Research on antecedent configuration of digital transformation in manufacturing enterprises：a fuzzy-set QCA approach

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Abstract. In the era of digital economy, digital technology continues to integrate with the real economy. How to effectively realize the digital transformation has become an important research topic. Based on a fuzzy-set qualitative comparative analysis of 62 Chinese manufacturing enterprises, we identify and explore four conditions that influence digital transformation. The four conditions are enterprise size, profitability, R&D capability and innovation environment. The results show that there are two main configuration pathways for digital transformation of manufacturing enterprises. One is resource-driven transformation with large enterprise size as the core condition. The other is innovation-driven transformation with strong R&D capability as the core condition.

Keywords: Digital transformation; Enterprise size; Innovation; fsQCA

1 Introduction

With the flourishing development of digital technologies such as artificial intelligence, blockchain, cloud computing and big data, human society is accelerating into the era of digital economy. The digital economy effectively promotes the growth of the real economy through new technologies, new elements and new business models. The real economy, with manufacturing as its core, creates large external demand and provides an important industrial base for the application of digital technologies and the development of digital industries. Enterprises have actively explored the innovative application of various digital technologies and accelerating the digital transformation process to enhance their core competitiveness. However, the digital transformation of manufacturing enterprises does not happen overnight. Due to the significant mobility and ease of aggregation of digital resources, the marginal cost of dissemination and replication is almost zero. And the number, scope and speed of digital resource collection can grow exponentially [1]. Digital resources require high fixed costs to be effective, which makes digital transformation not only dependent on the company's own conditions, but also on the external environment such as infrastructure development.

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In recent years, domestic scholars' research on enterprise digital transformation is still in the preliminary stage of conceptual model and direction guidance. Due to the complex mechanism of enterprise digital transformation, "not knowing how to transform" has become a common problem faced by enterprises. Therefore, it is of great significance to explore the elements of enterprise digital transformation and find the paths of enterprise digital transformation under different conditions.

From the perspective of configuration, combining resource-based view, competence-based theory, technical innovation theory and regional innovation system theory, we select 62 typical case enterprises of digital transformation in manufacturing industry as research samples, and use fsQCA to explore how enterprises can successfully achieve digital transformation.

2 Literature review and research framework

The academic circle's understanding of digital transformation is a gradual deepening evolution process. Digital transformation is divided into three evolutionary stages: Digitization, Digitalization and digital transformation [2]. The Digitization phase reflects the digitization of information, which is the process of converting analog information into digital information, such as the use of digital tabulation or the use of digital applications for internal financial reporting. The Digitalization phase emphasizes the digitalization of processes, that is, how to use IT and digital technologies to change existing business processes. The Digital transformation phase focuses on the strategic change of business model, so that enterprises can form new core competitiveness and develop new business in the digital business environment.

In terms of the factors affecting the success of digital transformation, Nadkarni et al. [3] summarized the factors driving enterprise digital transformation, including transformation leadership, working environment, management capabilities, and corporate culture. Wong et al. [4] found through empirical research that competitive pressure, complexity, cost and comparative advantage would affect the intention of Malaysian enterprises to use digital technologies such as blockchain. Eller et al. [5] found that digital technology, information technology and digital strategy have a positive impact on the digitalization of SMEs. It can be seen that most researches on the driving factors of enterprise digital transformation adopt the method of empirical research or induction and summary. And there are insufficient researches on the influence of various internal and external factors on the degree of digital transformation.

Rajagopalan et al. [6] believe that strategic change of an enterprise should match the internal conditions and external environment in order to achieve success. Therefore, the success of the digital transformation of manufacturing enterprises should not only consider the conditions of the enterprise itself, but also consider the connection with the outside, and its influence mechanism should change from a single causal element to multiple causal interactions.

3 Research design

Qualitative comparative analysis (QCA) is a case-oriented qualitative analysis method proposed by American scholars Ragin and Rihoux [7]. Based on Boolean algebra and set theory, the method uses the configuration idea to explore how the combination of antecedent variables makes the result variable appear observable discontinuous variables. QCA method is very suitable for digital transformation research to identify complex antecedents. At present, QCA method has been increasingly applied in the field of digitalization and information system, such as Park et al. [8] and Pappas et al. [9].

This paper selects four antecedent variables, namely enterprise scale, profitability, R&D capability and innovation environment, to explore the impact of different configuration combinations on enterprises' digital transformation and build a theoretical framework for research (Fig. 1).

Based on the availability of data, the sample cases selected in the study are 62 manufacturing A-share listed companies. The data used in the study are mainly from the annual reports of the enterprises, the CSMAR database, China national intellectual property website, etc. The data on regional innovation environment are derived from provincial and municipal statistical yearbooks. The variables are specified below.

