

Digital Economy, Industrial Upgrading, and Physical Retail Efficiency: A Study Based on Mediation and Heterogeneity

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Abstract: *From the perspective of industrial upgrading, this study examines the impact of the digital economy on physical retail efficiency. Theoretical analysis and empirical testing indicate that digital economy development significantly enhances retail efficiency through four pathways—precise market analysis, intelligent supply chain management, personalized customer experience, and business model innovation—with industrial upgrading serving as a key mediator. Heterogeneity analysis reveals marked differences in benefits across retail subsectors. Corresponding policy recommendations are proposed to inform the digital transformation of the physical retail industry.*

Keywords: Digital economy, Physical retail efficiency, Industrial upgrading, Mediation effect, Digital transformation.

1. INTRODUCTION AND LITERATURE REVIEW

The report of the 20th National Congress of the Communist Party of China clearly states that "we will accelerate the development of the digital economy, promote its deep integration with the real economy, and build internationally competitive digital industrial clusters." In the context of the increasingly digital global economy, the digital economy has evolved into the core driving force for economic growth and industrial upgrading. This is not only a profound insight into the current economic situation but also an accurate grasp of future development trends. With the deepening of the new round of scientific and technological revolution and industrial transformation, digital technologies and the digital economy are integrating into all fields and the whole process of economic and social development at an unprecedented speed and scale. This transformation has not only reshaped the global innovation landscape and economic structure but also brought opportunities for the transformation and upgrading of traditional physical retail. With its unique advantages such as high efficiency, low cost, and personalization, the digital economy is profoundly changing the operation mode and market pattern of physical retail. In the wave of the digital economy, physical retail faces unprecedented opportunities and challenges. On the one hand, by using advanced technological means such as big data, cloud computing, and artificial intelligence, physical retail can achieve precise marketing, improve operational efficiency, and expand omni-channel sales, thus effectively coping with the competitive pressure from e-commerce platforms. On the other hand, physical retail also needs to face up to issues such as the technological threshold brought by digital transformation, consumer privacy protection, and the competition and cooperation relationship with new business forms.

The role of the digital economy in promoting the physical retail industry has been widely recognized. In terms of the mechanism research on the impact of the digital economy on the physical retail industry, Shen Huaxia and Yin Feng (2019) pointed out that the digital economy, through advanced technological means such as big data and cloud computing, has significantly changed consumers' shopping behaviors and brought about an innovation in the operation mode of the physical retail industry. These technological means provide the physical retail industry with precise market analysis and consumer behavior prediction tools, thereby optimizing its operation efficiency and decision-making process. However, Liu Shuangjun (2020) also pointed out that current research mostly focuses on the macroeconomic level, and there is still a relative lack of detailed analysis at the micro level (such as the operation of specific enterprises and stores). In terms of the research on the digital transformation strategy of the physical retail industry, the research by Hou Yuwei (2020) shows that in order to adapt to the rapid development of the digital economy, the physical retail industry must carry out technological upgrades and business model innovations. These transformation strategies include, but are not limited to, the deep integration of online and offline, the construction of an intelligent logistics distribution system, etc. However, existing research often lacks an in-depth evaluation of the specific implementation steps and actual effects of digital transformation, which is a direction that needs to be further strengthened in future research (Ma Xiaojun et al., 2022). In addition,

the integration mode of the digital economy and the physical retail industry has also received extensive attention. For example, Han Guyuan et al. (2023) explored the new business models of the combination of the digital economy and the physical retail industry, and particularly emphasized the important role of the O2O model in promoting the growth of the physical retail industry. However, when analyzing the integration mode, these studies still lack an in-depth analysis of the specific operation steps, implementation difficulties, and possible challenges in the integration process (Zhang Chen and Tang Weibo, 2023). To sum up, although current research on the impact of the digital economy on the physical retail industry has made some progress, there is still room for further deepening in terms of micro-level analysis, the implementation and effect evaluation of digital transformation strategies, and the specific operation of the integration mode.

Therefore, this paper hopes to study the impact of the digital economy on the efficiency of the physical retail industry from the perspective of industrial upgrading by deeply analyzing the characteristics and development trends of the digital economy, as well as the current situation and problems of the physical retail industry. This not only helps to deepen the understanding of the law of the integrated development of the digital economy and the real economy, but also provides theoretical support and policy recommendations for the digital transformation and industrial upgrading of the physical retail industry.

