The Impact of "Technology-Organization-Environment" Factors on the Digital Transformation of Retail Enterprises

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Abstract

Based on the framework of "Technology-Organization-Environment", using the fuzzy set qualitative comparative analysis method, we take A-share listed retail enterprises as the research object, and explore the influence mechanism of the seven antecedents, namely, digital resource infrastructure, digital human resources, innovation capacity, absorption capacity, adaptive capacity, digital economy policy and marketization process, on the digital transformation of enterprises. digital transformation. The study finds that there are five types of groupings in high-level digital transformation, which can be categorized into four types: learning and transformation with technological-environmental synergy, coordinated pioneering with technological-organizational-environmental linkage, environment-led passive change, and technology-supported self-driven change. The study shows that digital resource infrastructure has a general driving effect on digital transformation of retail enterprises, and to a certain extent, it can substitute for innovative and adaptive capabilities; digital economy policy, as a key environmental element, is the main force driving the transformation. In addition, firms that fail to achieve a high level of digital transformation generally lack digital resource infrastructure, innovation capacity, digital economy policies and marketization processes.

Keywords: "technology-organization-environment" framework, retail enterprises, digital transformation, fuzzy set qualitative comparative analysis

1. Introduction

The report of the 20th Party Congress emphasized that "accelerate the development of the digital economy and promote the deep integration of the digital economy with the real economy".2023 The Measures on Restoring and Expanding Consumption issued by the Ministry of Commerce and other departments clearly pointed out that "accelerate the digital transformation of traditional consumption". In order to gain a head start in the fierce market competition, it has become an inevitable trend for traditional retail enterprises to innovate their organizational structure, production and operation models and business processes through digitalization. However, according to the "2024 Digital Retail Growth White Paper", the digital transformation of retail enterprises is at a critical stage, and they are still exploring the gradual transition from "online" to "digital intelligence". 55% of retail enterprises are still in the process of "online". 55% of retail enterprises are still in the stage of "onlineization", 30% of retail enterprises have started to enter the stage of "digital intelligence", and only 10% of retail enterprises have the ability of "platformization". Most retail enterprises pay little attention to digital transformation, lack systematic planning, and are not strong in the execution of digital transformation strategies. Therefore, it is of practical significance to study how to promote the digital transformation of enterprises to help retail enterprises maintain their competitive advantages and build an efficient and smooth modern distribution system.

Digital transformation is a hot issue for scholars, and most of the existing literature focuses on the driving factors and economic effects of digital transformation in retail enterprises. Xie's research shows that retail enterprises are

faced with the long-tail demand of the Internet and the "pull" logic of production and marketing, and they should utilize digital technology to promote flexible production for a higher level of dynamic equilibrium between supply and demand [1]. Bao et al. pointed out that retail business model innovation promotes the transformation of traditional consumption to digital consumption, and combined with the demonstration effect of e-tailing will promote the digital transformation of retail enterprises [2]. Supply chain finance [3], financial technology [4], and inclusive finance [5] provide enterprises with a higher level of financial services, and effectively open up the financing blockage in the process of enterprise digital transformation. Pilot policies such as Smart City [6], Information Consumption [7], National Comprehensive Pilot Zone for Big Data [8], and Free Trade Pilot Zone [9] provide development opportunities and favorable conditions for enterprises to make decisions on digital transformation. In addition, the promotion effect of smart city construction on enterprise digital transformation is preferred to traditional industries. In the study of the economic effect of digital transformation of retail enterprises, Liu showed that digital transformation pushes help retail enterprises to strengthen the connection with suppliers and consumers, improve the degree of supply chain synergy, optimize the internal organizational structure, and then strengthen the operational capacity [10]. The level of digital technology will more significantly promote the high-quality development of the retail industry after crossing the threshold value [11]. Wang believes that their own factor endowment and lack of dynamic capabilities are the reasons limiting the digital transformation of retail enterprises. Non-state-owned retail enterprises are more constrained by digital resource endowment and should prioritize to push forward the digital transformation process in depth in key areas, while state-owned retail enterprises are more constrained by dynamic capabilities and are more suitable for multi-sectoral and multi-disciplinary digital transformation [12]. Wang et al. pointed out that retail enterprises can improve their organizational resilience by triggering demand dynamic capabilities through digital transformation [13]. In the process of digital transformation, the combination of brick-and-mortar retailing and Internet platforms in omni-channel retailing scenarios will effectively improve the efficiency of personalized transaction demand matching and reshape the relationship between retailers and consumers [14].

