

Exploring Key Factors of Ambidextrous Innovation in SMEs: A Hybrid Fuzzy DEMATEL-ISM-MICMAC Analysis from a Dynamic Capabilities Perspective

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Abstract: In the context of accelerating digital transformation and intensifying global market competition, ambidextrous innovation has become crucial for small and medium-sized enterprises (SMEs) seeking sustainable competitive advantages. Drawing on the dynamic capabilities theory, this study integrates the resource-based view and the knowledge-based view to systematically explore the influencing factors of SMEs' ambidextrous innovation from the three dimensions of sensing ability, capturing ability, and reconfiguring ability. Experts have been invited to conduct evaluations using fuzzy language, and the COWA-DEMATEL-ISM-MICMAC model was employed to analyze the relationships among the factors and identify the key ones. The results show that the core influencing factors are government subsidies, knowledge sharing, corporate social responsibility, entrepreneurial spirit, and entrepreneurial orientation. Among them, the entrepreneurial spirit and entrepreneurial orientation, as underlying factors, profoundly influence ambidextrous innovation, while government subsidies and knowledge sharing act as bridges in the hierarchical structure.

Keywords: Ambidextrous Innovation; SMEs; DEMATEL-ISM-MICMAC; Fuzzy linguistic term.

1. Introduction

In today's dynamic and competitive global business environment, enterprises must develop both exploratory and exploitative innovations to achieve sustainable competitive advantages (Benner & Tushman, 2003; Nie et al., 2022). Competitive advantage is achieved through superior resources and capabilities that enable enterprises to outperform competitors and maintain this edge (Manning et al., 2020). By the end of 2023, SMEs in China accounted for about 79.4% of employment, making them crucial for job stability and livelihood improvement. Despite significant progress in innovation, Chinese enterprises still occupy a low position in the global value chain, with their traditional cost advantages weakening (Luo et al., 2022).

Innovation, particularly exploratory innovation, requires costly and time-consuming experimentation and commercialization (Adams et al., 2006). In contrast, exploitative innovation focuses on optimizing existing products and services to meet current market demands. The resource-based view and resource orchestration theory emphasize that effective resource utilization is key to innovation and growth. However, SMEs face limitations in resources, making it difficult to balance exploratory and exploitative innovation. The "better to buy than to make" concept has also reduced their motivation to explore cutting-edge technologies.

Existing studies on ambidextrous innovation predominantly examine the synergy between exploratory and exploitative innovation (He & Wong, 2004; Li et al., 2023), yet lack an in-depth exploration of its internal mechanisms. Integrating Resource-Based View (RBV), Knowledge-Based View (KBV), and Dynamic Capability Theory (DCT), this study proposes that ambidextrous innovation emerges through three dynamic capabilities: sensing, transformation, and reconfiguration. While RBV emphasizes technological, human, and organizational resources as foundational

elements (Barney, 1991), KBV highlights knowledge management's critical role in balancing exploration and exploitation (O'Reilly & Tushman, 2008). DCT further bridges these perspectives by demonstrating how organizations dynamically integrate resources and knowledge to adapt to environmental uncertainties (Teece et al., 1997).

Based on this, this paper proposes the following research questions.

- (1) What factors influence SMEs' ambidextrous innovation?
- (2) How do these influencing factors relate to one another? Which ones are the key ones?
- (3) Based on the key influencing factors, how can SMEs boost ambidextrous innovation?

This study used the Scopus database to search for relevant literature on ambidextrous innovation and conducted an in-depth analysis using the comprehensive bibliometric analysis method. The research evaluated academic journals from 2007 to 2024 to identify trends, obstacles, and patterns in ambidextrous innovation implementation. The COWA-DEMATEL-ISM-MICMAC method was applied to examine the hierarchical relationships among influencing factors. The COWA operator ensured scientific rationality in information fusion, DEMATEL identified mutual influence relationships, ISM constructed a hierarchical model, and MICMAC classified factors based on driving and dependence characteristics.

This study systematically explores the influencing factors of SMEs' ambidextrous innovation based on the dynamic capability theory framework. It innovatively applies the COWA-DEMATEL-ISM-MICMAC method, combines quantitative and qualitative approaches, and provides practical suggestions for SMEs to improve innovation performance and market competitiveness.