2. THEORETICAL ANALYSIS

In the macro context of industrial upgrading, the impact of digital economy on the efficiency of physical retail has become the focus of research. This impact mechanism is not single or linear, but a complex system composed of multiple intertwined and interacting factors. This paper attempts to deeply analyze how digital economy affects physical retail and 进而 influences its efficiency from four aspects: precise market analysis, intelligent supply chain, personalized customer experience and business model innovation.

First of all, precise market analysis is of great significance for improving the efficiency of physical retail. In the era of booming digital economy, the wide application of cutting-edge technologies such as big data and artificial intelligence endows physical retail enterprises with unprecedented capabilities, enabling them to obtain, process and analyze market data at higher speeds and accuracies. These data not only cover basic information such as consumers' shopping habits, preferences and behavior patterns, but also important information such as market trends and competitor situations. Through precise market analysis, physical retail enterprises can more accurately grasp market dynamics, understand consumer needs, and thus formulate more precise and effective market strategies. This not only helps to improve sales performance, but also enhances the market sensitivity and response speed of enterprises, enabling them to maintain a leading position in the fierce market competition.

Secondly, the intelligent transformation of the supply chain is particularly important in the digital economy era. In the traditional mode, the supply chain management of physical retail enterprises is often troubled by problems such as information asymmetry, slow response speed and inventory backlog. These problems not only seriously affect the operation efficiency of enterprises, but also increase the operation costs of enterprises. However, in the digital economy era, with the help of advanced technologies such as the Internet of Things and cloud computing, physical retail enterprises can transform their supply chains intelligently. The intelligent supply chain management system can monitor inventory situations in real time, optimize logistics distribution routes, predict market demands, etc., thus significantly improving the collaborative efficiency and response speed of the supply chain. This not only helps to reduce inventory costs and waste, but also enhances the overall operation efficiency and competitiveness of enterprises, enabling them to remain invincible in the fierce market competition.

Secondly, the personalization of the customer experience is a new manifestation of the competitiveness of physical retail in the digital economy era. With the increasing diversification and personalization of consumer demands, the traditional and uniform shopping experience can no longer meet consumer needs. They pursue a more personalized, convenient and efficient shopping method. Therefore, physical retail enterprises need to rely on digital technologies to provide consumers with more personalized services and experiences. For example, using intelligent recommendation systems to recommend products that match consumers' tastes and needs; using augmented reality technology to provide services such as virtual fitting for consumers; interacting and communicating with consumers through social media platforms, etc. These personalized services and experiences can not only improve consumer satisfaction and loyalty, but also stimulate consumers' desire to purchase and increase consumer stickiness, thus bringing new growth points and competitive advantages to physical retail enterprises.

Finally, business model innovation is also the key to the competitiveness of physical retail in the digital economy era. The traditional physical retail model is often restricted by factors such as time and space and is difficult to meet the increasingly diverse needs of consumers. In the digital economy era, physical retail enterprises can break these restrictions by innovating business models. For example, the O2O model combines the advantages of online and offline to provide consumers with more convenient and rich shopping options; unmanned convenience stores use automation technology to achieve 24-hour unattended operation to meet consumers' immediate needs; intelligent retail improves the degree of shopping intelligence and convenience by introducing technologies such as artificial intelligence and the Internet of Things. These innovative models can not only better meet consumer needs, but also bring new growth points and profit margins to physical retail enterprises. At the same time, business model innovation also promotes the transformation and upgrading and sustainable development of physical retail, making physical retail show new vitality and vigor in the digital economy era.

3. RESEARCH DESIGN

3.1 Variable Design

Explained variable: Efficiency of physical retail (eff). To accurately measure the efficiency of physical retail, this paper uses the DEA-Malmquist index method in data envelopment analysis for calculation. The specific input and output indicators of the efficiency of physical retail are shown in Table 1.

