Research on Path of Digital Transformation of Small and Medium-sized Enterprises:Based on fsQCA

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Abstract. An empirical analysis of the drivers and paths of digital transformation of 759 SMEs in China GEM using TOE theoretical framework and fsQCA method. The study found that human capital, technology development, enterprise size, profitability, government support, foreign investment and industry competition are not necessary conditions for digital transformation of SMEs alone. There are four paths to digital transformation for SMEs, namely technology-environment-led, technology-environment-led organizational collaboration, technology-led environmental collaboration, and technology-organization-environment-led. Key elements play different roles in different paths, and SMEs should combine their own endowments to choose the right digital transformation path.

Keywords: SMEs;digital transformation;fsQCA .

1. Introduction

Small and medium-sized enterprises have become a major force in the country's economic development and are a mainstream form of industrial organization representing the direction of social and economic development[1]. With the development and application of 5G, big data, artificial intelligence, cloud computing, blockchain and other technologies, China's digitalization process continues to accelerate. China's"Fourteenth Five-Year Plan"for the development of the digital economy mentions that it is necessary to vigorously implement special actions for the digital empowerment of SMEs and promote the digital transformation of industries. Digital transformation of enterprises has become an important part of the country's implementation of the new development concept and the construction of a new development pattern. However, due to the continued impact of the new crown pneumonia epidemic, the development of SMEs has encountered unprecedented difficulties, and SMEs want to survive and must seek ways to transform. How to promote the digital transformation of SMEs has become a pressing issue.

Digital transformation of enterprises is a systematic project, which is influenced by a combination of factors in the internal and external environment[2], and the synergistic driving effect of multiple factors on the digital transformation of SMEs can be explored more comprehensively based on a configuration perspective. In terms of research perspectives, the TOE framework based on "technology-organization-environment" can select different influencing factors according to different research questions and research contexts, which is highly universal[3]. In terms of research methods, fsQCA(fuzzy set qualitative comparative analysis)can explore the influence of different paths composed of multiple antecedent conditions on the results, and can better illustrate the complex causal relationships behind the phenomena. In view of this, this paper uses the TOE theoretical framework and the fsQCA method to explore the impact of several elements on the digital transformation of SMEs, in order to provide theoretical guidance for the development of digital transformation of SMEs.

2. Theoretical foundation and analytical framework

2.1 Digital Transformation of SMEs

Digital transformation of enterprises refers to the process of digital information management throughout the chain by using information, computing and communication technologies to penetrate

the business processes of enterprises. The existing research on digital transformation of SMEs is on the one hand a qualitative research method of empirical summary, analyzing the current situation and problems of digital transformation of SMEs and giving corresponding countermeasure suggestions. On the other hand is the quantitative research approach of single factor empirical analysis, such as exploring the impact of digital technology, human capital, government financial support and market competition on the digital transformation of SMEs. However, most of the existing studies on digital transformation of enterprises are normative discussions, and there are relatively few empirical studies based on large samples. In particular, quantitative analysis on digital transformation of SMEs mostly analyzes the net effect of individual elements, and it is difficult to explain the linkage effect of multidimensional elements on digital transformation of SMEs.

