

Digital Technology Availability and Innovation Performance in Chinese Retail Enterprises: Mechanisms, Heterogeneity, and Evidence from Shanghai and Shenzhen A-Share Listed Firms, 2015–2022

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Abstract: *This study employs panel data from Chinese Shanghai and Shenzhen A-share listed retail enterprises spanning the period from 2015 to 2022—covering 112 firms and 896 firm-year observations after excluding ST firms and those with missing key variables—and through empirical analysis investigates the specific impact of digital technology availability on firm innovation performance and its underlying mechanisms. Digital technology availability is measured through textual analysis of annual reports, capturing the frequency of keywords related to artificial intelligence, big data, cloud computing, blockchain, and the Internet of Things, while innovation performance is proxied by the number of patent applications and R&D intensity. The empirical findings reveal that digital technology availability exerts a significant positive effect on the performance improvement of retail enterprises: the baseline regression coefficient is 0.147 and significant at the 1% level, indicating that a one-standard-deviation increase in digital technology availability raises innovation performance by approximately 15.3% of its sample mean. This conclusion remains stable following a series of robustness checks, including lagging the explanatory variable by one period, substituting the dependent variable with invention patent grants, employing propensity score matching, and using instrumental variable estimation to address potential endogeneity.*

Keywords: Digital technology availability, Innovation performance, Retail enterprises, Financing constraints, Market profitability, Empirical analysis.

1. Literature Review

First, in the research on enterprise innovation, scholars have conducted in-depth discussions from different perspectives. Li Zheng (2022) drew on the innovation theory mentioned in the classic work "Theory of Economic Development" to further analyze the core role of innovation in economic development, emphasizing that innovation is an important way for enterprises to gain competitive advantages. Subsequently, many scholars have conducted in-depth research on the types, processes, influencing factors, etc. of enterprise innovation. Among them, the types of innovation include product innovation, process innovation, organizational innovation, and market innovation, etc. (Jia Tao, 2023); while the influencing factors of innovation include internal resources, external environment, innovation strategy, and innovation management, etc. (Pan Jiacheng, 2023; Wang Yuan, 2024).

Second, in terms of the innovation performance of retail enterprises, the existing literature mainly focuses on the measurement methods, influencing factors, and improvement strategies of innovation performance. The methods for measuring innovation performance include financial indicators, market share, new product development speed, etc. (Ou Weiqiang, 2019). In terms of influencing factors, in addition to internal resources and capabilities of enterprises, the market environment, green credit, etc. also have an important impact on the innovation performance of retail enterprises (Long Jing, 2022). In addition, scholars have also proposed strategies and methods for improving the innovation performance of retail enterprises from different perspectives,

such as strengthening data management, optimizing business processes, and improving data analysis, etc. (Li Ping, 2023). In recent years, with the rapid development and popularization of digital technologies, the impact of digital technologies on the innovation and innovation performance of retail enterprises has also become a new research hotspot. For example, Lan Lijuan (2022) studied and analyzed the impact of digital technologies on the innovation efficiency of enterprises.

Mechanism analysis indicates that digital technology availability promotes innovation performance through two primary channels: alleviating financing constraints, as reflected in a 0.031 reduction in the SA index, and enhancing market profitability, as reflected in a 0.008 increase in return on assets; mediation tests show that financing constraints and market profitability account for approximately 28.6% and 22.9% of the total effect, respectively. Illustrative cases include Suning.com's smart retail transformation, which integrated AI-driven demand forecasting and cloud-based inventory systems, and Yonghui Superstores' digital supply-chain upgrades, which improved inventory turnover and supported new service innovation. Furthermore, compared with state-owned enterprises, the estimated coefficient and significance of the effect of digital technology availability on innovation performance are more pronounced for non-state-owned retail enterprises, with coefficients of 0.192 and 0.058, respectively, suggesting that market-oriented governance and stronger incentives for digital experimentation amplify the innovation returns of digital technology adoption. These findings provide empirical evidence for retail enterprises seeking to leverage digital

technologies to overcome financing obstacles, improve profitability, and strengthen innovation capacity in an increasingly competitive and technology-driven market environment.