Table 1: Input and Output Indicators of the Efficiency of Physical Retail

Type	Indicator	Unit
Output Indicator	Main Business Income of Above-Norm Retail Enterprises by Region	100 million yuan
	Main Business Income of Above-Norm Retail Enterprises by Region and National Economic Industry	100 million yuan
	Main Business Income of Shanghai- and Shenzhen-listed Retail Enterprises by Region	100 million yuan
Input Indicator	Fixed Assets of Above-Norm Retail Enterprises by Region	100 million yuan
	Fixed Assets of Above-Norm Retail Enterprises by Region and National Economic Industry	100 million yuan
	Fixed Assets of Shanghai- and Shenzhen-listed Retail Enterprises by Region	100 million yuan
	Number of Employees of Above-Norm Retail Enterprises by Region	person
	Number of Employees of Above-Norm Retail Enterprises by Region and National Economic Industry	person
	Employee Salaries of Shanghai- and Shenzhen-listed Retail Enterprises by Region	100 million yuan

Explanatory variable: Level of digital economy development (dig). To measure the level of digital economy development, this paper comprehensively considers multiple dimensions such as Internet penetration rate, proportion of relevant employees, relevant output, mobile phone penetration rate, and digital inclusive finance. All indicators are calculated using the entropy method, and the specific indicator selection is shown in Table 2.

Table 2: Measurement indicators of the digital economy development level

First-level indicator	Second-level indicator	Indicator weight
Digital infrastructure	Number of Internet broadband access users per 100 people	0.067
	Proportion of employees in computer services and software	0.145
Digital industries	Per capita telecommunications services	0.274
	Per capita postal services	0.241
	Proportion of postal and telecommunications services in GDP	0.187
Digital inclusive finance	Coverage breadth	0.085
	Usage depth	
	Digitalization degree index	

Mediating variable: Industrial upgrading (update). Industrial upgrading mainly refers to the optimization of industrial structure or the improvement of industrial efficiency. Therefore, this paper uses the proportion of the added value of the tertiary industry in GDP to measure the level of industrial upgrading in each region.

Control variables. This paper considers the following key control variables: Construction of circulation channels (circu), measured by comparing the sales of above-scale wholesale and retail enterprises in each region; Infrastructure construction (inf), calculated by dividing the total mileage of highways, waterways, and railways by the area of the region; Local economic level (gdp), evaluated based on per capita GDP; Scale of retail business (scale), based on the sales of above-scale retail enterprises; Degree of government support (gov), reflected by the

proportion of fiscal expenditure in GDP.

3.2 Model Design

To deeply explore the specific impact of the digital economy on the efficiency of physical retail, this paper uses panel data for empirical analysis and testing, and constructs the following model:

$$\text{eff}_{it} = \alpha + \beta * \text{dig}_{it} + \gamma * \text{control}_{it} + \mu_{it} + \varepsilon_i + v_{it}$$

Among them, t represents the year, and i represents the province. eff represents the total factor productivity of the retail industry in each region of China; dig_{it} represents the level of digital economy development; control is the control variable; ε_i is used to control the regional fixed effect, μ_t is used to control the time fixed effect, and v_{it} is the random disturbance term.

3.3 Data Sources

This paper selects the panel data of 29 provinces in China (excluding Xinjiang, Tibet, Hong Kong, Macao and Taiwan regions) from 2012 to 2021. The data mainly comes from the "China Statistical Yearbook" and the "China Foreign Trade and Economic Statistics Yearbook", and also uses the data publicly disclosed by the research group of the Digital Finance Research Center of Peking University and the China E-commerce Research Center. For some retail enterprises listed on the Shanghai and Shenzhen stock exchanges, their financial data is obtained through the Wind database.

4. EMPIRICAL ANALYSIS

4.1 Full Sample Analysis

As can be seen from the data presented in Table 3, regardless of whether fixed effects, random effects, or pooled OLS methods are used for analysis, the coefficient of the digital economy development level (dig) is significantly positive and statistically significant at the 1% confidence level. This result indicates that the development of the digital economy has a significant and positive impact on the efficiency of physical retail. Specifically, with the widespread application of digital technologies and the continuous improvement of the degree of digitalization, physical retail has achieved substantial improvements in aspects such as supply chain management, consumer experience optimization, and marketing strategy innovation, thereby effectively enhancing overall efficiency. In terms of control variables, the coefficient of the construction of circulation channels (circu) is significantly positive and significant at the 5% confidence level. This shows that the construction and improvement of circulation channels also have a positive promoting effect on the efficiency of physical retail. The unobstructed circulation channels between wholesale and retail enterprises contribute to improving the efficiency of commodity circulation and thus promoting the steady development of physical retail. The coefficient of the infrastructure construction level (inf) is positive under all three analysis methods and significant at the 10% confidence level. This indicates that although infrastructure construction has a positive impact on the efficiency of physical retail, this impact is relatively weak. This may be because, although the improvement of transportation infrastructure provides convenient conditions for commodity circulation, its role in enhancing the efficiency of physical retail is relatively limited. The coefficients of the local economic development level (gdp) and retail scale (scale) are both significantly positive and significant at the 1% confidence level. This shows that the local economic development level and retail scale have a significant and positive impact on the efficiency of physical retail. With the continuous prosperity of the local economy and the gradual expansion of the retail scale, physical retail has obtained more development opportunities and resource support, thereby effectively enhancing efficiency.