Combined with the previous analysis, the use of emerging digital technologies by traditional enterprises can disrupt the original business processes and explore new value creation opportunities, however, the reality of limited digital resources, insufficient capacity, the complexity of the market environment and other issues will exacerbate the plight of enterprises caught in the paradox of digital transformation. What are the specific ways to drive the digital transformation of retail enterprises? Do different drivers affect digital transformation in retail to the same extent? And what combination of these drivers is most suitable for digital transformation of retail enterprises? All these questions need to be studied in depth. Existing literature on digital transformation of retail enterprises is mostly based on regression analysis to explore causality or based on theoretical model derivation, and few papers use fsQCA to explore the impact of different combinations of drivers on the digital transformation of retail enterprises, this paper explains the causal complexity of promoting high-level digital transformation of retail enterprises based on a comparative qualitative approach. This paper adopts the "technology-organization-environment" framework to analyze the impact of different drivers on digital transformation with the data of listed retail enterprises from 2001 to 2023. The possible marginal contributions of this paper are: first, it enriches the literature on the drivers of digital transformation by focusing on retail enterprises. Second, this paper expands and validates the antecedent conditions affecting digital transformation of enterprises by driving the path of digital transformation of retail enterprises from technological, organizational, and environmental perspectives, deepening the research on digital transformation of retail enterprises. Third, this study constructs large-scale sample data based on seven antecedent conditions, aiming to fill the gaps in the existing literature on research on driving digital transformation in retail enterprises.

2. Theoretical Analysis and Research Framework

Digital transformation enables retail enterprises to develop digital distribution channels in a fast and timely manner by using digital technologies, cross organizational boundaries, connect online and offline, and create a "new retail" model. The reason why this paper introduces the "Technology-Organization-Environment" (TOE) theory to build a research framework is that the TOE framework is a theoretical model to study the influencing factors of enterprises' digital transformation, and it can analyze the process of enterprises' adoption of emerging digital technologies from the three dimensions of technology, organization, and environment [15]. The technological dimension includes the technological base and professional talents of the enterprise; the organizational dimension includes the dynamic capabilities of the enterprise; and the environmental dimension includes external factors such as the marketization process and the policy support of the digital economy. It has been shown that the proportion of skilled employees [16], R&D investment [17], and management characteristics [18] are the key internal factors of enterprises' digital transformation; and the "follow-the-leader effect" brought by the digital transformation of

peer enterprises is the main external factor of enterprises' digital transformation [19]. In addition, the improvement of business environment can promote enterprises to increase technological innovation and R&D investment, reduce transaction costs, and promote organizational change and business model innovation [20]. Therefore, the TOE framework provides a multidimensional analytical perspective for understanding the digital transformation of retail enterprises, which helps to deeply explore and assess the influencing factors and effects of digital transformation.

Digital resource infrastructure promotes the digital transformation of retail enterprises mainly in three aspects: technical empowerment, process reconstruction and value creation. First, through the application of Internet of Things, cloud computing and big data technologies, the digital resource infrastructure conducts all-round data collection and analysis of consumer behavior, supply chain status and market trends, which not only provides enterprises with accurate decision support, but also promotes data-driven scientific management [21]. Secondly, digital technology has reconstructed the operation process of retail enterprises, optimized the procurement, inventory and logistics links, and significantly improved the operation efficiency and reduced the cost, for example, through the intelligent supply chain management system and automated warehousing technology. Finally, digital resource infrastructure enables business model innovation and customer experience upgrading, which not only enhances consumers' shopping experience, but also helps enterprises realize value creation [22].

Digital human resources drive the digital transformation of retail enterprises mainly through three aspects: talent empowerment, organizational change and performance improvement. First, through data-driven recruitment, training and performance management, retail enterprises accurately match the highly skilled talents needed for digital transformation, providing human capital support for technology application and innovation. Second, enterprises optimize their internal communication and collaboration modes through the application of digital tools such as HRMS and collaboration platforms, promoting the flattening and agility of the organizational structure, and enhancing the responsiveness of enterprises to market changes [16]. Finally, digital HR improves employee efficiency and satisfaction through intelligent analysis and forecasting, and stimulates employee potential through personalized training programs and career development path design.

The ability to innovate is the core driving force behind the digital transformation of retail enterprises. On the one hand, in today's highly competitive market environment, the ability to innovate is not only reflected in the innovation of products and services, but also includes the innovation of business models, operational processes and technology applications. Retailers need to continuously explore new sales methods, optimize customer experience and develop personalized services to meet the increasingly diverse needs of consumers. For example, through the introduction of artificial intelligence and machine learning algorithms, enterprises can achieve accurate marketing and provide customized product recommendations; the application of emerging technologies such as unmanned stores and virtual reality shopping has enhanced the consumer experience. On the other hand, innovation capability is reflected in the organizational structure and management mechanism of enterprises, and flexible organizational forms and flat management structures help stimulate the creativity of employees, promote the flow and sharing of internal knowledge, and provide sustained momentum for digital transformation [24].

Absorptive capacity refers to an enterprise's ability to identify, acquire, digest and apply external knowledge, and is an essential and important factor for retail enterprises in the process of digital transformation. With the development of information technology, the speed of knowledge iteration accelerates, and enterprises have efficient absorptive capacity in order to maintain competitiveness [10]. On the one hand, retail enterprises actively acquire external technological resources and market information by establishing supply chain partnerships, participating in industry associations or joining technology innovation alliances; on the other hand, they build a more complete learning platform and training system internally to help employees familiarize themselves with and master the latest digital technologies and tools, and improve their professionalism. At the same time, enterprises support their employees to carry out project research and technology experiments while creating a favorable atmosphere of cooperation by carrying out cross-departmental knowledge exchange activities or setting up internal innovation funds, so as to enhance the overall absorptive capacity of the enterprise.