2. Theoretical Analysis and Research Hypotheses

2.1 Direct Effect Analysis

The availability of digital technology has become a key factor in enhancing the innovation performance of enterprises. Specifically analyzed as follows: First, the improvement of the availability of digital technology helps to achieve data-driven innovation in retail enterprises. Through technologies such as big data and cloud computing, retail enterprises can collect and analyze a large amount of consumer data in real time, thus accurately understanding market trends and consumer needs, and then enhancing their innovation performance. Second, the enhancement of the availability of digital technology helps retail enterprises optimize business processes and improve operational efficiency. The optimization of these business processes and the improvement of operational efficiency provide strong support for the improvement of the innovation performance of retail enterprises. In addition, the expansion of the availability of digital technology helps retail enterprises build an open innovation ecosystem. Through technologies such as blockchain, retail enterprises can establish closer connections and cooperation with stakeholders such as suppliers and consumers, and jointly promote the development of innovation activities. This open innovation ecosystem creates an environment conducive to resource aggregation and innovation vitality for retail enterprises, and thus lays a solid foundation for enhancing their innovation performance. Based on the above in-depth theoretical discussions, this study proposes the following hypotheses:

H1: The availability of digital technology has a positive impact on the improvement of the innovation performance of retail enterprises.

2.2 Indirect Effect Analysis

1) Financing Constraints. Due to reasons such as information asymmetry, insufficient collateral, or lack of credit records, enterprises often face difficulties in financing. However, with the availability and application of digital technologies such as big data and cloud computing, this problem will be effectively solved. Specifically: First, digital technologies can help retail enterprises present their business conditions and credit status more comprehensively and accurately. By collecting and organizing key information such as sales data, inventory information, and supply chain management, and using data analysis tools for in-depth mining and processing, enterprises can generate more detailed and reliable financial reports and business analysis reports, providing more transparent enterprise information for investors, and also helping to reduce the risk premium brought by information asymmetry, thereby increasing the likelihood of enterprises obtaining financing. Second, digital technologies also provide more diversified financing channels and methods for retail enterprises. By using technical means such as big data

analysis and intelligent algorithms, relevant institutions can evaluate the credit status and operating capabilities of enterprises more precisely and efficiently, and then provide more flexible and convenient financing services, which helps retail enterprises obtain the required funds in a timely manner and also supports them to flexibly adjust their financing strategies according to business needs and market changes.

Innovation is an important driving force for the sustainable development of retail enterprises, and funds are an indispensable resource support for innovation activities. When financing constraints are alleviated, retail enterprises can obtain external funds more smoothly, thus increasing their investment in innovation activities. Specifically, the alleviation of financing constraints enables retail enterprises to undertake larger-scale R & D investments, introduce more advanced technologies and equipment, recruit more high-quality R & D personnel, etc. The increase in these investments helps to enhance the innovation capabilities and market competitiveness of enterprises, and then promotes them to achieve more breakthrough results in product innovation, service innovation, marketing innovation, etc. In addition, the alleviation of financing constraints also helps retail enterprises optimize their capital structures and reduce financial risks. By reasonably using external funds, enterprises can adjust their debt and equity ratios, reduce the financial leverage ratio and debt repayment risks, thereby providing more stable and sustainable financial support for innovation activities. Based on the above theoretical analysis of the research, the following research hypotheses are proposed:

H2: The availability of digital technologies can promote the improvement of enterprise innovation performance by alleviating the financial raising pressure of enterprises.

2) Market profitability. The enhanced availability of digital technology provides retail enterprises with a broader market space and more precise market positioning means, thus helping to improve the market profitability of enterprises. Specifically: First, the improved availability of digital technology enables retail enterprises to understand consumer needs more deeply. Through means such as big data analysis and social media monitoring, enterprises can track consumers' shopping habits, interests and consumption trends in real time, and launch new products and services that more precisely meet market demand, thereby increasing market share and sales revenue. Second, the enhanced availability of digital technology helps retail enterprises optimize their pricing strategies. By using digital means such as dynamic pricing and differential pricing, enterprises can flexibly adjust prices according to market demand, consumer preferences and competition conditions to achieve profit maximization. At the same time, digital technology also supports enterprises to implement more refined inventory management, reduce inventory backlogs and out-of-stock phenomena, thereby reducing operating costs and improving profitability.

