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Configuration effects of enterprise digitization and innovation capability of strategic emerging industries

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The development of strategic emerging industries is a necessary condition to achieve industrial transformation and upgrading. And industrial digitalization has given strategic emerging industries a new opportunity to accelerate their development. The aim is to explore the configuration effects of digital transformation and innovation capabilities in strategic emerging industries. This paper using the fuzzy-set qualitative comparative analysis. Seven representative condition variables are selected for configuration analysis from three dimensions: digital transformation awareness, digital transformation capability and digital transformation achievement to conduct configuration analysis. The results show that: (1) There are three configurations to improve the innovation capability of strategic emerging industries, which are digital awareness leads, digital capability facilitation and digital innovation breaks through substitution. (2) The configuration effect of digital transformation on innovation capability of strategic emerging industries in different regions of China is different. To enhance the innovation ability of strategic emerging industries, we should attach importance to the core role of digital innovation awareness.

Keywords Enterprise digital transformation, Strategic emerging industries, Innovation ability, Digital technology, Fuzzy-set qualitative comparative analysis

It is very important to develop and expand investment in strategic emerging industries. From the perspective of industrial evolution, technology and knowledge-intensive strategic emerging industries are one of the important directions for the transformation and upgrading of traditional industries[1]. Strategic emerging industries are important strategic choices for China's long-term economic development and play an important role in supporting the current economic and social development. Survey data from the State Information Center showed that in the first two quarters of 2021, the industry climate indices of strategic emerging industries stood at 153.7 and 149.3 respectively. The index remained at the highest level in the past three years for two consecutive quarters. In addition, The Purchasing Managers' Index of China's Strategic Emerging Industries, which also reflects the prosperity of strategic emerging industries, also showed a high level. Among them, the Emerging Industries Purchasing Manager's Index (EPMI) in the second quarter of 2021 was 58.4%, the highest since 2018. To some extent, this shows that the overall development of strategic emerging industries is fast.

Digital transformation of enterprises is closely related to strategic emerging industries. First, both are highly dependent on emerging technologies such as the new generation of information technology and digital technology[2]. Second, digital transformation can not only bring new opportunities for strategic emerging industries, but also provide important support for them[3]. Specifically, enterprises implementing digital transformation can take advantage of the convenience of information, computing and communication of digital technology. Enterprise digital transformation strengthens the inter-collaborative relationship between different participating subjects inside and outside the enterprise. Ultimately, it achieves the improvement of production and operation efficiency[4], and the improvement of enterprise innovation performance[5]. Nowadays, we are in the context of the new scientific and technological revolution and industrial change. We emphasise the need to promote the deep integration of the Internet, big data, artificial intelligence and other industries. This move is to release the digital superimposed multiplier effect. Second, it is an inevitable choice to accelerate the development of strategic emerging industries and build a comprehensive competitive advantage[6].

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Previous studies on the factors influencing the innovation capability of strategic emerging industries have mainly focused on government subsidies, R&D investment, and financing constraints[7–9]. In terms of research methods, scholars have employed structural equation modeling and hypothesis testing[10,11]. However, the existing literature primarily examines the impact of single variables on the innovation capability of strategic emerging industries. In empirical studies, single-variable regression often overlooks the holistic and interactive effects of conditional combinations on the outcome variable. Moreover, methods such as structural equation modeling fail to identify the interdependencies and causal asymmetries between conditional variables. Research on enterprise digital transformation is still immature, and scholars have not yet reached a consensus on its definition. The research objectives of this paper are:

To investigate the impact of enterprise digital transformation on the innovation capability of strategic emerging industries and its underlying pathways.

This paper aims to fill the gap in previous research that has largely focused on theoretical aspects while neglecting the testability of the studies. Additionally, by focusing on the innovation capability of strategic emerging industries, this study enriches the research on antecedent variables. Moreover, this paper employs fuzzy-set Qualitative Comparative Analysis (fsQCA) to examine the pathways and mechanisms through which enterprise digital transformation affects the innovation capability of strategic emerging industries, integrating multiple dimensions and perspectives.

Literature review and theoretical construction

This section reviews the literature on enterprise digital transformation, the determinants of innovation capability in strategic emerging industries, and their interrelationship, focusing on the research theme and objectives. By synthesizing the existing literature, this part lays a theoretical foundation for the subsequent research questions.

Digital transformation of enterprises

In the construction of enterprise digital transformation index system, most scholars use text analysis method and classification method to study. First, the index system of enterprise digital transformation can be constructed by word frequency statistics and keyword extraction from the annual reports of listed companies[12]. Second, the ability, level and technology of enterprise digital transformation can also be classified, and the index system can be constructed from different dimensions. For example, the index system of regional digital transformation is constructed from three aspects: basic capability, core capability and guarantee capability of regional digital transformation[13]. Or measure the degree of regional digital transformation from the perspective of digitalization level[14]. Reviewing the above research findings, there are still problems in the existing research on the index system of enterprise digital transformation. To be specific, it lacks logicality and hierarchy to construct index system by text analysis method. However, it lacks comprehensiveness and objectivity to construct the index system by using the classification method.

Given the limited research on enterprise digital transformation and its multidimensional nature, its impact on enterprise innovation performance may follow multiple pathways[15]. This paper defines enterprise digital transformation as using digital technologies to drive social structural changes, create new value, and achieve sustained competitive advantage[16]. To measure this transformation, the study adopts the "Compass Model"[17]. This model clearly delineates the hierarchical structure of the indicator system, reflecting the progress of enterprise digital transformation. It also integrates different indicators effectively, ensuring the system's integrity. The study focuses on three dimensions of enterprise digital transformation—awareness, capability, and achievements. We select seven conditional variables: digital technology awareness, digital innovation awareness, digital capability, networking capability, intelligence capability, single coverage achievements, and innovative breakthrough achievements.