Integration capability, on the other hand, refers to an enterprise's ability to effectively combine internal and external resources to form a synergy effect in order to achieve the goal of digital transformation. Retail enterprises face many challenges in the transformation process, such as multi-channel integration, supply chain optimization, data asset management, etc., which all require strong integration capabilities to support [10]. Enterprises with strong integration capabilities are more capable of breaking down inter-departmental barriers and establishing integrated information systems, which contribute to the seamless connection between business segments. Specifically, by implementing an ERP system, retail enterprises can automate and intellectualize business processes such as purchasing, inventory, and sales to improve operational efficiency. On the other hand, for massive data assets,

enterprises apply big data analytics, cloud computing and other technical means with the help of data management platforms to explore the value of data and provide a scientific basis for management decisions [23]. The enhancement of integration capability not only helps optimize the allocation of internal resources, but also promotes interaction and cooperation with external ecosystems, creating favorable conditions for digital transformation [21].

With the increasing degree of marketization, retail enterprises are facing more intense market competition and long-tailed consumer demand, forcing them to enhance their competitiveness through digital transformation. On the one hand, increased marketization effectively improves information transparency, and consumers are able to use the Internet platform to obtain information about products and services, and make comparisons and choices. Reduced information asymmetry forces retailers to continuously optimize the quality of their products and services and improve operational efficiency to attract and retain customers [12]. On the other hand, the process of marketization promotes the blurring of industry boundaries, the boundaries between traditional retailing and e-commerce are gradually disappearing, and the integration of online and offline has become a new development trend. In order to adapt to the market changes, retailers have actively laid out omni-channel retailing to enhance customers' shopping experience to meet the challenges from emerging e-commerce and other cross-border competitors [10]. In addition, the liberalization of the market also brings more investment opportunities and technical cooperation possibilities for enterprises, which help introduce advanced digital technologies and management experience and accelerate the pace of digital transformation [13].

Digital economy policies provide clear guidance and support for the digital transformation of enterprises. A series of policy measures introduced by the government in the process of promoting the development of digital economy not only create a favorable external environment for retail enterprises, but also provide substantial help in terms of capital, technology and talents [25]. First, the state has issued the "14th Five-Year Plan for the Development of the Digital Economy", "Guidelines for the Construction of the National Data Infrastructure" and other digital economy development strategies and new infrastructure policies, which clearly define the key areas and development paths for the digital transformation of the retail industry, and reduce the uncertainty in the exploration of the digital transformation of enterprises. Second, the government has supported micro, small and medium-sized enterprises (MSMEs) and startups to carry out digitization projects through the establishment of special funds, tax incentives and other measures, reducing the financial burden on enterprises. Once again, the government also actively promotes the research, development and application of cutting-edge technologies such as 5G, IoT and AI, and provides technical support and infrastructural safeguards for retail enterprises [8]. Especially in terms of data protection and privacy security, the government has formulated relevant laws and regulations, which not only regulate the data processing behavior of enterprises, enhance consumers' trust, but also promote the formation of a healthy and orderly digital market environment [17]. Finally, the government organizes various training and exchange activities to train professionals with digital skills for retail enterprises and enhance the digitalization level of the whole industry [21].
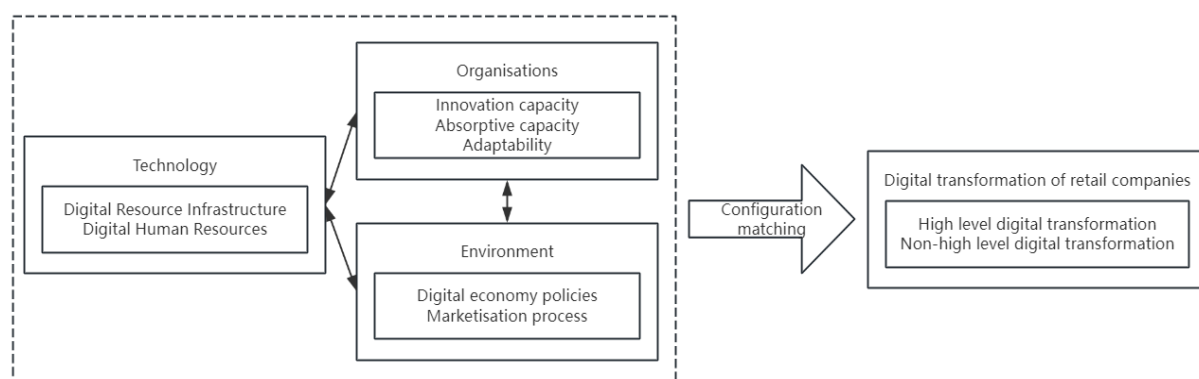

Figure 1. Theoretical model

In summary, this paper constructs a configuration model for digital transformation of retail enterprises as shown in Figure 1.