Table 3: Full Sample Regression Analysis

Variable	(1) Fixed effects	(2) Random effects	(3) Pooled OLS
dig	0.385*** (3.281)	0.422*** (4.125)	0.398*** (3.687)
circu	0.192** (2.493)	0.211** (2.672)	0.201** (2.548)
inf	0.127* (1.892)	0.143* (1.986)	0.134* (1.924)
gdp	0.546*** (5.679)	0.582*** (6.124)	0.561*** (5.893)
scale	0.274*** (3.562)	0.298*** (3.871)	0.283*** (3.698)
Constant term	3.082* (1.768)	4.093** (2.436)	3.087*** (3.328)
Regional fixed effects	Yes	No	Yes
Time fixed effects	Yes	No	Yes
R^2	0.652	0.638	0.645

Note: ***, **, * indicate significance at the 1%, 5% and 10% levels respectively. The values in parentheses are *t* values, the same below.

4.2 Industry-specific Analysis

According to the industry classification standard, the retail industry is divided into the following sub-sectors: (1) General retail; (2) Specialized retail of food, beverages and tobacco products; (3) Specialized retail of textiles, clothing and daily necessities; (4) Specialized retail of cultural, sports goods and equipment; (5) Specialized retail of medicines and medical devices; (6) Sale of motor vehicles, motorcycles, parts and accessories, fuels and other power; (7) Specialized retail of household appliances and electronic products; (8) Specialized retail of hardware, furniture and interior decoration materials. From the perspective of industrial upgrading, the digital economy has had a significant positive impact on the efficiency of each sub-sector of the physical retail industry, as shown in Table 4. The coefficient of the digital economy (dig) is positive in all sub-sectors and has passed the significance test, indicating that the development of the digital economy has a positive effect on improving the efficiency of the physical retail industry. From different sub-sectors, the digital economy has the most significant effect on improving the efficiency of the retail industry of medicines and medical devices, with a coefficient of 0.435, which may be related to the relatively high demand for information technology and digital applications in this industry. For the food, beverage and tobacco products industry, the impact of the digital economy is relatively small, with a coefficient of 0.368, but still has a significant positive effect.

Table 4: Industry-specific regression analysis

Variable	Industry (1)	Industry (2)	Industry (3)	Industry (4)	Industry (5)	Industry (6)	Industry (7)	Industry (8)
挖掘	0.423 * 10 (3.652)	0.368 and medium (3. 125)	0.412* (3.548)	0.391*** (3.421)	0.435*M (3.812)	0.376 (3.287)	0.405 * 10 (3.516)	0.388 in (3.394)
循环	0.223** (2.678)	0.174* (2.136)	0.211** (2.589)	0.198** (2.437)	0.235 (2.784)	0.186* (2.293)	0.204** (2.512)	0.192** (2.406)
inf	0.148* (1.975)	0.112 (1.653)	0.137* (1.914)	0.129* (1.812)	0.156* (2.038)	0.121 (1.768)	0.139* (1. 936)	0.127* (1.849)
gdp	0.582* (6.235)	0.523* (5.712)	0.571* (6.148)	0.554*k* (5.987)	0.593* (6.382)	0.531* (5.826)	0.567 * 10 (6.093)	0.542* (5.918)
规模	0.291** (3.784)	0.258*** (3.426)	0.283*** (3.712)	0.272*** (3.594)	0.302*** (3.918)	0.264*# (3.506)	0.288*h* (3. 762)	0.276* (3.648)
Constant term	3.197* (2.532)	3.578** (3.268)	3.691* (4.463)	4.084** (6.365)	3.103** (2.428)	4. 182* (1.742)	3. 994** (2.116)	3.887* (1.812)
Regional fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.671	0.654	0.668	0.659	0.675	0.661	0.670	0.663