Influencing factors of innovation capability of strategic emerging industries

Scholars at home and abroad have studied the connotation and characteristics of strategic emerging industries. Studies have suggested that the emergence and development of strategic emerging industries depend on innovation[18]. Therefore, it is very important to study the innovation capability of strategic emerging industries. The existing research on innovation capability of strategic emerging industries mainly focuses on its influencing factors, including theoretical analysis and empirical test.

In theoretical analysis, scholars mainly study from different perspectives. Firstly, from the internal perspective of enterprises, endogenous factors influencing the development of strategic emerging industries include technology, innovation, and resource allocation. From the external perspective, exogenous factors consist of industrial policy, competitive environment, and the global industrial chain[18]. Secondly, Liu et al. (2014) proposed the innovation-driven four-factor spiral model based on the experience summary of the biomedical industry[19]. Thirdly, factors affecting the innovation capability of strategic emerging industries include intellectual property rights, industrial clusters, financial support, government subsidies, industrial policies, and technological innovation[20]. Finally, from the perspective of industry life cycle theory, the influencing factors of sustainable innovation capability in strategic emerging industries vary across different periods. For example, these factors differ in the technology research and development period and the technology breakthrough period[21].

In terms of empirical test, scholars have studied the factors influencing the innovation capability of strategic emerging industries through empirical analysis and index construction. Zhou and Lu (2019) established a dynamic panel econometric model[11]. They found that R&D investment is an internal factor, while market demand is an external factor influencing the innovation capacity of strategic emerging industries. Zhang (2018) found that internationalization strategy can significantly improve the innovation capability of strategic emerging industries[22]. In the context of enhanced international intellectual property protection, government subsidies also play a role in promoting innovation performance of strategic emerging industries[23]. In addition, some

scholars have constructed the evaluation index system of innovation capability of strategic emerging industries based on different levels and discussed the relevant influencing factors. For example, Liu et al. (2015) explored the mechanism of institutional environment on innovation capability by constructing an evaluation model of innovation capability of strategic emerging industries[24]. Shao et al. (2020) constructed an evaluation system of innovation capability of China's strategic emerging industries from five aspects, including innovation policy support, based on the perspective of capability view[25].

Most studies on the influencing factors of innovation capability in strategic emerging industries emphasize the important role of emerging technology and innovation input. This is evident through both theoretical analysis and empirical testing. The digital transformation of enterprises involves using big data and other digital technologies to drive the transformation and innovation of production and service operation modes[26]. And the level of digitalization has a considerable impact on the innovation capability and development trend of high-tech industries[13]. Therefore, it is necessary to study the impact of enterprise digital transformation on the innovation capability of strategic emerging industries.

Digital transformation of enterprises and innovative capabilities of strategic emerging industries

Digital transformation impacts corporate operations and organizational change, offering both opportunities and challenges for innovation[27]. On the one hand, digital transformation offers opportunities to enhance enterprise innovation capabilities. Research suggests that digital transformation can empower innovation and boost its vitality[28]. For example, it can manage knowledge flows and innovation, thereby fostering enterprise creativity[29]. By building digital platforms, firms can achieve innovation outcomes at lower costs and facilitate the implementation of innovation projects[30]. Additionally, digital transformation through internet platforms enables open innovation that is not restricted by time or location[31].

On the other hand, digital transformation also poses challenges to enhancing enterprise innovation capabilities. The influx of external knowledge can lead to information overload, which may result in underutilization of existing information resources and negatively impact innovation capabilities[32]. Moreover, Gong et al. (2023) argue that over-pursuing digital transformation can increase the difficulty of aligning the enterprise innovation system with rapidly evolving digital technologies[33]. Excessive digital transformation not only raises coordination costs for firms but also makes it harder to achieve innovation improvements.

Given the varying impacts of different condition variables on the innovation capacity of strategic emerging industries. Meanwhile, there is a complex correlation between enterprise digital transformation and innovation capability. This paper adopts the fsQCA method to explore. From a configurational perspective, it integrates seven conditional variables influencing the innovation capacity of strategic emerging industries. The aim is to deeply explore the influence pathways of enterprise digital transformation on enhancing the innovation capacity of strategic emerging industries, as well as the interactions among these conditional variables. The research model is shown in Fig. 1.

Methods

Sect "Methods" focuses on the methodology. We will delve into the theoretical underpinnings and practical advantages of employing fuzzy-set Qualitative Comparative Analysis (fsQCA). The entire process of data collection, processing, measurement, and calibration will be systematically elaborated to ensure the scientific rigor and reliability of the research findings.

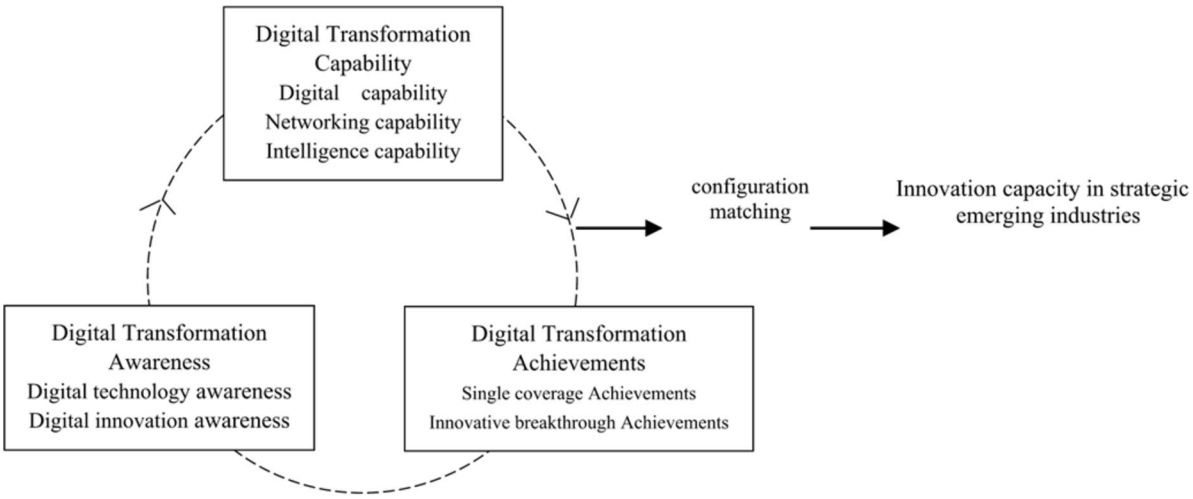

Fig. 1. Research framework.