2. Literature Review

In the field of organizational management, ambidextrous innovation has become a key research topic. March (1991)

first proposed the concepts of exploitation and exploration in the context of organizational learning, theoretically differentiating the two: exploration focuses on exploring new knowledge, technologies and methods, while exploitation is dedicated to optimizing and advancing existing knowledge, technologies and capabilities. (March, 1991). Building on this theory, Tushman and O'Reilly (1996) further expanded the notion of ambidextrous organizations, arguing that enterprises in market competition need to balance incremental optimization of existing businesses with radical innovative transformation, and only by combining sensitive market insight with decisive decision-making can they achieve innovation breakthroughs and seize market opportunities. Their subsequent empirical research on 35 typical innovation projects also verified that ambidextrous organizations have obvious advantages in innovation performance. (O'Reilly & Tushman, 2004; Tushman & O'Reilly, 1996).

Existing research mainly considers the influencing factors of ambidextrous innovation from both internal and external aspects of the enterprise. Kortman (Kortmann, 2015) used two executive-level data sets from the United States and India based on previous literature to confirm how the decision-making of the senior management team cultivates ambidextrous innovation behavior and proposed that strategic orientation is crucial for realizing ambidextrous innovation behavior. The study conducted by Yang (Yang & Xiao, 2024) shows digitalization more significantly boosts radical innovation in listed SMEs. There's a complementary effect between enterprise digitalization and employees with a master's degree or higher in promoting it, and the financial background of top-management team members strengthens this effect. Xie (Xie et al., 2019) studied the impact of inter-organizational relationships on ambidextrous innovation and found that the relationships between partners have a positive impact on ambidextrous innovation.

3. Indicator Construction and Data Collection

When exploring the ambidextrous innovation capabilities of SMEs, based on the framework of the Dynamic Capability Theory, we have identified sensing ability, capturing ability, and reconfiguration ability as the key capabilities (Table 1).

In addition, combined with the Resource-Based View and the Knowledge-Based View, when selecting secondary indicators, we have particularly emphasized the necessity of resources and the fundamentality of knowledge for innovation.

3.1. Sensing Ability

The factors in the aspect of sensing ability focus on how to identify and understand the changes in the external environment. Through multi-channel collection and analysis of information, a comprehensive environmental cognitive basis for the enterprise's ambidextrous innovation is constructed. The following secondary indicators are selected for this dimension: enterprise digitalization, highly educated staff, entrepreneurial orientation, innovative organizational culture, informal networks, and entrepreneurial spirit.

3.2. Capturing Ability

The capture ability is dedicated to the efficient integration and internalization of the abundant information obtained through perception. Based on the enterprise's resource status, core capabilities, and strategic planning, a practical action plan is formulated. Enterprises need to have a rapid information-processing mechanism, a flexible decision-making process, and cross-departmental collaborative integration capabilities, which can transform changes in the external environment into specific strategies to promote the innovative development of the enterprise. The following secondary indicators are selected for this dimension: supplier interaction, knowledge sharing, organizational learning, and TMT behavioral integration.

3.3. Reconfiguration Ability

The reconfiguration ability mainly involves adaptive changes and optimization and upgrading of key elements such as organizational structure, business process, resource allocation mode, and corporate culture in a dynamic environment, ensuring that the enterprise always maintains its dominant position in the long-term competitive landscape. The following secondary indicators are selected for this dimension: organizational resilience, corporate social responsibility, government subsidies, flexible organizational structure, and innovation ecosystem.

