knowledge workers in technology-based SMEs are high, and it is difficult for OL to impact sustained loyalty and NOL in the short term. In general, however, technology-based SMEs should focus on the tasks of cultivating OG, PGC and learning organizations, thereby improving employee loyalty, especially AOL, and ultimately improving their organizational resilience.

B. RESEARCH LIMITATIONS AND PROSPECTS

This study enriches the literature on organizational resilience and highlights practical methods that can be used to promote the organizational resilience of technological SMEs. However, this study also faces certain limitations. First, it uses a single data source, and second, its sample data were obtained at a single time point and did not take into account differences over time. Hence, future research should expand the sample data, increase the number of regions and industries

included in the survey sample, and consider adding the temporal dimension to research organizational resilience and thus promote the dynamic adaptability of organizations.

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