Research methods

This paper uses fsQCA method to explore the causal and complex mechanism of enterprises' digital transformation to improve the innovation capability of strategic emerging industries. QCA method, proposed by Ragin in 1987, is a case study-oriented theoretical set research method. QCA can be divided into clear set qualitative comparative analysis (csQCA), multi-valued set qualitative comparative analysis (mvQCA) and fuzzy set qualitative comparative analysis (fsQCA). Considering the continuous variation of variables across different cases in this study, the fuzzy-set Qualitative Comparative Analysis (fsQCA) method is deemed appropriate. The rationale for employing fsQCA to examine the relationship between digital transformation and innovation capability in strategic emerging industries is mainly based on the following reasons:

First, the robustness of fsQCA results does not depend on sample size[34]. The evaluation metrics of fsQCA output can assess the reliability and explanatory power of the pathways through which digital transformation enhances innovation capability. Given the small sample size in this study, multivariate statistical analysis cannot ensure the reliability and validity of the results.

Second, enterprise digital transformation is multidimensional and involves multiple elements, making its impact on innovation complex. FsQCA is a configurational analysis method that examines the complex causal relationships and pathways between the configuration of digital transformation conditions and innovation from a configurational perspective[35].

Third, fsQCA is suitable for exploratory research in areas where there is a lack of theoretical support and consensus[36]. The definition of enterprise digital transformation has not yet reached a consensus in existing research, making fsQCA a more scientifically appropriate method for studying this phenomenon.

Data collection and processing

Data collection

This paper selects 31 regions (provinces, autonomous regions and municipalities directly under the Central Government) in China in 2019 as case samples. There is a wide gap in the process of enterprise digital transformation and innovation capability of strategic emerging industries in various regions, which can ensure the external validity of conclusions and full comparison between cases[37]. The result variable is the innovation capacity of strategic emerging industries, which is measured by the number of patents granted. The data comes from Sixlens global industrial innovation and science and technology intelligence database. Among the conditional variables, the number of unicorn enterprises, the measure index of digital innovation awareness, comes from The Great Wall Enterprise Strategy Consulting Institute. The data for the 14 indexes under the six condition variables are obtained from the statistical database. This database is maintained by the public service platform for the integration of industrialization and informatization at the National Industrial Information Security Development and Research Center.

Data processing

Considering that the number of patents applied in the current year has a lag effect on the innovation capability of enterprises[38]. This paper selects the number of patent inventions granted in 2020 as a proxy variable of innovation capability of strategic emerging industries. In the process of collating data for the conditional variables, the statistics and data characteristics of digital transformation disclosed by the public service platform for the integration of industrialization and informatization have an influence. Therefore, the average values of the relevant indicators are processed on a scheduled and quarterly basis. In addition, the problem of dimensionality between the various indicators and the lag of one period can have an impact on the outcome variable. We choose the data of 2019 as the base period data to conduct "0–1 standardization" on the original data of conditional variables. Its calculation formula is as follows:

$$V = \frac{V_i - V_{\min}(0)}{V_{\max}(0) - V_{\min}(0)} \times 100 \tag{1}$$

Where, V_i is the original data of this indicator. $V_{min}(0)$is the minimum value of this indicator in all regions in the original data of the base period. $V_{max}(0)$ is the maximum value of this indicator in all regions in the original data of the base period. V is the score calculated by this index after cross-year standardized treatment, and the range is between 0 and 100.

Data measurement and calibration

Data measurement

Data measurement of outcome variable. There may be a problem of missing data when innovation input is used as an index to measure innovation capability. Patent is usually used to represent the innovation or creativity of an enterprise in new technology or process, which can better measure the novelty of technology[39]. Therefore, we measure the innovation capacity of strategic emerging industries by the number of patent grants.

Data measurement of conditional variables. The first step is the selection of the conditional variables. Referring to the evaluation system of "compass model" of enterprise digital transformation, the measurement index of each condition variable is determined on this basis. Considering the number of conditional variables and the actual situation of enterprises, the indicators are selected as follows: First, three secondary indicators are set under the digital transformation awareness. There is a secondary index under the digital innovation awareness. Second, there are three secondary indicators of digital capability, networking capability and intelligence capability. Third, a secondary index is set under single coverage achievement and innovation breakthrough achievement. In general, 7 conditional variables and 15 secondary indicators are selected in this paper.

Conditions and outcome	Index selection	Weight
Digital technology awareness (*DTA*)	Number of enterprises/total number of enterprises that set up a website	0.576
	Number of enterprises using LAN/Total number of enterprises	0.334
	Number of enterprises using information management/total number of enterprises	0.090
Digital innovation awareness (*DIA*)	Number of local unicorns/number of national unicorns	1
Digital capability (*DC*)	Digitization rate of production equipment	0.820
	R&D equipment tool digitization rate	0.118
	Numerical control rate of key processes	0.062
Networking capability (*NC*)	Rate of e-commerce application	0.842
	Network synergy ratio	0.106
	Proportion of industrial cloud platforms	0.052
Intelligence capability (*IC*)	Smart manufacturing readiness rate	0.047
	Personalization ratio	0.070
	Service manufacturing ratio	0.883
Single coverage achievement (*SCA*)	Proportion of single coverage achievement	1
Innovative breakthrough achievement (*IBA*)	Proportion of innovative breakthrough achievement	1
Innovation capacity in strategic emerging industries (*Patent*)	Number of patent inventions granted for strategic emerging industries	/

Table 1. Index selection and weight of variables.