Table 1. Evaluation Index System for Ambidextrous Innovation Capability

Criteria	Sub-criteria	Code	Reference(s)
Sensing ability	Enterprise digitization	ED	(Wang & Yan, 2024; Zhang et al., 2024)
	Highly educated staff	HES	(Escribá-Esteve et al., 2009; Yang & Xiao, 2024)
	Entrepreneurial spirit	ES	(Chen et al., 2024; Liu, 2019)
	Innovative organizational culture	IOC	(AlSaied & McLaughlin, 2024; AlSaiedAlSaied & AlkhoraiifAlkhoraiif, 2024)
	Informal network	IN	(DIETSCH & KHEMIRI, 2018; Forero-Pineda et al., 2010)
	Entrepreneurial orientation	EO	(Ge & Li, 2023; Tobias et al., 2017)
Capturing ability	Supplier interaction	SI	(Håkansson & Waluszewski, 2013; Leischnig et al., 2014)
	Knowledge sharing	KS	(Berraies et al., 2020; Singh et al., 2021)
	Organizational learning	OL	(AlSaiedAlSaied & AlkhoraiifAlkhoraiif, 2024; Wei et al., 2011)
	TMT behavioral integration	BI	(Luo et al., 2016; Wasike & Joseph, 2020)
reconfiguration ability	Organizational resilience	OR	(Garrido-Moreno et al., 2024)
	Corporate social responsibility	CSR	(Ji et al., 2019; Zahid et al., 2024)
	Government subsidies	GS	(Guo et al., 2022; Wenxin & Yongjun, 2023)
	Flexible organizational structure	FOS	(He & Wong, 2004; O'Reilly & Tushman, 2013)
	Innovation ecosystem	IE	(Zhao, 2020)

4. Research Method

This paper initially identified the relevant factors that affect the ambidextrous innovation of SMEs. Subsequently, experts

from enterprises, academic institutions, and government departments were invited to use the Delphi method to finally confirm these factors. The Fig. 1 describes the steps taken to develop the DEMATEL-ISM-MICMAC model in this work.