2.2 TOE theoretical framework

The TOE framework was first proposed by Tornatizky and Fleischer. It includes three categories: technical level, organizational level, and environmental level. Technology level mainly includes enterprise technology conditions, such as human capital, technology R&D and technology facilities, etc;Organizational level mainly includes enterprise size and management, etc;Environmental level include policy environment, market environment and openness to the outside world, etc. In the digital economy, the digital transformation of SMEs is influenced by a combination of internal and external factors, so the TOE framework is used to study digital transformation with better explanatory power. The analysis framework is shown in Figure 1.
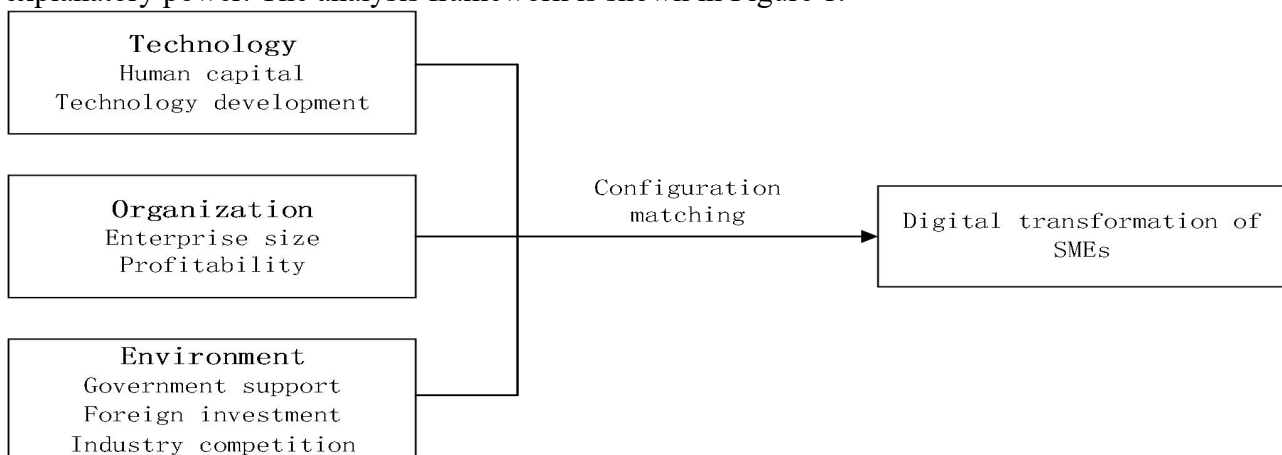

Figure 1 Analysis framework

2.3 Analysis Framework

Technical level. Technology is the first productive force, talent is the first resource. Technology is the basis for digital transformation of enterprises, and digital transformation of enterprises originates from the integration and transformation of technology into enterprise business and management[4]. In recent years, the development of digital technology has enabled many companies to transform their operational processes and build management systems for intelligent analysis and decision making[5]. Technical personnel are the main body of technology development and implementation. Enterprise digital transformation requires highly qualified personnel with professional knowledge and the ability to operate and harness digital technology to promote and implement the digital transformation of enterprises to provide a constant source of power. In summary, this paper uses technology R&D and human capital as the conditional variables for SME digital transformation at the technology level.

Organizational level. According to the "China's Two Integration Development Atlas", enterprise size has a significant impact on the transformation and development of enterprises, which can reflect differences in areas such as digitalization and intelligent collaboration. Organizational ecology shows that the larger a company is, the more conservative it is in its thinking and the less it

actively seeks change. In a market economy, a company's most reliable funding will always come from the products it trades in the marketplace. SME digital transformation requires higher incremental capital requirements and thus higher profitability. In summary, this paper uses firm size and profitability as the conditional variables for SME digital transformation at the organizational level.

Environmental dimension. The development of digital transformation of enterprises requires government support, especially financial support. The government can combine tax subsidies, financial expenditures on science and technology with industrial policies, which can guide the flow of financial and private capital into specific enterprises, and with financial security, enterprises can increase their innovation, enhance their confidence in transformation, and release the digital transformation potential as much as possible[6]. Foreign investment can compensate for the huge costs associated with digital transformation to acquire digital equipment and build digital factories. Factors such as technology and knowledge enter the enterprise along with the accompanying foreign investment, which can be imitated and applied by the enterprise for digital transformation[7]. Market competition amplifies the external decision-making environment, strengthens internal and external connections, and accelerates the flow of information. Digital transformation can improve information access and the ability to capture market changes in real time, contributing to the strategic agility of firms to find dynamic solutions and thus improve their market position. n summary, this paper uses government support, foreign investment, and industry competition as the conditional variables for digital transformation of SMEs at the environmental level.