	Calibration		
Conditions and outcome	More in	Crossover point	More out
Digital technology awareness	86.77	51.30	16.81
Digital innovation awareness	40.85	0.05	0.01
Digital capability	95.46	69.38	35.26
Networking capability	91.84	46.52	8.45
Intelligence capability	87.31	42.93	1.77
Single coverage achievement	66.71	40.88	12.47
Innovative breakthrough achievement	79.66	19.50	3.40
Innovation capacity in strategic emerging industries	210090.00	21229.10	781.00

Table 2. Calibration of condition and outcome variables. Considering that the calibration critical value is consistent with the original data, the number of cases will be reduced during calibration. In this paper, some critical data are processed by adding 0.1.

In the second step, calculate the weights of the condition variables. In this paper, principal component analysis and expert scoring method are adopted to determine the weights of indicators at all levels. First, principal component analysis method is adopted to determine the weight of the secondary indexes of digital technology awareness, digital capability, networking capability and intelligence capability. After the weights of the four groups of second-level indicators were calculated, the scores of corresponding conditional variables were further calculated. When principal component analysis was used to determine the weight of each index, the prior test results showed that the KMO test values of each group were between 0.5 and 1. Bartlett test results were also significant. Therefore, the principal component analysis method is suitable for determining the weight of the four conditional variables of digital technology awareness, digital capability, networking capability and intelligence capability. In addition, digital innovation awareness is calculated by the formula: number of local unicorns/number of national unicorns. Single coverage achievement and innovation breakthrough achievement were measured by the proportion of single coverage achievement and innovation breakthrough achievement respectively. The specific content is shown in Table 1.

Data calibration

Calibration is thought of as the process of assigning membership score to a collection of cases. It is helpful to explore the collective relationship between conditions and outcomes, and thus reveal the causal complexity of social phenomena. Due to the possible errors and uncertainties in the inferred results of the indirect calibration method, and it is less used in research. In this paper, the direct calibration method is chosen to calibrate the variables to fuzzy sets, i.e., a membership score is assigned to each case. Results and anchor points of conditional variables were selected according to the research of Andrews et al.[40]. 95% quantile value was selected as the full membership in the set, 50% quantile value as the cross critical value, and 5% quantile value as the full nonmembership in the set. The fuzzy values are further calibrated according to the calibrate calibration program provided by fsQCA3.0. Table 2 shows the calibration information of the conditional variables and the outcome variable.

Results

This section reports the empirical results of the fsQCA analysis. The output includes the necessity analysis of single conditions prior to configurational analysis, as well as the further analysis of condition combinations. To enhance the reliability and readability of the findings, robustness tests and explanatory case analyses were conducted.

Necessity analysis of single condition

In configuration analysis, it is necessary to test the necessity of all conditional variables after fuzzy set construction. If directly included in the truth table analysis, the necessary conditions may be simplified. Therefore, it is important to check the requirements. The necessary condition is the condition that results must exist, but only the existence of the necessary condition can not guarantee the result will happen. Consistency is an important criterion to measure a necessary condition. When a condition variable always exists and the consistency level is greater than 0.9, it is a necessary condition for the result.

Table 3 shows the test results of the necessary conditions for innovation capability of high strategic emerging industries analyzed by using fsQCA3.0 software. It can be seen from Table 3 that the consistency level of each conditional variable is lower than 0.9. The result indicates that there is no necessary condition affecting the innovation capability of high-strategic emerging industries. This shows that a single condition variable cannot constitute a necessary condition for a result variable. Further configuration analysis, that is, combination analysis of multiple conditional variables, is required.

Sufficiency analysis of conditional configuration

Different from the above analysis of necessary conditions, configuration analysis attempts to reveal the adequacy of results generated by different configurations composed of multiple conditions. When using fsQCA3.0 software for parameter setting, the original consistency threshold is set to 0.8 in order to determine whether the block grouping state can pass the consistency of fuzzy set theory. As there are only 31 cases in this paper, the frequency threshold is set as 1 in consideration of the impact of the number of observed cases[41]. At the same time, the PRI consistency threshold is set to 0.7 in order to avoid the existence of contradictory simultaneous subset relations in a certain configuration.

Conditional implicit variables need to be selected in the standard analysis of high-level strategic emerging industry innovation capability. We considered the actual situation of the digital transformation process of enterprises and the development of strategic emerging industries. In this paper, 'digital technology awareness × digital innovation awareness' and 'digital innovation awareness × single coverage achievements × innovation breakthrough achievements'are selected as conditional implicit variables. In the counterfactual analysis of the innovation capacity of high strategic emerging industries, there is no consistent conclusion between the conditional variables and the outcome variable. Therefore, 'presence or absence' was selected for all conditional variable.

Finally, fuzzy set qualitative comparative analysis (fsQCA) obtained three solutions: complex solution, simple solution and intermediate solution. Referring to the existing studies, the complexity is moderate considering that the intermediate solution only includes the logical remainder which conforms to the expectation of the theoretical direction. Therefore, we mainly choose the intermediate solution to report. At the same time, the intermediate and simple solutions are nested to identify the core conditions. Specifically, the conditions that appear in both intermediate and simple solutions are regarded as core conditions and are considered to play an important role in the results. The conditions that only appear in intermediate solutions are regarded as edge

	High innovation capacity in strategic emerging industries	
Conditions and outcome	Consistency	Coverage
High digital technology awareness	0.890800	0.735185
Low digital technology awareness	0.528048	0.477027
High digital innovation awareness	0.707554	0.894986
Low digital innovation awareness	0.583396	0.381792
High digital capability	0.839940	0.771821
Low digital capability	0.516081	0.419453
High networking capability	0.896784	0.748439
Low networking capability	0.419596	0.374499
High intelligence capability	0.869110	0.755036
Low intelligence capability	0.535527	0.458680
High single coverage achievement	0.774121	0.733003
Low single coverage achievement	0.607330	0.481043
High innovative breakthrough achievement	0.702319	0.640082
Low innovative breakthrough achievement	0.588631	0.481935

Table 3. Analysis of necessary conditions.

conditions and are considered to play an auxiliary role in the results. The analysis results of fsQCA3.0 software are shown in Table 4.