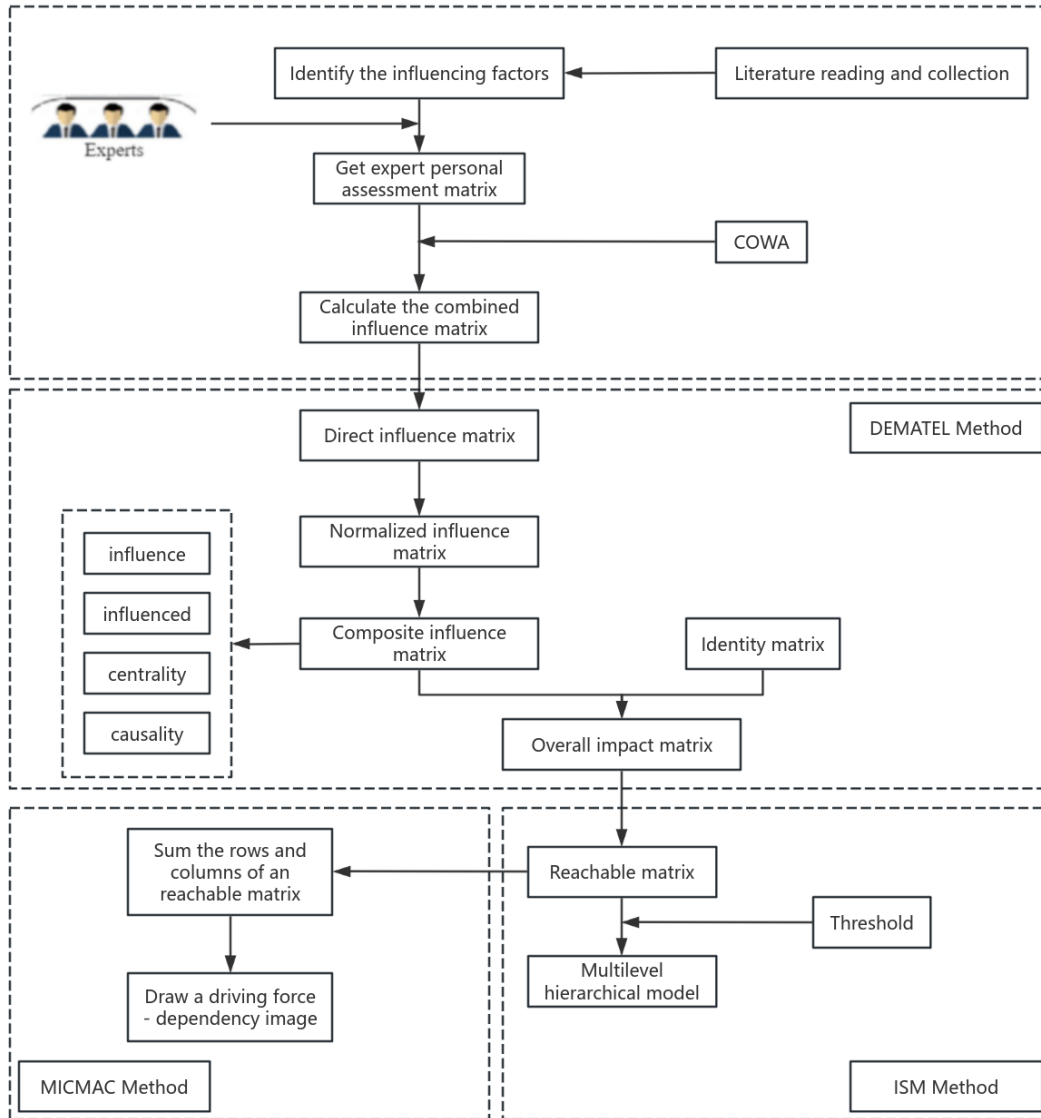


Figure 1. COWA-DEMATEL-ISM-MICMAC model steps

4.1. FLTS-COWA

FLTS is widely used in multi-attribute decision-making and is especially suitable for handling complex and uncertain issues. In practical applications, due to the complexity of the environment and the differences in evaluators' experience and knowledge, traditional precise language often cannot accurately express evaluators' viewpoints and judgments. Fuzzy linguistic terms can reflect people's way of thinking more flexibly and help handle the fuzziness and ambiguity in information expression more appropriately. We adopt the Center Ordered Weighted Averaging Operator (COWA) to solve the quantification problem of fuzzy linguistic expressions. COWA makes use of the fuzzy linguistic information provided by evaluators, comprehensively considers the relative importance of different evaluations, and aggregates the fuzzy scores of individual evaluators into a comprehensive and accurate evaluation value (Table 2).

Definition 1 Let $F : R^n \rightarrow R$, then a COWA operator is defined as follows:

$$F(\partial_1, \partial_2, \dots, \partial_n) = \sum_{j=1}^n v_j \beta_j \quad (1)$$

Where β_j is the j th largest element in $\partial_l (l = 1, 2, \dots, n)$, $v = (v_1, v_2, \dots, v_n)^T$ is an associated weighting vector of the operator with $v_j > 0 (j = 1, 2, \dots, n), \sum_{j=1}^n v_j = 1$ and satisfies the following two properties:

- (1) Symmetric: $v_j = v_{n-j+1}$
- (2) Strongly decaying: if $i > j \geq (n+1)/2$, then $v_i < v_j$; and if $i < j \leq (n+1)/2$, then $v_i < v_j$

When calculating the weights, this paper adopts the method of defining weights through the centering function studied by Yager.

Definition 2: The centering function $\varphi: [0, 1] \rightarrow R$ satisfies

the following three properties:

- (1) $\varphi > 0$
- (2) φ is symmetric about 0.5
- (3) g is unimodal

Definition 3: Let φ be a centering function. The centering OWA weight vector $\nu = (\nu_1, \nu_2, \dots, \nu_n)^T$ is defined as follows:

$$\nu_j = f\left(\frac{j}{n}\right) - f\left(\frac{j-1}{n}\right) = K \int_{\frac{j-1}{n}}^{\frac{j}{n}} \varphi(y) dy \quad (2)$$

Where $K = 1 / \int_0^1 \varphi(y) dy$.

Table 2. Element weights

	Element 1	Element 2	Element 3	Element 4	Element 5
Weight	2/25	6/25	9/25	6/25	2/25

4.2. Fuzzy linguistic DEMATEL

DEMATEL is a system analysis technique that uses graph theory and matrix tools to identify and quantify the causal relationships and mutual influences among various elements in a complex system.