3. Research Design

3.1 Research Methodology

Qualitative comparative analysis has the advantages of both qualitative and empirical research, and can compensate for the shortcomings of traditional research methods. This method is an analysis method based on group perspective and overall perspective, based on set theory and Boolean algebraic operations, which can explore the influence of different paths composed of multiple elements linked together on the results, and can better explain the complex cause-and-effect relationship behind the phenomenon. The TOE framework is often used to study areas such as the diffusion of technologies, and it is feasible to explore the digital transformation paths of SMEs using a fuzzy set qualitative comparison approach and combining it with the TOE framework.

3.2 Data sources and variable descriptions

3.2.1 Data sources

This paper selects a sample of 759 SMEs in China's GEM from 2019-2020 as cases. Corporate level data from Wind database and CSMAR database. Macro-level data from the China Statistical Yearbook and regional statistical yearbooks.

3.2.2 Variable descriptions

Conditional variables

Human capita(HC). It can be considered as the ensemble of knowledge carried in workers, and the level of education has a strong correlation with knowledge, therefore, it is expressed as the logarithm of the number of people with a bachelor's degree or above.

Technology development(TD). It is expressed in terms of technology R&D as a percentage of operating revenue.

Enterprise size(ES). It uses the logarithm of the total assets of the enterprise to express.

Profitability(PR). Measuring the profitability of sample companies using "(operating revenue-operating costs-selling expenses-administrative expenses)/operating revenue".

Government support(GS). The ratio of fiscal science and technology expenditure to general public budget revenue is used to indicate the government's support to enterprises.

Foreign investment(FI). Using the total foreign direct investment in the region where the enterprise is located to indicate the foreign investment (USD million).

Industry competition(IC). Using the Herfindahl-Hirschman Index to reflect Industry Competition. Calculation formula:

$$HHI = \sum_{i=1}^{n} (Xi/X)^2 \tag{1}$$

In formula (1), Xi is the total assets of a single firm, X is the total assets of the industry to which the firm belongs.

Result variables

Digital transformation(DT). Drawing on Wu Fei's research[8], this paper uses the logarithmic value of the total word frequency of digital transformation keywords to portray the degree of digital transformation of enterprises.

Combining the measurements of the condition and outcome variables, the data for the sample enterprises were organized and the descriptive statistics of the variables are shown in Table 1 below.

Table 1 :Descriptive statistics

Conditional variables	Average value	Standard deviation	Maximum	Minimum
HC	5.929	1.062	9.147	3.258
TD	7.942	6.814	78.895	0.000
ES	21.597	0.847	25.582	18.830
PR	0.170	0.172	0.748	-1.54
GS	0.067	0.019	0.117	0.015
FI	8.798	1.003	9.933	3.332
IC	0.132	0.121	1.000	0.040
HC	2.343	1.593	6.270	0.000

3.3 Variable calibration

In the QCA, the collected raw data needs to be calibrated, i. e. , the raw data has to be converted into an aggregate affiliation score of 0 to 1. The data used in this section is the average of each variable for 2019-2020. In this paper, the upper quartile(0. 75), median(0. 5)and lower quartile(0. 25)of the sample data are selected as fully affiliated, intersection and fully unaffiliated points for calibration using the direct calibration method. The calibration results for each variable are shown in the following Table 2.

Table 2 Variable calibration

Conditional variables		Calibration		
		Fully affiliated	Intersection	Fully unaffiliated
Technology	HC	6.484	5.854	5.190
	TD	9.670	5.885	3.965
Organization	ES	22.078	21.530	20.977
	PR	0.255	0.168	0.097
Environment	GS	0.083	0.069	0.056
	FI	9.451	8.737	8.027
	IC	0.154	0.094	0.070
DT		3.584	2.197	1.099

4. Analysis results

4.1 Necessary conditions analysis

Before performing the configuration analysis, it is necessary to check the necessity of all condition variables. In fsQCA, when the consistency of the condition variable is greater than 0. 9, it is considered as a necessary condition for the result[9]. The results obtained after data calibration are shown in Table 3, and it can be seen that the consistency of all condition variables is less than 0. 9. Therefore, all the conditional variables in this paper do not constitute a necessary condition for a high degree of digital transformation of SMEs.