As shown in Table 4, there are three configurations of innovation capability of high strategic emerging industries. So far, we find that there are three equivalent paths for enterprise digital transformation to enhance the innovation capacity of strategic emerging industries. The consistency of the three paths is 0.97929, 0.974359 and 0.969008, respectively. The consistency of the overall solution is 0.96247, which is far higher than the threshold value 0.8. The raw coverage of the three paths is 0.495138, 0.397906 and 0.350785 respectively, and the solution coverage is 0.594615. The empirical results show that these three configurations are sufficient conditions for high strategic and emerging industry innovation capacity. In addition, both individual and overall configurations have good explanatory power for the outcome variable. On the other hand, the coverage range of the three configurations is between 0.35 and 0.50, indicating that each configuration can cover a certain number of cases. The overall coverage of the three configurations is 0.594615, indicating that the final analysis results can cover about 59.46% of the cases.

From the perspective of each configuration, we can further identify the differentiated adaptation relationship between digital transformation awareness, digital transformation capability and digital transformation achievements on innovation capability of strategic emerging industries. There are similarities and differences between the three configurations. Specifically, the three configurations emphasize the central role of digital innovation awareness and the subsidiary role of networking and intelligence capabilities. The difference is that digital technology awareness and digital innovation awareness are taken as the core conditions in configuration H1, which emphasizes the key role of digital awareness leading the innovation ability of strategic emerging industries. In configuration H2, single coverage achievement, innovation breakthrough achievement and digital innovation awareness are the core conditions, while the subsidiary conditions are digital capability, networking capability and intelligence capability. The role of digital capability in promoting innovation capability of strategic emerging industries is emphasized. Configuration H3 differs from the other two configurations. Among them, innovation breakthrough achievement as the core condition is missing, digital technology awareness, digital innovation awareness and single coverage achievement as the core condition, network capability and intelligent capability as the subsidiary condition. Five conditional variables replace the impact of innovation breakthrough achievements on innovation capability of strategic emerging industries.

Digital awareness leads

H1 is the digital awareness leads type. The core conditions of digital awareness driving innovation capability of strategic emerging industries include digital technology awareness and digital innovation awareness under digital transformation awareness. Subsidiary conditions include four conditional variables: digital capability, network capability, intelligence capability and single coverage achievements. This configuration emphasizes the leading role of digital transformation awareness on innovation capability of strategic emerging industries.

Digital technology awareness and digital innovation awareness have the following two impacts on the innovation capability of strategic emerging industries. First, awareness has strong subjective initiative, and it plays a leading role in people's decision-making and behavior. Digitization not only uses technology to improve efficiency, but also means the transformation of management thinking and paradigm[42]. The high ladder team theory proposes that corporate decisions are directly influenced by the psychology or values of senior executives[43]. Therefore, executives with innovative consciousness are more willing to accept changes in technology and culture, which to some extent plays a leading role in the improvement of innovation capability of strategic emerging industries.

Second, enterprises with "digital thinking" can make use of emerging digital technologies to empower enterprise development, which is conducive to the restructuring of enterprise strategic content and strategic

Conditions for configuration	Configuration H1 Digital awareness leads	Configuration H2 Digital capability facilitation	Configuration H3 Digital innovation breaks through substitution
Digital technology awareness	●		●
Digital innovation awareness	●	●	●
Digital capability	•	•	
Networking capability	•	•	•
Intelligence capability	•	•	•
Single coverage achievement		●	●
Innovative Breakthrough Achievement	•	●	×
Consistency	0.97929	0.974359	0.969008
Raw coverage	0.495138	0.397906	0.350785
Unique coverage	0.100224	0.0029918	0.0964847
Solution consistency	0.96247		
Solution coverage	0.594615		

Table 4. Configuration of innovation capability of high strategic emerging industries. ●represents the existence of core conditions, ×represents the absence of core conditions, •represents the existence of subsidiary conditions, "blank" represents the condition may or may not exist.

decision-making procedures[44]. Strategic emerging industries are supported by scientific and technological innovation and highly depend on emerging technologies such as digital technology. Promoting emerging technological innovation is the key to developing strategic emerging industries[45]. In addition, the improvement of enterprises' innovation ability is also an important factor and fundamental driving force to promote the development of China's strategic emerging industries[46]. It can be seen that the digital thinking and technological level of enterprises play the role of awareness guidance and technological empowerment respectively. The result is an effective enhancement of the innovation capacity of strategic emerging industries.

Digital capability facilitation

Configuration H2 is digital capability facilitation type. The core conditions for digital capability facilitation to drive the innovation capability of strategic emerging industries include digital innovation awareness under digital transformation awareness. It also includes three condition variables such as single coverage achievements and breakthrough innovation achievements under digital transformation achievements. The subsidiary conditions include three conditional variables: digital capability, networking capability and intelligence capability under digital transformation capability. This configuration emphasizes the role of digital transformation capability in promoting innovation capability of strategic emerging industries.