Step 1: Through experts' assessment of the direct influence degree among various elements, an individual evaluation influence matrix $X^k = (x_{ij}^k)_{n \times n}$ is obtained. Experts choose from S0 to S4 according to the relationships among the elements. x_{ij} represents the degree of influence that factor i has on factor j as perceived by the k -th expert ($k \in \{1, 2, \dots, l\}$).

Step 2: Collect the scoring results of the experts and use the COWA operator to aggregate the information. Combine the individual evaluation matrices into a comprehensive final influence matrix A through the weight set.

Step 3: Normalize the direct influence matrix by dividing each element by the maximum value of its row to form a normalized matrix D .

$$D = A / b, A = (a_{ij})_{n \times n}, b = \max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij} \quad (3)$$

Step 4: Calculate the comprehensive influence matrix T .

$$T = D \times (I - D)^{-1} \quad (4)$$

Where I is the identity matrix

Step 5: Calculate the degree of influence and the degree of being influenced of the factors. D is the degree of influence, which is the sum of each row of matrix T ; C is the degree of being influenced, which is the sum of each column of matrix T .

$$D_i = \sum_{j=1}^n T_{ij}, C_j = \sum_{i=1}^n T_{ij}, i = 1, 2, \dots, n \quad (5)$$

4.3. ISM

ISM is a structural model method used to analyze complex

systems. By establishing an adjacency matrix and a reachability matrix, it divides levels and draws a hierarchical structure among factors to reveal the logical relationships among the elements within the system.

Step 1: Based on the comprehensive influence matrix T of DEMATEL, the overall influence matrix H is obtained.

$$H = T + I \quad (6)$$

Where I is the identity matrix.

Step 2: The average value of all items in the overall influence matrix H is calculated through tools and is set as λ .

Step 3: Compare the values of the overall influence matrix H with λ to obtain the reachability matrix M .

$$M_{ij} = \begin{cases} 0 & \text{if } H_{ij} < \lambda \\ 1 & \text{if } H_{ij} > \lambda \end{cases} \quad (7)$$

Step 4: Carry out hierarchical decomposition through the reachability matrix to determine the multi-level hierarchical structure of the system. Calculate the reachability set $P(s_i)$ and the antecedent set $Q(s_i)$ of each element, as well as their intersection $C(s_i)$. Identify the top-level elements according to the intersection $C(s_i)$. Remove the top-level elements from the reachability matrix and repeat the above process until all elements have been assigned to the corresponding levels.

4.4. MICMAC

The basic principle of the MICMAC method is based on matrix multiplication. By calculating each factor's driving and dependence forces within the system, these factors are categorized into four quadrants: autonomous factors, dependent factors, linkage factors, and independent factors. This method can help identify the critical variables in the system and reveal the inter-relationships and influence paths among these variables.

Step 1: Calculate each factor's force and dependence. Sum up each row of the matrix to obtain the driving force, and sum up each column to obtain the dependence.

Step 2: Calculate the average values of the driving force and dependence of all factors, which will be used as the dividing lines to classify the factors into autonomous factors, dependent factors, linkage factors, and independent factors.

Step 3: Classify the factors according to their dependence values and driving forces.

5. Analysis Results

5.1. FLTS-COWA Result Analysis

5 experts were invited to give their evaluation matrices. The ranking weights from the first to the fifth (Table 3) were calculated using the COWA operator and then integrated into a collective evaluation matrix (Table 4). Subsequently, according to the assignment of language, the fuzzy language was transformed into precise language.

Table 3. Linguistic term set assignments

S0: very low impact	S1: low impact	S2: media impact	S3: high impact	S4: very high impact
0	1	2	3	4