4.3 Mechanism Analysis

To further explore the internal mechanism of the impact of digital economy on the efficiency of physical retail, this paper introduces the "mediation effect" theory for in-depth analysis. Under this framework, special attention is paid to the role played by industrial upgrading as a mediating variable. Table 5 details the results of the mechanism analysis. In column (1), the regression coefficient of the digital economy development level is 0.398, and it is significantly positive at the 1% level. This indicates that the development of digital economy has an obvious promoting effect on the efficiency of physical retail, which is in line with the expectations of this paper. In column (2), the impact of the digital economy development level on industrial upgrading is examined. The regression coefficient is 0.250, which is significantly positive at the 5% level, indicating that the digital economy also plays a positive role in promoting industrial upgrading. To comprehensively explore the relationship among digital economy, industrial upgrading and the efficiency of physical retail, in column (3), both the digital economy development level and industrial upgrading are included in the model. The results show that when considering the mediating role of industrial upgrading, the regression coefficient of the digital economy development level decreases slightly, but it is still significantly positive at the 1% level (the coefficient is 0.385). At the same time, the regression coefficient of industrial upgrading is 0.230, and it is significant at the 5% level. This indicates that industrial upgrading plays an important mediating role in the impact of digital economy on the efficiency of physical retail. This finding not only deepens the understanding of the relationship between digital economy and physical retail, but also provides useful inspiration for the transformation and development of physical retail in the digital economy era. Future research can further explore the dynamic relationship among digital economy, industrial upgrading and the efficiency of physical retail, as well as the heterogeneous effects among different

regions.

Table 5: Results of Mechanism Analysis

Variable	eff	update	eff
dig	0.398*** (3.687)	0.250** (2.478)	0.385*** (3.546)
update	-	-	0.230** (2.387)
Constant term	4.087*** (2.687)	4.908*** (3.124)	5.091*** (2.812)
Control variables	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
R^2	0.645	0.648	0.655

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

This paper deeply explores the impact mechanism of digital economy on the efficiency of physical retail under the perspective of industrial upgrading. The digital economy effectively promotes the efficiency improvement of physical retail through paths such as precise market analysis, intelligent supply chain management, personalized customer experience, and business model innovation. Through empirical analysis, this paper finds that the development of digital economy significantly improves the efficiency of physical retail, and industrial upgrading plays an important mediating role in this process. The digital economy has a positive impact on the efficiency of each sub-sector of physical retail, but the degree of impact varies. This indicates that different sub-sectors benefit differently in the process of digital transformation and targeted digital transformation strategies need to be formulated. Based on the above analysis, this paper puts forward the following suggestions:

First, promote business model innovation and diversified development. Under the background of the rapid development of digital economy, the government should use various policy tools, such as financial support and tax exemptions, to encourage physical retail enterprises to explore and innovate business models. For example, encourage the development of new business models such as O2O and smart retail to meet the increasingly diverse needs of consumers. In addition, the government should also support retail enterprises to expand into diversified business fields, such as cross-border e-commerce and social commerce, to enhance the overall competitiveness and market adaptability of enterprises.

Second, strengthen the supervision of data security and privacy protection. With the deepening of digital transformation, the government should establish and improve the legal and regulatory system for data security and privacy protection and increase law enforcement efforts. Require physical retail enterprises to strictly abide by laws and regulations in the links of data collection, storage, and use to ensure the security of consumer data and the privacy rights and interests are not violated.

Third, optimize the market environment and fair competition mechanism. The government should strive to break down industry barriers and regional restrictions and promote the formation of a unified, open, competitive, and orderly market environment. By simplifying the approval process and lowering the market access threshold and other measures, stimulate market vitality and innovation drive. At the same time, strengthen market supervision and anti-unfair competition law enforcement efforts to prevent the occurrence of market monopolies and unfair competition behaviors and ensure the healthy development of physical retail in a fair market competition.

Fourth, promote the deep integration and development of online and offline. The government should encourage physical retail enterprises to actively embrace digital transformation, carry out in-depth cooperation with e-commerce platforms, and achieve the optimal allocation and complementary development of online and offline resources. Expand the sales market and enhance brand influence through online channels; use offline physical stores to provide high-quality consumption experiences and after-sales services, and enhance consumer stickiness and loyalty. The government can promote the in-depth progress of online and offline integration through policy support and capital guidance.

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