3. Research Design

3.1 Research Methodology

This paper uses qualitative comparative analysis (QCA) in order to systematically compare the relationship between combinations of conditions and digital transformation of retail firms in different cases.The core idea of QCA is the idea that multiple conditions can be combined in different ways to produce the same result, i.e., the principle of equivalence [26]. This approach emphasizes the matching and interdependence of conditions rather than the role of independent variables in traditional regression analysis. The types of qualitative comparative analysis methods mainly include clear set qualitative comparative analysis (csQCA), multi-valued set qualitative comparative analysis (mvQCA) and fuzzy set qualitative comparative analysis (fsQCA). Among them, csQCA is applicable to dichotomous variables, mvQCA is applicable to multi-categorical variables, and fsQCA is applicable to continuous variables. The article chooses fuzzy set qualitative comparative analysis because, on the one hand, fsQCA allows for partial affiliation of conditions, is able to simultaneously consider the effects of combinations of multiple antecedent conditions on the outcome condition, and is suitable for dealing with complex causality especially when there are different degrees of influence between conditions. Therefore, its results are usually easier to interpret than csQCA or mvQCA; on the other hand, the research object of this paper has 747 samples, which is a large sample study. Using the fsQCA method can handle a large amount of data and consider the ambiguity of the conditions in the analysis, and is able to utilize configuration theory, combined with Boolean algebra and set theory to resolve multiple concurrent causal relationships, while maintaining sensitivity to the original data [27].

3.2 Sample Selection and Data Sources

This paper takes A-share listed retail companies from 2011 to 2022 as the research object, and the sample is processed according to the following criteria: (1) excluding companies that have been specially handled due to financial anomalies (e.g., ST, ST*, and PT status) and delisted companies during the study period; (2) excluding the samples with missing data; and (3) applying an upward and downward 1% to the continuous variables with a shrinkage treatment. Finally, 747 annual observations of 74 listed companies are obtained, and the data are mainly from CSMAR database and Wind database.

3.3 Variable Design

3.3.1 Antecedent Variables

(1) Digital resource infrastructure. Referring to Wang and Jiang, the sum of digitization-related fixed assets and intangible assets in the sample firms is selected to take logarithms to measure the level of their digital resource infrastructure [28]. Specifically, based on the year-end intangible asset details disclosed in the notes to the financial reports of listed companies, the ratio of the digitization-related part of the enterprise to the total intangible assets is calculated as a measure of the enterprise's digital infrastructure. In terms of fixed assets, digital resources mainly include computers and electronic equipment, etc.; in terms of intangible assets, digital resources include various software and big data platforms, etc.

(2) Digital human resources. Drawing on Ruan's research, the ratio of the number of employees with a master's degree or higher to the total number of employees was used to measure [29]. This ratio reflects the importance that companies place on highly skilled and qualified personnel, as well as their need for specialized knowledge and innovation capabilities in the process of digital transformation.

(3) Innovation capacity. Drawing on Yang's research methodology, the data obtained from the standardized processing of the two indicators of the proportion of R&D investment and the proportion of technical personnel are summed up, and the final indicator obtained is used to measure the innovation capacity [30].

(4) Absorptive capacity. The ratio of R&D investment to operating revenue of the sample firms was used to measure absorptive capacity.

(5) Adaptive capacity. The coefficients of variation of the sample firms' annual major expenditures on R&D, capital and advertising are used to measure their adaptive capacity. This paper takes negative values for the coefficient of variation, and the larger the value of the adjusted coefficient of variation, the stronger the adaptive capacity of the enterprise.

(6) Digital economy policies. drawing on the research of Jin [31], first, the report texts and other related materials disclosed on government websites or other related platforms were crawled; second, the Chinese word segmentation process was carried out on the government work reports of each province, and the frequency of keywords related

to digital economy in the reports was counted; lastly, the total number of keyword word frequencies was logarithmized.

(7) Marketization process. The degree of marketization in each province was measured using the marketization index from the China Sub-Provincial Marketization Index Report published by Fan and Wang, et al. in 2021.

3.3.2 Outcome Variables

Digital Transformation of Retail Enterprises. This paper adopts text analysis and entropy value method to measure the metrics of digital transformation of retail enterprises, and the specific process is as follows: firstly, drawing on the research of Huang, M.Y., keywords are selected from the categories of digital business model, digital channel and digital technology and establish a lexicon of digital transformation features of retail enterprises [32]. Secondly, crawl the annual reports of the sample enterprises disclosed on the Juchao Information Network, select the MD&A part of the annual reports, and use the Chinese lexical library jieba in Python to perform word frequency statistics [17] . Among them, the MD&A section includes not only the management's discussion and analysis of the current business situation, future development trend and uncertainties faced by the enterprise, but also non-financial information of the enterprise, the management's sentiment tendency, and so on. The reason why the article chooses this section for text analysis is to exclude a large number of interfering texts that are not related to enterprise operations, in order to more accurately reflect the degree of importance attached to digital transformation by enterprise management. Finally, the word frequency statistics were processed by entropy method using Matlab, and the comprehensive score was used to measure the digital transformation level of retail enterprises. According to the calculation results, the obtained weight coefficients are 35.08%, 19.20% and 45.72% in order.