Table 4. Collective evaluation matrix

Factors	ED	BI	ES	HES	GS	SI	FOS	OL	IE	OR	CSR	IOC	EO	IN	KS
ED	S0	S4	S0	S1	S3	S2	S1	S4	S1	S1	S4	S1	S0	S2	S3
BI	S0	S0	S0	S1	S3	S2	S1	S1	S1	S1	S1	S0	S0	S2	S3
ES	S4	S3	S0	S4	S2	S1	S4	S3	S1	S1	S3	S4	S1	S1	S2
HES	S1	S4	S0	S0	S2	S1	S1	S4	S1	S1	S4	S1	S0	S1	S2
GS	S0	S0	S0	S0	S0	S3	S0	S3	S3	S3	S3	S0	S1	S3	S1
SI	S0	S0	S0	S0	S0	S0	S0	S0	S4	S4	S0	S0	S0	S2	S0
FOS	S1	S3	S0	S1	S2	S1	S0	S3	S1	S1	S3	S1	S0	S1	S2
OL	S0	S1	S1	S0	S3	S2	S0	S0	S2	S2	S1	S0	S1	S2	S3
IE	S0	S0	S0	S0	S0	S0	S0	S0	S0	S4	S0	S0	S0	S0	S0
OR	S0	S0	S0	S0	S0	S0	S0	S0	S4	S0	S0	S0	S0	S0	S0
CSR	S0	S1	S0	S0	S3	S3	S0	S1	S2	S2	S0	S0	S0	S3	S3
IOC	S1	S4	S0	S1	S3	S2	S1	S4	S1	S1	S4	S0	S0	S2	S3
EO	S4	S3	S1	S4	S2	S1	S4	S3	S1	S1	S3	S4	S0	S1	S2
IN	S0	S0	S0	S0	S0	S2	S0	S0	S4	S4	S0	S0	S0	S0	S0
KS	S0	S0	S1	S0	S1	S3	S0	S0	S2	S3	S0	S0	S1	S3	S0

5.2. DEMATEL Result Analysis

The fuzzy evaluation matrix is converted into a precise matrix according to the language assignment. In this paper, the normalized matrix is calculated based on the maximum row sum: the numbers in the direct influence matrix are divided by the maximum row sum. Then, the influence value, the influenced value, the centrality, and the cause degree are calculated in turn. It can be seen from the table that BI, GS, SI, OL, IE, OR, CSR, IN, and KS are the result factors, while ED, ES, HES, FOS, IOC, and EO are the cause factors.

In the Fig. 2 that influences the ambidextrous innovation of SMEs, the causal factors can be seen intuitively. The higher the centrality away from the center, the higher the importance (Table 5).

Table 5. Centrality and causality ranking

Factors	Influence	Influenced	Centrality	Causality
ED	1.42	0.42	1.84	1.00
BI	0.79	1.00	1.79	-0.21
ES	2.05	0.17	2.22	1.88
HES	1.23	0.48	1.71	0.76
GS	0.92	1.22	2.14	-0.29
SI	0.35	1.32	1.67	-0.96
FOS	1.07	0.48	1.55	0.60
OL	0.91	1.19	2.10	-0.28
IE	0.14	1.80	1.94	-1.67
OR	0.14	1.86	2.00	-1.72
CSR	0.81	1.19	2.01	-0.38
IOC	1.42	0.42	1.84	1.00
EO	2.05	0.23	2.28	1.82
IN	0.35	1.32	1.67	-0.96
KS	0.65	1.22	1.87	-0.56