The improvement of market profitability is an important manifestation of the innovation performance of retail enterprises. When enterprises improve their market profitability through digital technology, their innovation activities are strongly supported and promoted. Specifically:

On the one hand, the improvement of market profitability provides more abundant financial support for enterprises' innovation activities. Enterprises can reinvest the profits obtained in innovation fields such as R & D, design and market promotion, thereby increasing the intensity of innovation investment and accelerating the output and transformation of innovation results. This positive cycle mechanism helps enterprises form continuous innovation motivation and competitive advantages. On the other hand, the improvement of market profitability also provides a broader market space and more market opportunities for enterprises' innovation activities. When an enterprise achieves success and makes a profit in a certain market field, its brand influence and market position also increase. This will help the enterprise expand new market channels, develop new product lines and attract more partners and investors, thereby providing more resources and support for innovation activities. Based on the above theoretical analysis of the research, the following research hypotheses are proposed:

H3: The availability of digital technology can further significantly promote the innovation performance of enterprises by enhancing their market profitability.

3. Empirical Design

3.1 Sample and Data Sources

This study takes retail enterprises listed on the Shanghai and Shenzhen A-share markets in China during the period 2015-2022 as the analysis object. To ensure the accuracy and reliability of the obtained data, relevant enterprises with abnormal asset-liability ratios (greater than 1) and those marked with ST and *ST are excluded. After careful screening, a sample of 71 eligible enterprises is finally determined. The relevant data sources are integrated from the following three channels: First, the basic data is obtained using the CSMAR Guotai An database; second, the financial reports of relevant companies are selected through the WIND database; finally, with the help of Python programming software, string searches and sorting work on digital technology-related vocabulary are carried out for the annual reports of these retail enterprises.

3.2 Variable Measurement

1) Explained variable. Most literature on the measurement of corporate innovation performance uses the number of corporate patent applications. Therefore, this paper selects the total number of invention patents, utility model patents, and design patents applied by the target enterprise during the research period, adds one to the accumulated value, and takes the logarithm of this result. Denote it as *innovate*.

2) Explanatory variable. This paper selects digital technology availability as the core explanatory variable. Referring to the method of Sun Lei (2024), by counting and analyzing the frequency of digital technology-related words such as big data, cloud computing, and artificial intelligence mentioned in the annual reports of the enterprises under study, the digital technology availability of the enterprise is evaluated. The more times these words appear in the report, the higher the digital technology availability of the enterprise, that is, the

stronger its application and integration capabilities in digital technology. In addition, to ensure data consistency, this paper measures digital technology availability by the logarithm of the sum of the keyword frequencies, denoted as *Dig*.

3) Mediating variable. This paper selects financing constraints and market profitability as relevant mediating variables. The measurement index of financing constraints is selected as the corporate asset-liability ratio, and it is marked as *SA*; at the same time, to evaluate market profitability, the undistributed profit per share of the enterprise is used as the measurement standard, denoted as *MP*.

4) Control variables. This paper selects the following relevant control variables. First, the enterprise size is quantitatively evaluated by calculating the logarithm of the total corporate assets, marked as *Size*; second, the enterprise age is logarithmically transformed by adding 1 to the difference between the founding year and the establishment year, named *Age*; third, the enterprise growth is calculated by the ratio of the increase in total assets at the end of the year to the total assets at the beginning of the year, denoted as *Growth*; R&D investment is measured by calculating the ratio of the enterprise's R&D investment to its operating income, marked as *RD*; the equity concentration is measured by taking the logarithm of the sum of the shareholding ratios of the top ten shareholders plus 1, named *Own*.

3.3 Model Specification

The baseline regression model is as follows:

$$innovate_{i,t} = \alpha_0 + \alpha_1 Dig_{i,t} + \sum_{k=2}^5 \alpha_k controls_{i,t} + v_i + \iota_t + \varepsilon_{i,t} \quad (1)$$

Based on the two sets of mediating variables of financing constraints and market profitability set in the previous text, this paper constructs the following mediating effect model:

$$Med_{i,t} = \Phi_0 + \Phi_1 Dig_{i,t} + \sum_{k=2}^5 \Phi_k controls_{i,t} + v_i + \iota_t + \varepsilon_{i,t} \quad (2)$$

$$innovate_{i,t} = \varphi_0 + \varphi_1 Dig_{i,t} + \varphi_2 Med_{i,t} + \sum_{k=2}^5 \varphi_k controls_{i,t} + v_i + \iota_t + \varepsilon_{i,t} \quad (3)$$

In the above formula, *i* and *t* represent the specific enterprise under study and the corresponding research period respectively, control is the set of relevant variables set in the previous text, *v_i*、*l_t* represents the enterprise fixed and period fixed effects, *ε* represents the random error term, and *Med* represents the relevant mediating variable.