3.3.3 Variable Calibration

In this paper, the direct calibration method is used to calibrate each of the above variables to a fuzzy set, and the full affiliation, crossover, and full disaffiliation points for digital resource infrastructure, digital human resources, innovation capacity, absorptive capacity, adaptive capacity, the strength of policy support for the digital economy, the degree of marketization, and the digital transformation of retail enterprises are set to the quartile values of 80%, 50%, and 20%, respectively. Table 1 presents the calibrated anchor points and descriptive statistics of the variables.

Table 1. Calibration anchors and descriptive statistics for variables

Conditions and results		fuzzy set calibration			descriptive statistics			
		Full affiliation	intersection point	Totally unaffiliated	Mean	Str.	Min.	Max.
Technology	Digital resource infrastructure	2.1972	1.0986	0.0000	3.8909	0.9546	0.0000	7.1436
	Digital human resources	2.3680	0.6464	0.0000	1.4977	2.5628	0.0000	21.1000
Organisations	Innovation capacity	0.1982	0.0943	0.0066	0.1412	0.1839	0.0000	1.4377
	Absorptive capacity	0.0081	0.0000	0.0000	0.0066	0.0197	0.0000	0.2309
	Adaptive capacity	-0.8789	-1.2875	-1.7321	-1.2387	0.4060	-1.7321	-0.2638
Environment	Digital economy policy	3.4657	3.0445	1.7918	2.8989	0.7008	0.0000	4.3307
	The marketization process	11.3420	10.1040	7.4820	9.8828	1.7452	4.1380	13.3560
Results	Digital Transformation for Retailers	0.0016	0.0007	0.0002	0.0013	0.0022	0.0000	0.0227

4. Findings and Analysis

4.1 Necessity Analysis of Individual Conditions

To identify which preconditions are indispensable for the occurrence of outcomes, this paper conducts a necessity analysis of individual conditions, which facilitates simplification of the causal model, focuses on key drivers, and excludes irrelevant variables. This analysis helps to reveal the underlying patterns in complex social phenomena and ensures that subsequent grouping analyses are more precise and meaningful. As shown in Table 2, there are no conditions necessary to facilitate digital transformation of retail enterprises as the consistency levels of individual conditions are all below 0.90. This means that a single condition is not enough to become a bottleneck for digital transformation of retail enterprises, therefore, this paper starts from the grouping perspective to explore

in depth how multiple antecedent conditions work together to influence the realization of digital transformation of retail enterprises.

Table 2. Necessity Analysis

	High-level digital transformation		Non-high-level digital transformation	
	consistency	degree of coverage	consistency	degree of coverage
Digital resource infrastructure	0.7380	0.6971	0.4987	0.4606
~Digital resource infrastructure	0.4289	0.4577	0.6780	0.7205
Digital human resources	0.5533	0.5877	0.5291	0.5598
~Digital human resources	0.5856	0.5553	0.6110	0.5764
Innovation capacity	0.5428	0.5530	0.5777	0.5862
~Innovation capacity	0.5938	0.5854	0.5594	0.5493
Absorptive capacity	0.8157	0.6255	0.7406	0.5656
~Absorptive capacity	0.4335	0.6266	0.5096	0.7335
Adaptive capacity	0.5448	0.5500	0.5622	0.5654
~Adaptive capacity	0.5695	0.5664	0.5524	0.5473
Digital economy policy	0.6848	0.6686	0.4818	0.4685
~Digital economy policy	0.4556	0.4689	0.6592	0.6757
The marketization process	0.6307	0.6328	0.4976	0.4972
~The marketization process	0.4989	0.4993	0.4956	0.4945

4.2 Configuration Analysis

The results of the antecedent group state of the degree of digital transformation of the 74 sample companies are shown in Table 3. The consistency level of the overall solution is 0.8105, which is greater than the threshold of 0.75, and the coverage of the overall solution is 0.5882, which proves that the overall solution is highly reliable and explanatory. The analysis results show the existence of a total of five antecedent condition groupings: H1a, H1b, H2, H3, and H4. Among them, groupings H1a and H1b are grouped together due to the consistency of the core conditions. All of these consistency results are above the consistency criterion of 0.80, with an overall coverage of 0.5882. Table 3 demonstrates the final results of the grouping analysis, and each grouping that advances the digital transformation of retail enterprises is analyzed in detail in the following section.

Table 3. Configuration results for digital transformation of retail enterprises

	High-level digital transformation					Low-level digital transformation	
	H1a	H1b	H2	H3	H4	HN1	HN2
Digital resource infrastructure	●	●	●		●	⊗	
Digital human resources	⊗	⊗		⊗	●		
Innovation capacity	●	⊗	●	⊗	●	●	⊗
Absorptive capacity	●	●	●	●	●	⊗	⊗
Adaptive capacity	●	⊗	●	⊗	⊗	⊗	●
Digital economy policy	●	●		●		⊗	⊗
The marketization process	●		●	●	⊗		⊗
consistency	0.8672	0.8170	0.8477	0.8569	0.8170	0.8746	0.8408
original coverage	0.1300	0.3062	0.2440	0.2354	0.3062	0.3143	0.1799
Unique coverage	0.0415	0.0575	0.0788	0.0475	0.0575	0.0364	0.0318
Overall solution coverage	0.5882					0.4990	
Overall solution consistency	0.8105					0.8168	

Note: ● means that the core condition exists, ● means that the edge condition exists, ⊗ means that the core condition is missing, ⊗ means that the edge condition is missing, and blank means that the condition may or may not exist, the same below.