Centrality and Causality

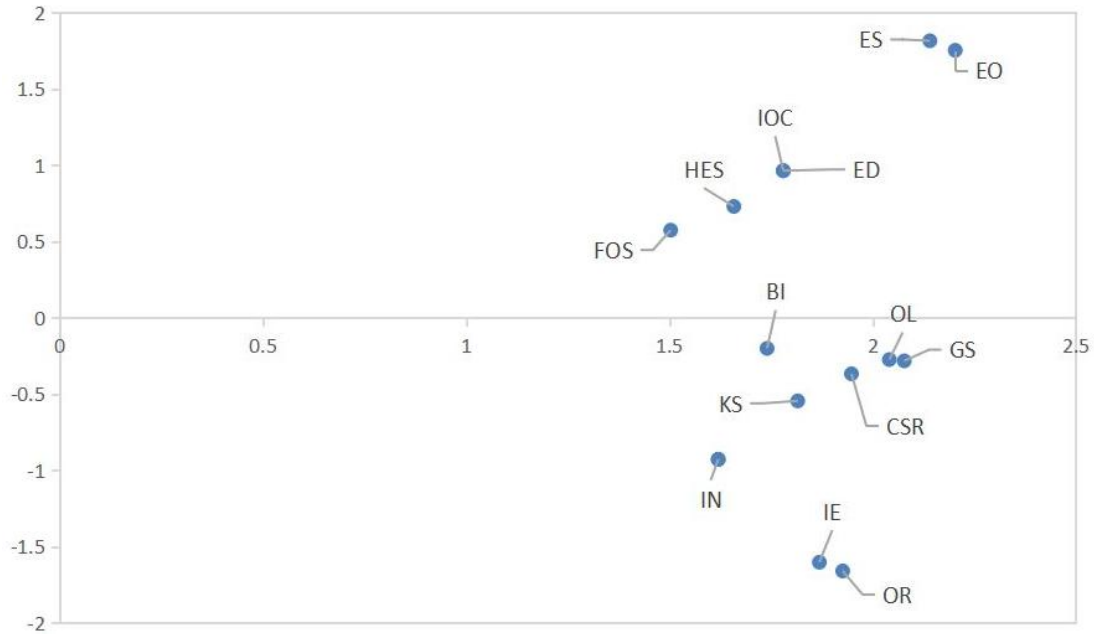


Figure 2. Centrality and Causality

5.3. ISM Result Analysis

We obtained the reachability matrix by using the comprehensive influence matrix and then carried out hierarchical processing. It can be seen from Figure 3 that entrepreneurial spirit and entrepreneurial orientation are located at the bottom layer of the structure and are the

cornerstones for SMEs to conduct ambidextrous innovation. Organizational resilience, innovation ecosystem, supplier interaction, and informal network are the top-level elements. According to our observation, government subsidies and knowledge sharing are the most crucial as they connect the low-level factors and high-level factors in the hierarchical structure.

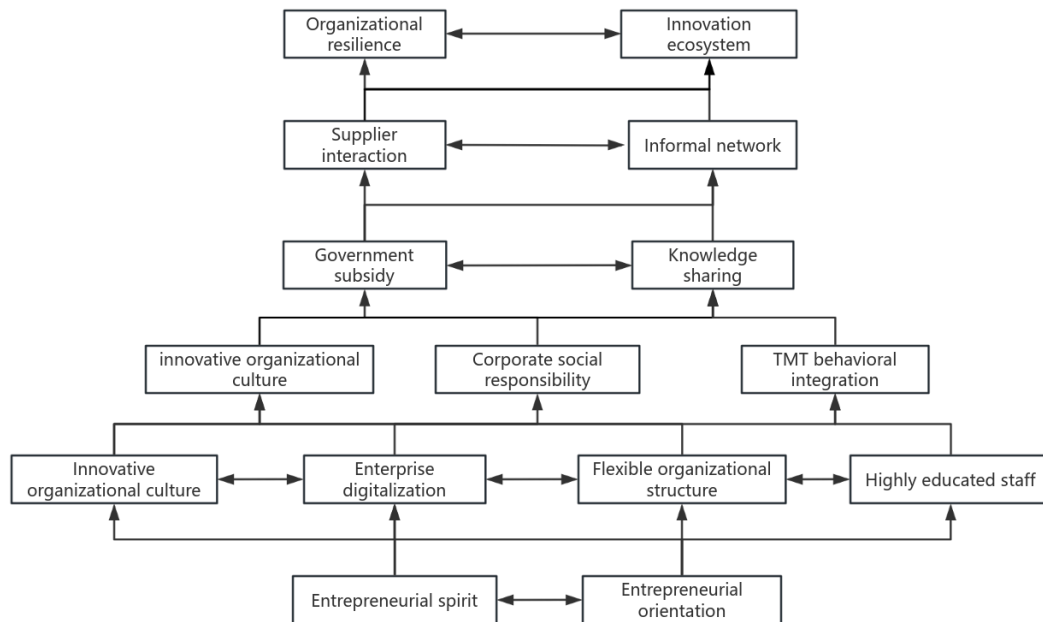


Figure 3. Hierarchical structure model of influencing factors

5.4. MICMAC Result Analysis

Calculate the row sum of the reachability matrix as the driving force and the column sum as the dependence. Use the

average value of the row sum and the average value of the column sum as the dividing lines to form four quadrants. (Figure 4)