The digital transformation ability promotes the innovation ability of strategic emerging industries in two aspects. On the one hand, the further development of strategic emerging industries needs to enhance enterprises' information capability. As a technology-intensive integration industry of emerging technologies and industries, strategic emerging industries have higher requirements on production equipment and cutting-edge technologies[2]. It requires not only the input of labor and capital, but also the further integration of digital technologies such as modern microelectronics, digital control and industrial robots[1]. The improvement of enterprise digital ability can not only improve the business process and business model, but also greatly improve the flexibility of enterprises, which is conducive to promoting the rapid development of strategic emerging industries. On the other hand, networking and intelligence capabilities can improve the low efficiency of strategic emerging industries. Whether data, information and other new production factors are reasonably allocated or not is the core and key to determine the technical efficiency of strategic emerging industries[2]. However, networked and intelligent enterprises can break through the information barriers between different enterprises and realize the network collaboration and resource aggregation among enterprises. In order to make up for the lack of R&D capacity and market instability in the early stage of the development of strategic emerging industries[47]. For example, the establishment of cloud platforms for strategic emerging industries can effectively integrate massive data and promote the accumulation and inheritance of knowledge and experience among enterprises. This not only helps to form a shared knowledge network, but also improves the technical efficiency of enterprises to a certain extent.

Digital innovation breaks through substitution

Configuration H3 is digital innovation breaks through substitution type. The core conditions of this typology include digital technology awareness, digital innovation awareness and single coverage achievements. The subsidiary conditions include two conditional variables, network capability and intelligence capability, which are set under digital transformation capability. In configuration H3, the innovation breakthrough achievement under digital transformation achievement is missing as the core variable. This configuration emphasizes the effective substitution of other conditional variable combinations on innovation breakthrough achievements.

The development of strategic emerging industries is based on major technological breakthroughs and meeting major needs. Although the breakthrough of exploratory innovation can upgrade the technological track of the original industry and even break through the original industrial boundary[48], it can provide power for the formation and development of strategic emerging industries. However, there are few key technologies leading in China, and even less original and innovative achievements from 0 to 1. Moreover, breakthrough innovation is characterized by large investment, long cycle, high risk and high failure rate[49]. At present, most enterprises still face the problem of high uncertainty risk but low achievement conversion rate. Therefore, as one of the core conditions to drive the innovation capability of strategic emerging industries, innovation breakthrough achievements are obviously insufficient in the context of the urgent need to improve the transformation rate of achievements. Therefore, under such a realistic background, the coupling of transformation consciousness and transformation ability plays a substitution role to some extent, and thus slightly improves the innovation ability of strategic emerging industries.

Comparative analysis of conditional configuration

The condition variable "digital innovation awareness" is the common core condition of H1, H2 and H3 configurations by comparing the three configurations. When Gui (2012) explored the growth driving mechanism of strategic emerging industries[50]. He found that innovation driving mechanism is the most important part no matter what stage the industry is located in the life cycle. It can be seen that digital innovation driving mechanism has an important impact on the innovation capability of strategic emerging industries. This is consistent with the results of configuration analysis in this paper. It shows that digital innovation awareness to be the core condition of innovation capability of strategic emerging industries is reasonable.

In addition, the results of configuration analysis show that the condition variables "network capability" and "intelligence capability" are the common subsidiary conditions of the three configurations. This may be due to the fact that strategic emerging industries are characterized by high complexity, integration and uncertainty. The enterprises need to form an industrial interconnection network of resource sharing and technological complementarity[51], so as to improve the efficiency of technological innovation. Enterprises with networking and intelligence capabilities can increase the proportion of enterprise cloud platforms, the rate of network

collaboration and the rate of smart manufacturing readiness. These behaviours can facilitate the rapid sharing of resources, knowledge and other elements within industrial clusters.

Robustness test

In QCA studies, it is necessary to test the robustness of the analysis results. Generally speaking, the robustness test includes four methods: increasing the case consistency threshold, improving PRI consistency, adding or deleting cases, and adding other conditions[37]. In this paper, the first two methods were used to test the robustness.

Changing the consistency level affects the number of truth table rows that are logically minimized, thus reducing the number of cases. Although it is difficult to achieve maximum configuration simplification, the result can be considered robust if the resulting new configuration is a subset of the previous configuration. Referring to the practice of Ordanini et al.[52], a more strict threshold was used to carry out the analysis again, that is, the consistency threshold was raised to 0.85. Robustness test results show that the new configuration is consistent with the above analysis results, which indicates that the analysis results have good robustness to a certain extent.

Secondly, the consistency of PRI is increased to 0.85, and the resulting configuration is basically consistent with the above configuration. The test results are shown in Table 5. The solution consistency increased to 0.979798, and the solution coverage decreased to 0.580404. A comprehensive comparison of the configuration results of 0.7 PRI consistency and 0.85 PRI consistency shows that H1, H2 and H3 in Table 5 are subsets of H1, H2 and H3 in Table 4 respectively. The test results again prove that the empirical results of this paper are robust.

Explain case analysis

Through the case analysis of the configuration of innovation capability of high strategic emerging industries, it is found that the gap of digital transformation of Chinese enterprises is obvious. Figure 2 shows configuration H1 (Digital Awareness Leads type) coverage cases. They specifically including six eastern regions of Shanghai, Jiangsu, Tianjin, Shandong, Zhejiang and Guangdong, and one western region of Sichuan. Figure 3 shows configuration H2 (Digital Capability Facilitation type) coverage cases, including jiangsu, Tianjin, Zhejiang and Guangdong in the east and Chongqing in the west. Figure 4 shows the coverage cases of configuration H3 (Digital Innovation Breaks through Substitution type), including Hubei and Anhui in the two central regions. It can be seen that the eastern region and some western regions of China mainly promote the innovation capability of strategic emerging industries through H1 and H2 configurations. Among them, the coverage cases of the two configurations are mainly composed of the eastern region, while the coverage cases of the western region are less. For the central region, the innovation capacity of strategic emerging industries is promoted mainly through configuration H3. Through the above explanation and case analysis, it is found that:

First, the digital transformation system of enterprises in eastern China is more perfect than that in other regions. This is mainly reflected in the coverage cases represented by Guangdong, Jiangsu, Tianjin and Zhejiang in both configuration H1 (Digital Awareness Leads type) and configuration H2 (Digital Capability Facilitation type). It shows that enterprises in eastern China can improve the innovation ability of strategic emerging industries through multiple paths. This may be due to the fact that enterprises in the eastern region started digital transformation earlier and tried to carry out digital transformation in business in a high proportion[53]. Perfect enterprise digital transformation system and complete transformation ability can better provide driving force for the innovation ability of strategic emerging industries. Take Guangdong as an example, in the 2020 industrial Internet platform application level key indicators report released by the National Industrial Information Security Development Research Center, Guangdong ranked first in the country. By the end of June 2021, Guangdong had promoted the digital transformation of 17,000 industrial enterprises.

Conditions for configuration	Configuration H1 Digital awareness leads	Configuration H2 Digital capability facilitation	Configuration H3 Digital innovation breaks through substitution
Digital technology awareness	•		•
Digital innovation awareness	●		●
Digital capability	●	●	●
Networking capability	•	•	•
Intelligence capability	•	•	•
Single coverage achievement		•	•
Innovative breakthrough achievement	•	•	
Consistency	0.981538	0.974359	0.969008
Raw coverage	0.477188	0.397906	0.350785
Unique coverage	0.0822737	0.0029918	0.0964847
Solution consistency	0.979798		
Solution coverage	0.580404		

Table 5. Configuration of innovation capability of high strategic emerging industries. ●represents the existence of core conditions, •represents the existence of subsidiary conditions, "blank" represents the condition may or may not exist.

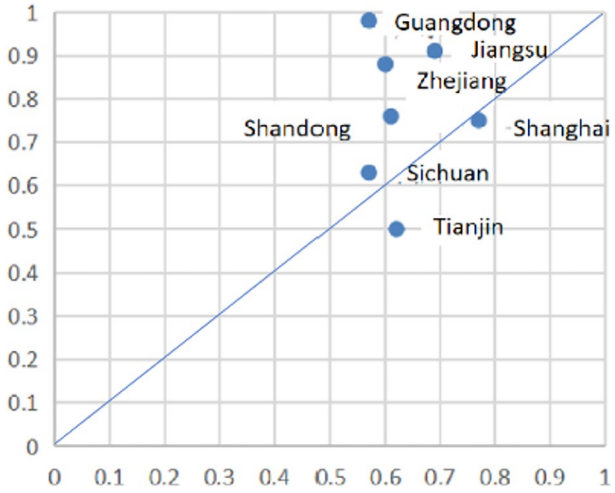

Fig. 2. Digital awareness leads.

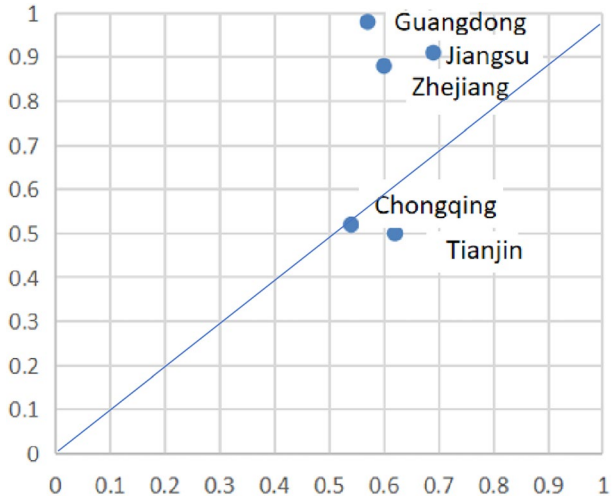

Fig. 3. Digital capability facilitation.

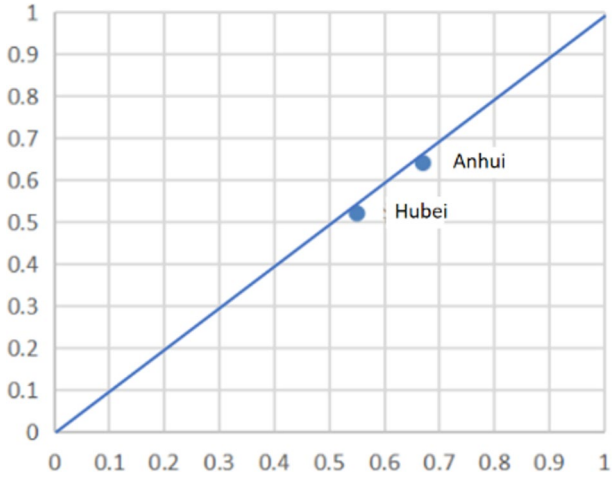

Fig. 4. Digital innovation breaks through substitution.

Second, the digital transformation of enterprises in western China has a significant advantage of backwardness. This is mainly reflected in configuration H1 (Digital Awareness Leads type) and configuration H2 (Digital Capability Facilitation type) in western China represented by Sichuan and Chongqing respectively. Although the development degree of digital economy in western China, represented by Sichuan and Chongqing, is relatively low compared with other regions. But the western region is gradually realizing "overtaking on the curve". Take Sichuan as an example. In 2019, Sichuan province was selected as the National Digital Economy Innovation and Development Pilot Zone. It is estimated that the total digital economy of the province will reach more than 2 trillion yuan by 2022. Visible, under the tilt of national policy, the digital economy in western China has also achieved leapfrog development.