4.3 Group Analysis for Generating a High Level of Digital Transformation

4.3.1 Transformative Learning in Synergy with the Technological Environment

H1a with digital resource infrastructure and digital economy policy as the core conditions, and there is a close interaction between them and the marginal conditions such as innovative capacity, absorptive capacity, adaptive capacity, and marketization process; H1b with digital resource infrastructure and digital economy policy as the core conditions, absorptive capacity can make up for the enterprise's deficiencies in innovative capacity, adaptive capacity, and digital human resources, and provide a strong support for the digitalization of retail enterprise transformation provides strong support. It can be illustrated that: (1) When retail enterprises face a shortage of digital human resources, the synergy of innovation capacity, absorptive capacity and adaptive capacity can play an important complementary role and jointly promote the digital transformation process. First of all, retail enterprises with strong innovation ability can break through the traditional mindset and realize the value reshaping of existing human resources by reconstructing the business model and organizational structure. Specifically, enterprises can establish a hierarchical digital skills training mechanism, and design differentiated competency enhancement programs for different positions, so that the stock of human resources can quickly adapt to the needs of digital transformation [10]. Second, absorptive capacity helps enterprises effectively identify, acquire and utilize external digital resources. By establishing cooperative relationships with technology service providers, research institutions, etc., enterprises are able to make up for the shortage of internal digital talents. Finally, adaptive capacity enables enterprises to flexibly adjust their digital transformation strategies and realize progressive innovation under resource constraints [33]. (2) H1b differs from H1a in that the absorptive capacity of retail firms serves as a marginal condition that can complement innovative and adaptive capabilities to some extent. Under the grouping framework of H1b, on the one hand, retail enterprises with strong absorptive capacity can effectively identify, digest and utilize external knowledge resources to provide rich knowledge reserves for enterprise innovation. At the same time, by absorbing external advanced digital technologies and management experience, retail enterprises can break through the limitations of internal innovation resources and smoothly promote the digital transformation process. On the other hand, when the market environment or technological paradigm changes, enterprises with strong absorptive capacity can quickly acquire and internalize external knowledge, and promptly adjust their digital transformation strategies [24].

4.3.2 Coordinated Pioneering Technology-Organization-Environment Linkages

With digital resource infrastructure, innovation capability, adaptive capacity and marketization process as core conditions and absorptive capacity as peripheral conditions, H2 helps retail enterprises achieve a high level of digital transformation. The perfect digital resource infrastructure and strong innovation capability, which are complementary to each other, jointly accelerate the digital transformation process of retail enterprises. Digital resource infrastructure provides the underlying support for innovation practice, and its computing power reserve, data resources and platform architecture constitute the basic carrier for the realization of innovative ideas, which significantly improves the transformation efficiency of innovation results. At the same time, the in-depth development of innovation practice reacts to the infrastructure, and the continuous emergence of consumer demand and digital scenarios drive the iterative upgrading of the infrastructure, and this two-way interaction mechanism forms a positive feedback loop of continuous optimization [21]. In the process of the cycle, the adaptive ability and marketization process of enterprises are systematically improved. In other words, enterprises are able to accurately capture market signals, quickly adjust operational strategies, and maintain strategic flexibility when the competitive landscape changes. With enhanced adaptive capacity, retail firms are able to maintain competitive advantage in a dynamic market environment. In addition, by facilitating the acquisition and internalization of external knowledge resources, enterprises with stronger absorptive capacity are able to strengthen the synergistic effect of digital resource infrastructure and innovation capabilities to ensure the effective integration and value release of core conditions, thus promoting digital transformation [20].

4.3.3 Environment-Led Reactive Change Type

H3 shows that in the digital transformation process of retail firms, when faced with the absence of the dual core conditions of digital human resources and innovation capacity, as well as the insufficient marginal condition of adaptive capacity, the alternative core conditions constituted by absorptive capacity and digital economy policies can play a key compensatory role. First, firms with strong absorptive capacity are able to quickly learn and internalize advanced digital technologies and management experience, and even if their internal digital human resources are limited, they are able to bridge this gap through external knowledge absorption. Second, digital economy policies provide special financial support, tax incentives and other measures to lower the threshold of digital transformation of enterprises and provide external impetus for innovative activities [8] . Once again, the

marketization process, as a marginal condition, indirectly promotes the digital transformation of enterprises by promoting the factor flow and competition mechanism. Under the marketization environment, enterprises take the initiative to seek external cooperation and technology introduction in order to maintain competitiveness, thus compensating for the lack of innovation capacity to a certain extent [25]. Under the dual mechanism of capability substitution and policy-driven, retail enterprises are able to continue to push forward the digital transformation process and realize progressive capability enhancement and value creation despite the lack of core conditions.