Table 3 : Necessity analysis

Conditional variables	DT		Conditional variables	DT	
	Consistency	Coverage		Consistency	Coverage
HC	0. 676162	0. 678379	～HC	0. 423777	0. 429400
TD	0. 635496	0. 660349	～TD	0. 462274	0. 452645
ES	0. 557771	0. 567078	～ES	0. 531558	0. 531530
PR	0. 541646	0. 552387	～PR	0. 551368	0. 549673
GS	0. 565978	0. 600504	～GS	0. 513211	0. 492935
FI	0. 613125	0. 547633	～FI	0. 467500	0. 541059
IC	0. 571125	0. 607196	～IC	0. 500666	0. 480006

Note:"～"indicates non-high

4.2 Configuration analysis

In this paper, we use the set-theoretic model of fsQCA 3. 0 software to analyze the adequacy antecedent grouping of SMEs to achieve digital transformation by comparing intermediate and parsimonious solutions, identifying core and auxiliary conditions, and using the consistency of solutions to measure. In this paper, the case frequency threshold is set to 2, the consistency threshold is set to a more desirable threshold of 0. 8, the PRI consistency threshold is set to 0. 75, and the recoding is performed according to the above criteria, and finally the intermediate and parsimonious solutions are obtained. Where " ● " represents the core condition exists, " ⊗ "represents the core condition is missing, " ● "represents the auxiliary condition exists, " ⊗ "represents the auxiliary condition is missing, blank represents the condition is optional, and the final result of the group analysis is shown in Table 4. The results show that QCA analysis yields five groups of conditions that achieve a high degree of digital transformation of SMEs, and the consistency level of individual solutions and the overall solution is higher than the lowest acceptable level of 0. 75[10].

Table 4 :Configuration analysis

Conditional variables	DT				
	H1a	H1a	H1a	H2	H3
HC	●	●	●	●	●
TD	●	●	●		●
ES			●	⊗	●
PR			●	⊗	⊗
GS	⊗			⊗	●
FI		●		⊗	●
IC	●	●	●	●	
Solution coverage	0. 312338				
Solution consistency	0. 854743				
Consistency	0. 865115	0. 874476	0. 869317	0. 900887	0. 844825
Raw coverage	0. 162089	0. 185715	0. 134908	0. 0610512	0. 0931971
Unique consistency	0. 0239656	0. 0267623	0. 0179285	0. 0190262	0. 0345502

4.3 Configuration analysis for digital transformation of SMEs

The H1a and H1b can be grouped into a category of configurations, which will be named as technology-environment-led. In H1a, Human capital, technology development and industry competition are the core conditions, and non-high government support is the auxiliary conditions. This configuration shows that with less competitive pressure on enterprises and lack of local government support, some SMEs can achieve digital transformation by increasing technological development and using their own highly qualified talents to a high degree. In H2a, human capital, technology development and industry competition are the core conditions, and foreign investment is the auxiliary conditions. This configuration is more similar to configuration H1a, the difference is that the enterprise will receive some foreign support. The reason for the above two configurations is that less competitive pressure can lead to a more stable environment for innovation and transformation for SMEs. High-quality human capital has higher innovation ability and stronger adaptability. Technology is the foundation of enterprise digital transformation, the advanced digital technology use to promote enterprise digital transformation, digital technology research and development can help enterprises to shape new business models , for enterprises to develop new markets.

Naming H1c as technology-environment-led organizational synergy. In H1c, human capital, technology development and industry competition are the core conditions, while firm size and profitability are auxiliary conditions. The configuration shows that, in the case of a more concentrated industry, some larger SMEs and maintain a certain degree of profitability, by increasing technology research and development, and vigorously cultivate talent, can achieve digital transformation. Big enterprises have more resources and accumulated rich transformation experience, and such enterprises have more funds to invest in talent training and technology development, under the premise of technology and financial security, SMEs are more likely to achieve digital transformation.