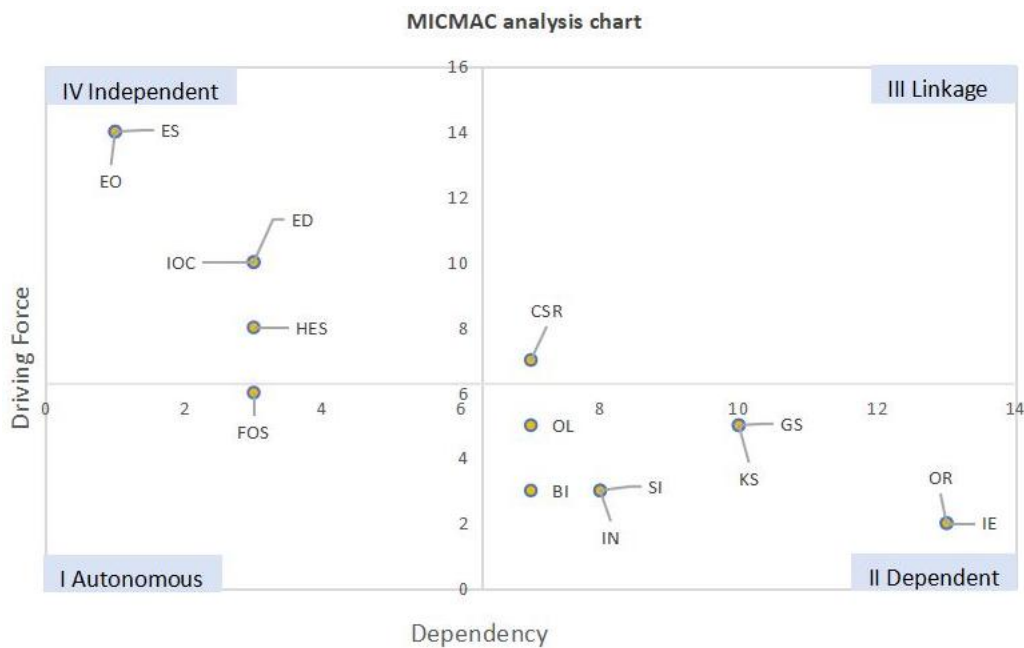


Figure 4. MICMAC analysis

6. Discussion

In response to the three core questions raised in the introduction, this study identified the influencing factors of ambidextrous innovation in small and medium-sized enterprises (SMEs) through extensive literature review and expert evaluation, sorted out the relationships and hierarchical structure of these factors using the DEMATEL-ISM-MICMAC method, and put forward targeted suggestions based on data analysis, successfully achieving the research objectives.

Corporate social responsibility (CSR) is an important associated factor of ambidextrous innovation, and its fluctuations will affect the functional state of other factors. The traditional view holds that fulfilling social responsibility will increase enterprise costs, damage the rights and interests of stakeholders, and even be questioned as "grandstanding"; however, more studies have shown that as a strategic pillar for the long-term development of enterprises, it can help enterprises obtain government subsidies and improve innovation quality. Moreover, the digital transformation of enterprises can strengthen its positive impact on ambidextrous innovation by alleviating financing constraints and optimizing internal control.

Entrepreneurial spirit and entrepreneurial orientation are the core underlying factors of the ambidextrous innovation system, both of which have high centrality, strong driving force and weak dependence. Among them, entrepreneurial spirit, as an individual trait, focuses on leading enterprise vitality and knowledge transfer, and has a more significant role in promoting exploratory innovation; entrepreneurial orientation, as an organizational strategy, emphasizes innovation, risk-taking and proactivity, and provides support for ambidextrous innovation by optimizing organizational structure and promoting knowledge sharing. The two factors exert radiating impacts on enterprise innovation operations from the individual and organizational levels respectively.

Both government subsidies and knowledge sharing are in the key bridge position connecting low-level and high-level factors, with prominent importance. Government subsidies can provide financial support and policy incentives for

ambidextrous innovation, alleviate the capital and information dilemmas of suppliers, and lay a foundation for underlying innovation activities. Although there are problems such as excessive dependence on subsidies and false acquisition by enterprises.

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