4.3.4 Self-Driven Change-Oriented Technical Support

H4 takes digital resource infrastructure, digital human resources and innovation capacity as the core conditions and absorptive capacity as the marginal conditions, which can synergize and effectively complement the lack of adaptive capacity, while compensating for the lack of the marketization process as the marginal conditions, and jointly promote the process of digital transformation of retail enterprises. First, the construction of digital resource infrastructure lays the technical foundation for the digital transformation of retail enterprises. A perfect data processing and analysis system can support enterprises to realize real-time collection and analysis of operational data, providing quantitative basis for market trend research and consumer behavior insight. Secondly, in the human resources dimension, the reserve of digital professionals ensures the match between technology application and strategy implementation. It has been shown that management teams with digital skills can more effectively drive business process optimization and business model innovation [24]. Again, by establishing innovation incentives and investing in R&D, retailers can continue to explore emerging digital application scenarios and develop differentiated service models . Finally, retail enterprises with strong absorptive capacity can realize rapid response through knowledge reconstruction in the face of market fluctuations. Therefore, the synergy of multidimensional capabilities is conducive to retail enterprises maintaining a sustainable competitive advantage in a dynamic competitive environment.

4.4 Grouping Analysis that Produces a Non-High Level of Digital Transformation

This paper provides insights into two histogram results that lead to non-high-level digital transformation in retail firms. Specifically, histogram NH1 reveals that, against the backdrop of the absence of digital resource infrastructure and digital economy policies as core conditions, and the absence of absorptive and adaptive capacities as peripheral conditions, even if firms possess high innovative capabilities, it is still difficult for them to improve their level of digital transformation. In other words, the advantage of innovation capability cannot compensate for the lack of digital resource infrastructure, digital economy policy, absorptive capacity and adaptive capacity alone. Histogram NH2 further points out that when there are shortcomings at both the organizational level (including perceptual, absorptive, and integration capabilities) and the environmental level (digital economy policies, marketization process), even if a retail enterprise has strong adaptive capabilities, it is still difficult for its digital transformation to reach a high level. This suggests that although strong adaptive capacity has a positive impact on digital transformation of retail enterprises, its facilitating effect is difficult to be fully realized in the absence of both organizational and environmental factors, thus limiting the overall improvement of the digital transformation level of retail enterprises.

In summary, both grouping NH1 and grouping NH2 emphasize the importance of organizational factors in advancing digital transformation in retail enterprises and the decisive role of these factors in overcoming the limitations of technological endowments and the external environment to achieve a high level of digital transformation.

5. Robustness Tests

In order to ensure the authenticity of the grouping results, the original grouping results are analyzed for robustness in this paper. If the robustness results and the original grouping results are subset relations, the original grouping results are robust and the previous grouping analysis results are reliable. Firstly, the frequency of cases is adjusted, and Table 4 demonstrates the grouping result after adjusting the frequency of cases, which shows that the grouping result is basically consistent with the original grouping result.

Second, the PRI consistency threshold is adjusted, and Table 5 demonstrates the grouping results after adjusting the PRI, which shows that there is no fundamental change in the core and edge conditions of the grouping, and thus the causal relationship between the grouping conditions and the digital transformation of retail enterprises is stable.

Table 4. Robustness test results for the frequency of lifting cases

	High-level digital transformation					Low-level digital transformation	
	H1a	H1b	H2	H3	H4	HN1	HN2
Digital resource infrastructure	●	●	●		●	⊗	
Digital human resources	⊗	⊗		⊗	●		
Innovation capacity	⊗	⊗	●	⊗	●	●	⊗
Absorptive capacity	●	●	●	●	●	●	⊗
Adaptive	⊗	⊗	●	⊗	⊗	⊗	●
Digital economy policy	●	●		●		⊗	⊗
The marketization process	●	●	●	●	⊗		⊗
consistency	0.8170	0.8842	0.8477	0.8569	0.8390	0.8746	0.8408
original coverage	0.3062	0.2094	0.2440	0.2354	0.1530	0.3142	0.1799
Unique coverage	0.0517	0.0519	0.1085	0.0475	0.0502	0.0364	0.0318
Overall solution coverage	0.5927					0.5085	
Overall solution consistency	0.8089					0.8082	

Table 5. Robustness test results for raising PRI consistency thresholds

	High-level digital transformation					Low-level digital transformation	
	H1a	H1b	H2	H3	H4	HN1	HN2
Digital resource infrastructure	●	●	●		●	⊗	
Digital human resources	⊗	⊗	●	⊗	●	⊗	
Innovation capacity		⊗	●	⊗	●	●	⊗
Absorptive capacity	●	●	●	●	●	⊗	⊗
Adaptive capacity	●	⊗	●	⊗	⊗		●
Digital economy policy	●	●		●	●	⊗	⊗
The marketization process	●		●	●	⊗		⊗
consistency	0.8246	0.8984	0.8246	0.8569	0.8403	0.8746	0.8408
original coverage	0.2929	0.1658	0.2929	0.2354	0.1703	0.3143	0.1799
Unique coverage	0.4647	0.0206	0.0465	0.0480	0.0324	0.0179	0.0345
Overall solution coverage	0.5730					0.4865	
Overall solution consistency	0.8349					0.8330	