Naming H2 as technology-led environmental synergy type. In H2, human capital, non-high firm size, non-high profitability, and non-high government support are the core conditions, and non-high foreign investment is the auxiliary conditions. This path is more suitable for enterprises that have

just started to develop, because they have not yet formed a scale and have not started to make profits, they have received very little support from the government and foreign investors, and the resources they can rely on most are talents.

Naming H3 as technology-organization-environment-led. In H3, human capital, technology development, firm size, non-high profitability, and foreign investment are the core conditions, and government support is the auxiliary conditions. This configuration shows that enterprises can accelerate technological innovation and provide technical support for enterprise digitization by increasing technological technology research and development as well as training a large number of digital talents to promote advanced and specialized human capital structure. In the absence of profitability, foreign investment and some government financial support can ease the financial pressure of digital transformation of enterprises.

4.4 Robustness test

In this paper, we refer to the robustness testing practice of DU Y Z: increasing the case frequency threshold and the PRI consistency threshold[11]. The case frequency threshold is now adjusted from 2 to 3, and the PRI threshold is increased from 0. 72 to 0. 75. The data was analyzed by running the fsQCA 3. 0 software. The results(Table 5) show that the consistency of the overall solution improves from 0. 855 to 0. 867, the coverage of the overall solution decreases from 0. 312 to 0. 254, and the 4 configurations are a subset of the original 5 configurations. All indicators changed only slightly, so the research findings are highly robust.

Table 5 :Robustness test

Conditional variables	Configurations by increasing the frequency threshold and PRI threshold			
	F1	F2	F3	F4
HC	●	●	●	●
TD	●	●	●	●
ES		●		●
Pr			●	●
GS		⊗	⊗	
FI	●			
IC	●	●	●	●
Solution coverage	0. 254449			
Solution consistency	0. 867118			
Consistency	0. 874476	0. 845048	0. 872878	0. 869317
Raw coverage	0. 185715	0. 107467	0. 123644	0. 134908
Unique consistency	0. 0524006	0. 00854613	0. 0193921	0. 0179286

5. Research summary and recommendations

5.1 Summary

Taking 759 listed companies in China GEM as the research sample, this paper explores the complex causal mechanism of digital transformation of SMEs by applying the group state idea and fsQCA from the perspective of TOE theoretical framework. The study found that, first, human capital, technology development, enterprise size, profitability, government support, foreign investment, and industry competition do not individually constitute the necessary conditions for digital transformation of SMEs. At the same time, the research results show that the digital transformation of SMEs is the result of the synergy of multiple elements and is characterized by

"multiple concurrency". Second, there are four paths to digitize SMEs, namely technology-environment-led, technology-environment-led organizational synergy, technology-led environmental synergy, and technology-organization-environment-led. Human capital has appeared as a core condition in all the configurations, indicating that human capital is critical to the digital transformation of SMEs.

5.2 Recommendations

In view of this, we make the following policy recommendations. First, there are multiple paths to achieve digital transformation of SMEs, and there are differences in the effects of the same element under different paths. Therefore, enterprise managers have to choose the digital transformation path that fits the enterprise from the endowment they have. Second, human capital plays a crucial role in the digital transformation of enterprises. Enterprises can train their existing senior talents to learn advanced digital technologies and knowledge to facilitate their digital transformation. Thirdly, SMEs often face pressure in terms of talent, technology and capital for digital transformation. The government can give enterprises certain policy support in terms of talent training, technology research and development and financial subsidies to guide them to train talents and develop technology, help them relieve capital pressure and improve their confidence in digital transformation. The government can also increase the supervision of the market, improve the policy of attracting foreign investors, regulate the market order, and a stable and orderly market environment can help SMEs' digital transformation.

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