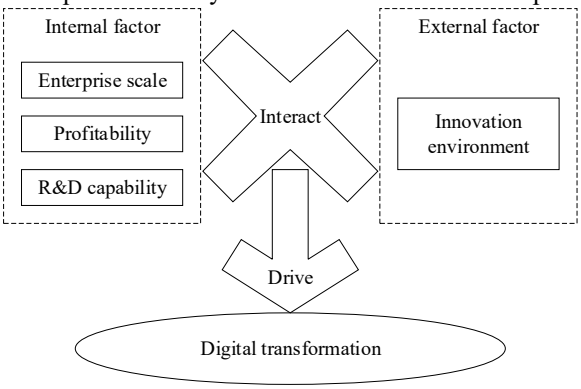

Fig. 1. The configurational framework of digital transformation.

1. **Result variable: Digital transformation.** This paper uses Python crawler tool to crawl the annual reports of listed companies, and counts the structured feature words of enterprise digital transformation proposed by Wu et al. [10] as an indicator to measure the degree of enterprise digital transformation.
2. **Antecedent variables: Enterprise scale.** This paper uses the total assets at the year-end to measure the size of the enterprise. **Profitability.** We measured profitability by the average profit growth rate of enterprises in the past three years. **Research and development ability.** We measured R&D capability by the number of patent applications a company makes. **Innovation Environment.** This paper evaluates the innovation environment of different regions from five dimensions: market scale, human resources, financial capital, government scale and infrastructure en-

vironment, and weights them equally to form a comprehensive index of innovation environment.

4 Results

We used the logical scheme proposed by Ragin [11] to show the analysis results of enterprise digital transformation configuration paths (see Table 1). The consistency of the overall enterprise digital transformation impact path is 0.9107, and the consistency level of all three configurations exceeds 0.9, meeting the full consistency level. The total coverage is 0.6184, indicating that the sum of each state can cover the total 61.84% cases. Based on the core conditions, we propose two pathways of achieving high levels of digital transformation as follows.

Table 1. Configurations strongly related to digital transformation.

Antecedent condition	High levels of digital transformation		
	1	2a	2b
Enterprise scale	●		⊗
Profitability		•	
R&D capability		●	●
Innovation environment	•	⊗	•
Raw coverage	0.5709	0.4765	0.3002
Unique coverage	0.0417	0.0266	0.1839
Consistency	0.9293	0.9801	0.9015
Overall solution coverage	0.6184		
Overall solution consistency	0.9107		

Note: ●=core casual condition (present). •=peripheral casual condition (present). ⊗=core casual condition (absent). ⊗=peripheral casual condition (absent). Blank spaces indicate "do not care".

Pathway one: Resource-driven digital transformation. The configuration of this pathway is large enterprise scale × good innovation environment, in which enterprise scale is the core condition and good innovation environment is the peripheral condition. Large-scale enterprises have more resources at their disposal and rich options for resource allocation, which enhances the autonomy of enterprise transformation and also provides enterprises with more opportunities for trial and error. When it comes to digital exploration, larger-scale organizations have higher success rates at key growth points.

Pathway two: Innovation-driven digital transformation. This pathway has two configurations: one is strong profitability × strong R&D capability × poor innovation environment; the other is small enterprise scale × strong R&D capability × good innovation environment. In the two configurations, R&D capability is the core condition. The peripheral conditions of the first configuration are strong profitability and poor innovation environment, and the strong innovation ability of enterprises can make up for the defects caused by the unsatisfactory innovation environment to a certain extent. This type of enterprise should continue to increase the development of digital products

to further enhance the core competitiveness of enterprises. The peripheral conditions of the second configuration are small enterprise scale and good innovation environment. Small-scale enterprises usually belong to the growth stage enterprises and generally have defects in resources and profits. However, if the government can provide enterprises with good infrastructure, financial capital, policy support, etc., the favorable innovation environment can make up for the disadvantages of new enterprises.

5 Conclusions

First, the digital transformation of manufacturing enterprises is not the result of a single factor driven by enterprise resources or R & D capability, but the result of the synergy of internal and external factors. There are multiple configurations that drive the digital transformation of manufacturing enterprises, indicating that the digital transformation of manufacturing enterprises has the characteristics of "multiple concurrency". We find two main configuration pathways for digital transformation of manufacturing enterprises. One is resource-driven transformation with large enterprise size as the core condition. The other is innovation-driven transformation with strong R&D capability as the core condition.

Second, for large-scale manufacturing enterprises, they should make full use of their resource advantages, continuing to increase digital investment. They can use digital technology to transform their original business and further expand the competitive advantage of enterprises. At the same time, large-scale manufacturing enterprises should pay attention to the training of digital talents, give digital talents a certain salary incentive to stimulate their initiative and creativity. In addition, digital technology is supposed to be embedded in the enterprise management system, reducing internal communication and operating costs, enhancing the flow and feedback of information, and improving the efficiency of production and management processes.

Third, enterprise innovation capability is an important internal factor for achieving high levels of digital transformation. Any enterprise should enhance its ability of independent innovation. Considering the difficulty of innovation and digital transformation for small-scale enterprises, it is possible to internalize knowledge spillover and carry out collaborative innovation through cooperation with other enterprises, universities and research institutes. Small manufacturing enterprises should take advantage of the external services to carry out digital upgrading of production, better realizing the collaborative allocation of external services and internal resources, and further expanding the competitive advantage of enterprises.

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