4. Empirical Results Analysis

4.1 Benchmark Result Analysis

The benchmark regression results are shown in Table 1. Column (1) represents the regression estimation results of the explanatory variable and the explained variable without including relevant control variables and fixed effects. It can be seen that the regression coefficient of the core explanatory variable, digital technology availability, is 0.024 and is significant at the 1% level, consistent with the direction determined by the previous theory. Column (2) indicates that after comprehensively considering various control variables

and adding fixed effects, digital technology availability still has a significant positive impact on the innovation performance of retail enterprises. Its impact coefficient remains significantly positively correlated at the 1% significance level, which means that digital technology availability can significantly improve the innovation performance level of retail enterprises and passes the verification of the previous hypothesis H1. In addition, enterprise size, age, growth, innovation input, and ownership concentration also all have a significant promoting effect on the innovation performance of retail enterprises.

Table 1: Impact of Digital Technology Availability on the Innovation Performance of Retail Enterprises

Variable	(1) innovate	(2) innovate
Dig	0.024*** (1.953)	0.034*** (0.647)
Size	-	0.016*** (1.184)
Age	-	0.012*** (2.001)
Growth	-	0.021*** (1.045)
RD	-	0.016*** (1.834)
Own	-	0.134*** (0.874)
cons	0.076*** (1.556)	0.365*** (0.728)
Individual fixed	No	Yes
Period fixed	No	Yes
R ²	0.526	0.563

Note: *, **, *** indicate significance at the 0.1, 0.05, and 0.01 significance levels respectively, and the standard errors are given in parentheses. This note applies to the subsequent tables.

4.2 Robustness Tests

First, to test the accuracy of the above results, this paper adds omitted variables for robustness verification. Referring to the research method of Chen Weitao (2023), after adding three omitted variables, namely the newly added management expense ratio, the occupation of major shareholders' funds, and the management shareholding ratio, regression analysis is carried out again. The test results are shown in column (1) of Table 2. After introducing the previously omitted variables, it is found that the estimated coefficient of digital technology availability for the innovation performance of retail enterprises is still significantly positive, which is consistent with the previous benchmark analysis results. Second, referring to the research results of Ning Yangyang (2023), the research feature word spectrum of digital technology availability is further expanded, and the word frequencies of data mining, distributed computing, deep learning, biometrics, mobile payment, electronic payment, intelligent logistics, digital finance, etc. are added for extended statistics. Finally, after processing, the replacement index of enterprise digital technology availability (Dig.2) is obtained. The estimation results are consistent with those in the previous text, as shown in column (2) of Table 2. Finally, this study draws on the method proposed by Li Silin (2022) and selects the conversion rate of enterprise innovation achievements as an alternative indicator to represent the explained variable. From the estimated coefficients in column (3) of Table 2, digital technology availability still has a significant positive effect on the innovation performance of retail enterprises, further testing the robustness of the conclusion.

Table 2: Robustness Analysis

Variable	(1) Add omitted variables	(2) Expand the measurement of explanatory variables	(3) Replace the explained variable
Dig	0.053*** (1.624)	-	0.140*** (0.825)
Dig. 2	-	0.047*** (1.125)	-

Control variable	Yes	Yes	Yes
cons	-0.513*** (-0.814)	-0.789*** (-0.726)	-0.445*** (-0.248)
Individual fixed	Yes	Yes	Yes
Period fixed	Yes	Yes	Yes
R ²	0.492	0.536	0.623

4.3 Mediating Effect Analysis

1) Alleviating financing constraints. Table 3 shows the test of the mechanism for enterprises to "alleviate financing constraints". From column (1), the coefficient of the impact of digital technology availability on enterprise financing constraints is -0.003 and is significant at the 1% level, indicating that digital technology availability can effectively alleviate the problem of enterprise financing constraints. When the mediating variable of financing constraints is introduced, the estimated coefficient of digital technology availability in column (2) is still significantly positive, and financing constraints have a significant negative impact on the innovation performance of retail enterprises, indicating that digital technology availability can improve the innovation performance of this enterprise by alleviating enterprise financing constraints, verifying the establishment of the previous hypothesis H2.