6. Discussion

This paper takes listed retail enterprises as the research object, introduces the framework of "technology-organization-environment", selects seven antecedents of digital resource infrastructure, digital human resources, innovation ability, absorption ability, adaptability, digital economy policy and marketization process, and conducts a group analysis by using the fsQCA method. And the study concludes as follows: first, the realization of digital transformation of retail enterprises relies on the combined effect of technological, organizational and environmental factors, which cannot be regarded as sufficient conditions for high-level digital transformation of enterprises individually, i.e., any single element is not sufficient to be a constraint for digital transformation of retail enterprises. Second, the study finds that the five types of groupings that promote high-level digital transformation of enterprises can be categorized into four types: The learning and transformation type of technology-environment synergy, the coordinated pioneering type of technology-organization-environment linkage, the environment-led type of passive change, and the technology-supported type of self-driven change, which demonstrate the diversity of multifactorial linkages in digital transformation. Finally, for retail enterprises, digital resource infrastructure plays a generally important role in the promotion of digital transformation, and to a certain extent, it can replace the innovative and adaptive capabilities to positively influence the enterprises. Among the environmental elements, digital economy policies are the main force driving digital transformation in retail firms. In the non-high level digital transformation level grouping pattern, there is a general lack of digital resource

infrastructure, innovation capacity, digital economy policies and marketization processes. Based on the above findings, we can put forward the following policy insights aimed at facilitating high-level digital transformation of retail enterprises and providing theoretical support and practical guidance for relevant policy formulation:

First, differentiated policies should be formulated for different grouping characteristics. For learning-converting retail enterprises with a synergistic technological environment, the Government can strengthen the construction of digital infrastructure, improve network coverage and service quality, and reduce the cost of access for enterprises. At the same time, it can help enterprises improve their digital skills and technology application level by organizing training and seminars, etc. For coordinated pioneering retail enterprises with technology-organization-environment linkage, the government should provide a full range of support, including but not limited to financial subsidies, tax incentives, introduction of talents, and other measures, to encourage enterprises to boldly try out new technologies and modes and expand their business areas; for environment-led passive transformational For environment-led passive change-oriented retail enterprises, the government should strengthen the publicity and interpretation of digital economy policies, help enterprises understand the policy guidance, and guide them to adapt to external changes and take the initiative to make internal adjustments; for technology-supported self-driven change-oriented retail enterprises, the government should create a good innovation ecosystem, such as streamlining the approval process, protecting intellectual property rights, and providing venture capital, to stimulate the intrinsic motivation of the enterprises, and encourage them to play a leading role in digital transformation. The government should create a favorable innovation ecosystem for them, such as simplifying the approval process, protecting intellectual property rights and providing venture capital, so as to stimulate their internal motivation and encourage them to play a leading role in digital transformation.

Secondly, the digital economy policy should be further improved and a sound monitoring and evaluation mechanism for its implementation should be established. In the process of promoting digital economy policies, specific operational details and support standards should be clarified to ensure that the policies are truly effective. For example, detailed guidelines on e-commerce development have been formulated to provide enterprises with a clear path of development, and the implementation rules of data protection regulations have been introduced to safeguard the rights and interests of consumers. At the same time, the effectiveness of the policies will be evaluated on a regular basis, and problems will be identified and solved in a timely manner. Independent evaluations will be conducted by third-party organizations to ensure the objectivity and fairness of the results.

Thirdly, the construction of public digital infrastructure should be strengthened and the digital resource infrastructure of enterprises should be improved. Increase investment in digital resource infrastructure, especially in the construction of 5G networks, cloud computing centers, big data platforms, etc., to provide retail enterprises with solid technical support. This will not only help improve the operational efficiency of enterprises, but also enhance their market competitiveness. Given that digital resource infrastructure can, to a certain extent, replace innovative and adaptive capabilities, the government should encourage enterprises to make full use of existing digital tools and services to reduce their reliance on their own R&D and adaptive capabilities. For example, it should promote the use of standardized e-commerce platforms and CRM systems, so as to reduce duplication of investment in IT construction by enterprises.

Fourth, Governments should take targeted measures to narrow the gap in the level of digital transformation among different enterprises. In response to the general lack of digital resource infrastructure, innovation capacity, digital economy policies and marketization processes, the government should target the introduction of policy tools. For example, it should comprehensively improve the digital quality of enterprises by strengthening infrastructure, providing innovation incentives and optimizing the business environment. In addition, it is important to increase investment in digital skills training, especially for employees of small and medium-sized enterprises (SMEs) and traditional retailers, to support them in acquiring the necessary digital skills and improve the overall quality of the workforce.

Acknowledgement

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