Third, the conversion rate of digital transformation results of enterprises in central China is in urgent need of improvement. This is mainly reflected in the configuration H3 (Digital Innovation Breaks through Substitution type) in the central region represented by Anhui and Hubei. This shows that the digital transformation system of enterprises in central China is relatively perfect. But the transformation of digital transformation results needs to be accelerated and upgraded. Taking Hubei province as an example. The transformation of scientific and technological achievements has always been a pain point and a blocking point in Hubei Province. Promoting the local transformation of more scientific and technological achievements is an important link for Hubei to transform the "key variable" of scientific and technological innovation into the "maximum increment" of high-quality development. Accelerating the transformation of scientific and technological achievements is an important measure to cultivate strategic emerging industries[24].

Discussion

This paper examines and validates the complex relationship between enterprise digital transformation and innovation capability. Although some studies have suggested a certain relationship between enterprise digital transformation and innovation capability, this relationship may be either positive opportunities[29,30] or negative challenges[32,33]. We argue that both digital transformation and innovation are critical strategic decisions for firms. The relationship between them is not as simple as considered in most previous studies. Our research is distinct from prior work in this regard.

First, we focus on the research subject. This study concentrates on strategic emerging industries, because their innovation capability is closely related to enterprise digital transformation. Both rely heavily on new-generation information technologies and digital technologies[2]. Although prior research on the drivers of innovation capability in strategic emerging industries is abundant[19], examining the impact of enterprise digital transformation on this innovation capability is more relevant and meaningful.

Second, we consider complex causality. Prior studies have focused on the impact of single factors on the innovation capability of strategic emerging industries[23]. They completely overlooking the fact that this capability is influenced by multiple factors. Based on three dimensions of digital transformation: awareness, capability, and achievements. We examine the complex influence of seven different variables on the innovation capability of strategic emerging industries.

Third, we improve the research methodology. Previous studies have employed regression analysis, which ignores the holistic and interactive effects of condition combinations on the outcome variable. Additionally, methods such as structural equation modeling cannot identify the interdependencies and causal asymmetries among conditional variables[10]. We use fsQCA to examine the impact of enterprise digital transformation on the innovation capability of strategic emerging industries. This study not only provides a rational approach but also offers a comprehensive explanation of the specific mechanisms and pathways involved.

Policy implications

First, companies should select appropriate pathways to enhance the innovation capability of strategic emerging industries based on the different stages of their digital transformation. During the digital transformation process, companies can establish dedicated digital transformation departments to monitor progress and adjust strategic deployments accordingly. Local governments should actively recruit specialized talent to support enterprise digital transformation and expand indirect financing channels.

Second, governments at all levels should regularly conduct publicity campaigns on digital transformation and cultivate industry-leading digital enterprises. Additionally, governments should establish mechanisms for cooperation among industry, academia, and research institutions, as well as one-on-one support mechanisms, to help companies overcome technical challenges and provide policy guidance.

Third, companies should focus on fostering a culture of management innovation. The departments in charge of digital transformation should define clear responsibilities, such as compensation incentives, process supervision, talent recruitment, and approval of special funds. Companies should also encourage executives and employees to participate in digital technology training, simulations of intelligent equipment operations, and exchange seminars to enhance their digital knowledge.

Conclusion

The last chapter is a summary that describes the main findings, contributions, limitations, and future research directions of this paper. The main findings of this paper are as follows:

First, three synergistic pathways were identified through which enterprise digital transformation enhances the innovation capability of strategic emerging industries. They are digital awareness leads, digital capability facilitation, and digital innovation breaks through substitution. The diverse configurations highlight the complexity of improving innovation capability in these industries.

Second, digital innovation awareness is a core condition across all three pathways, suggesting that awareness of digital transformation is more critical than its capabilities and achievements. Networking and intelligent capabilities are subsidiary conditions in all three pathways. It indicates that the supportive role of digital transformation capabilities in enhancing innovation capability.

Third, case analysis reveals significant regional disparities in digital transformation in China. The pathways for enhancing innovation capability in strategic emerging industries vary across regions. In eastern China and some western regions, companies mainly adopt two pathways: digital awareness leads and digital capability facilitation. In contrast, companies in central China tend to pursue alternative routes by leveraging digital innovation to enhance the innovation capability of strategic emerging industries.

Contributions

The theoretical contributions of our research to the structural change literature can be highlighted in three aspects. (1) Integration of digital transformation and innovation theories. Our study bridges the gap between digital transformation and innovation capability by examining how digital technologies reshape organizational practices and value creation processes. (2) Configurational approach to understanding complex relationships. By using fsQCA, we provide a nuanced understanding of the multiple pathways through which digital transformation can lead to enhanced innovation capability. This approach complements existing research that often focuses on linear relationships.(3)Focus on strategic emerging industries. Our research specifically targets strategic emerging industries, which are at the forefront of technological advancements and structural changes. We contribute to the understanding of how digital transformation can drive innovation in sectors that are critical for future economic growth.

Limitations

The subjects of this study are limited to the 31 regions (provinces, autonomous regions, and municipalities directly under the central government) in China. Although the data volume meets the requirements for fsQCA analysis. It is restricted to the regional level and cannot be expanded to the city level due to data limitations. Additionally, due to technical constraints, we did not employ combined methods such as fsQCA-NCA or fsQCA-ANN. Moreover, our attention to the influencing factors of innovation capability is not comprehensive enough. We have not yet considered the impact of macro factors such as external infrastructure construction on innovation capability.

Future research recommendations

Future research could expand the scope to include different countries or regions to explore the diverse impacts of culture, economy, and social institutions on the research topic. This would enhance the generalizability and applicability of the findings. Additionally, scholars in the field of artificial intelligence could integrate fsQCA with neural network analysis to further investigate the significance of various driving factors.

Data availability

Data available on request from the authors. To access the research data in this paper, please contact 18810671675@163.com.

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Author contributions

Z wrote the main manuscript text and contributed 60%. F reviewed the manuscript and contributed 40%.

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Declarations

Competing interests
The authors declare no competing interests.

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