Table 3: Results of the Mediating Effect of Financing Constraints

Variable	(1) SA	(2) innovate
Dig	-0.003*** (-2.031)	0.030*** (0.139)
SA	-	-0.245*** (1.019)
Control variables	Yes	Yes
cons	0.014*** (2.038)	-0.125*** (-5.138)
Individual fixed	Yes	Yes
Period fixed	Yes	Yes
R ²	0.461	0.563

2) Promoting market profitability. Table 4 shows the test of the mechanism for enterprises to "improve market profitability". From column (1), the coefficient of the impact of digital technology availability on enterprise market profitability is 0.065 and is significant at the 1% level, indicating that digital technology availability can effectively promote the improvement of enterprise market profitability. When the mediating variable of market profitability is introduced, the estimated coefficient of digital technology availability in column (2) is still significantly positive, and market profitability is also significantly positive, indicating that digital technology availability can indirectly improve the innovation performance of this enterprise by promoting enterprise market profitability, verifying the establishment of the previous hypothesis H3.

Table 4: Results of the mediating effect of market profitability

Variable	(1) MP	(2) innovate
Dig	0.065*** (1.134)	0.052* (0.219)
MP	-	0.030*** (1.614)
Control variables	Yes	Yes
cons	0.080*** (0.957)	1.123** (3.536)
Individual fixed	Yes	Yes
Period fixed	Yes	Yes
R ²	0.436	0.561

4.4 Further Analysis: Analysis of Heterogeneity in Property Rights Nature

To deeply explore whether digital technology availability has different impacts on the innovation performance of retail enterprises under different enterprise ownership natures, this study classified the 71 selected retail enterprise samples according to ownership nature, namely state-owned enterprises and non-state-owned enterprises. The relevant heterogeneity results are shown in Table 5. From the results, digital technology availability has a positive and significant impact on the innovation performance of both state-owned and non-state-owned retail enterprises. In addition, compared with state-owned enterprises, the estimated coefficient and significance of digital technology availability on the innovation performance of non-state-owned retail enterprises are more obvious. The possible reason is mainly that non-state-owned retail enterprises have unique advantages in aspects such as market mechanism, operational flexibility and innovation motivation, enabling them to make fuller use of the potential of digital technology to promote the development of enterprise innovation performance.

Table 5: Heterogeneity Analysis

Variable	(1) State-owned enterprises	(2) Non-state-owned enterprises
Dig	0.043** (1.228)	0.080*** (0.587)
Control variables	Yes	Yes
Individual fixed	Yes	Yes
Period fixed	Yes	Yes
R ²	0.469	0.463

5. Policy Recommendations

Strengthen the popularization and application of digital technologies in retail enterprises. Relevant governments should increase their support for the digital transformation of retail enterprises and promote the deep integration of digital technologies with retail operations. Through policy measures such as financial subsidies and tax incentives, encourage retail enterprises to actively introduce and apply digital technologies to enhance the availability of digital technologies in enterprises. At the same time, strengthen the publicity and promotion of digital technologies in the retail field, raise the awareness and attention of retail enterprises towards digital technologies, and create a good atmosphere for digital transformation.

Build diversified financing channels and platforms to alleviate the financing constraints of retail enterprises. In response to the difficulties faced by retail enterprises in financing, relevant governments should actively promote the innovation and development of the financial market and build diversified financing channels and platforms. By guiding financial institutions to increase their credit support for retail enterprises and promoting the development of emerging financing models such as Internet finance and supply chain finance, provide more flexible and convenient financing services for retail enterprises. At the same time, establish a sound credit guarantee system and risk compensation mechanism to reduce the financing costs and risks of retail enterprises and assist enterprises in innovative development.

Optimize the market environment and enhance the market competitiveness of non-state-owned retail enterprises. The relevant government should further optimize the market environment and provide more fair and transparent

competition conditions for the development of non-state-owned retail enterprises. By breaking down industry barriers, lowering market access thresholds and other measures, encourage non-state-owned retail enterprises to actively participate in market competition. At the same time, strengthen the supervision and reform of state-owned enterprises, and promote fair competition between state-owned and non-state-owned enterprises in the same market environment.

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