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Research on the Facilitating Role of the Digital Economy in Industrial Structure Upgrading -- An Empirical Analysis Based on Panel Data from Anhui Province

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Abstract. The digital economy is playing an increasingly prominent role as a key driver for promoting high-quality economic development and upgrading industrial structure. This study utilizes panel data from 16 prefecture-level cities in Anhui Province from 2011 to 2022 to conduct an empirical analysis. The results demonstrate that rapid progress in the development of the digital economy positively contributes to industrial structure upgrading, facilitating both the advancement and rationalization of the industrial structure. Based on the research findings, the following recommendations are proposed: local governments in Anhui Province should implement policies to support the sustained and healthy development of the digital economy and improve the integration of industry digitization and digital industrialization. By enhancing the application of digital technology in industries and increasing the proportion of digital technology adoption, continuous efforts should be made to strengthen the integration of industry and digital technology, improve the level of industrial informatization and intelligence, thereby facilitating the enhancement of industrial structure.

Keywords: Digital Economy; Industrial Structure Upgrading; Enabling Effect; Anhui Province.

1. Introduction

Scholars both domestically and internationally have conducted extensive research on the enabling effects of the digital economy on industrial structure upgrading. They have explored how digital technologies and the digital economy promote interconnectivity and integration among different industries, as well as how digital transformation influences the production efficiency and models of traditional industries, thereby driving their upgrading. Scholar Cao Yafang (2019) found that the widespread application of digital technologies has had a positive impact on the economic transformation and upgrading of Shanxi Province, proposing the promotion of industrial digital integration [1]. Chen Xiaodong, Yang Xiaoxia, et al. (2021), through model-building and dissipative structure theory, found that, the impact of the digital economy on China's industrial structure upgrading exhibits distinct phased characteristics [2]. They pointed out that the digital economy is a new engine that will lead industrial structure upgrading and drive economic development in the futurethat,hat efforts to build the digital economy must be accelerated. At the same time, various scholars have characteristics [e impact of the digital economy on different industrial structures.Wang Fatao and Bai Huihui (2021), adopting an industrial chain perspective, analyzed the development of Hebei Province's manufacturing sector using inductive methods. They examined the mechanisms through which the digital economy promotes the upgrading of the manufacturing industrial structure and proposed directions for industrial policy[3] .Zhang Jing (2023) examined the structural upgrading of cross-border e-commerce in the context of the digital economy by integrating government policies, talent development, technological innovation, corporate strategies, and cross-border e-commerce cooperation mechanisms, providing both theoretical support and practical guidance[4]. However, although some relevant research exists, studies at the regional level are relatively scarce, and research at the prefecture-level city level is particularly lacking.

Therefore, the enabling effect of the digital economy on industrial structural upgrading is a profound and significant topic. It requires both in-depth theoretical exploration of its underlying mechanisms and empirical analysis to reveal its specific impact mechanisms, with the aim of providing scientific

theoretical support and policy guidance for the development of the digital economy and the optimization of industrial structures. This paper selects 16 prefecture-level cities in Anhui to study the impact of the digital economy on industrial structure.

China's economy is currently at a critical juncture of transformation, and the shift from a phase of rapid growth to one of high-quality development is an inevitable trend. The scale of the digital economy within Anhui's urban clusters is also continuing to expand, demonstrating a positive development trajectory.

At the macro level, the rapid growth of the digital economy has a significant impact on industrial transformation, optimization, and upgrading. As a key driver of economic transformation and upgrading, the development of the digital economy not only facilitates the transition of traditional industries toward digitalization and intelligent transformation but also fosters new sources of economic growth. With the application and advancement of big data and the "Internet Plus" initiative, the digital economy continues to evolve. The development of the digital economy is continuously shaping and reshaping the modern economic system, serving as a vital driving force for economic restructuring, optimization, and upgrading, and injecting strong momentum into sustained, steady, and sustainable economic development.

From a microeconomic perspective, the impact of the digital economy on industrial restructuring is primarily manifested at the enterprise level. The development of the digital economy provides enterprises with more opportunities and possibilities for growth, while also bringing new challenges and competition. By conducting an in-depth analysis of the digital economy's impact on industrial restructuring, enterprise managers can better understand new trends and directions in industrial development, formulate more forward-looking and sustainable development strategies, and enhance the enterprise's competitiveness and risk-resilience.

In summary, analyzing the issue from both macro and micro perspectives helps to comprehensively understand the importance of the digital economy for economic development and its underlying mechanisms. This not only provides government departments with a scientific basis for formulating more effective policies and strategies to promote the sustainable development of the digital economy but also offers guidance to enterprises, helping them better cope with market competition and changes in the economic environment to achieve high-quality economic growth.

2. Theoretical Analysis and Research Hypotheses

2.1. Theoretical Analysis

With the application and continuous growth of Internet information technology, the digital economy has become a key driver of rapid economic growth and has permeated traditional production models and various industrial sectors. The digital economy is not merely an economic form but also a vital engine for promoting industrial upgrading and economic development. It provides new momentum and opportunities for the development of various industries, propelling the economy toward greater efficiency, intelligence, and sustainability.Under the current economic conditions, deepening the development of the digital economy and accelerating the pace of digital transformation will be key to industrial upgrading and the sustained, healthy development of the economy across all regions [5]. The digital economy is highly pervasive; it breaks down the boundaries of traditional industries, promotes integration and interaction among different sectors and fields, and forms new industrial ecosystems and business models. It provides new momentum and opportunities for the development of various industries, driving the economy toward greater efficiency, intelligence, and sustainability.

The mechanisms through which the digital economy drives industrial structure upgrading are multifaceted. On the one hand, the digital economy enhances the productivity of traditional industries, improves the efficiency of factor allocation, empowers traditional industries, and elevates the sophistication and rationalization of their structures. On the other hand, the widespread application of digital technologies facilitates the further development of knowledge- and technology-intensive

industries, propelling the process of industrial structure upgrading in China.At the same time, the application of information technology across different industries strengthens inter-sectoral linkages, improves resource allocation efficiency, and further advances the rationalization of the industrial structure [6]. Therefore, the digital economy enhances the productivity and supply quality of traditional industries, integrates factor resources, and achieves both the rationalization and upgrading of the industrial structure through these two pathways: traditional industries and digital industries.

2.2. Research Hypotheses

Currently, industrial structure upgrading can be approached using the methodology proposed by Liu Fang (2024), which considers two aspects: industrial structure rationalization on the one hand, and industrial structure upgrading on the other [7] . Upgrading the industrial structure refers to the process of increasing value added within the economy and raising the proportion of high-tech industries. This upgrading manifests as the transfer of more resources and labor within the economy toward technology-intensive, knowledge-intensive, and innovation-driven industries. Upgrading the industrial structure typically implies higher production efficiency, higher profit margins, and greater competitiveness. Upgraded industries often possess strong innovation capabilities and can drive the development of the entire economy. The rationalization of the industrial structure emphasizes the rationality and adaptability of the industrial structure in resource allocation and economic growth. This includes the coordinated development and mutual complementarity among different industries, as well as healthy competition between them. A rationalized industrial structure should fully leverage the advantages of resources, technology, and markets to achieve a balance between supply and demand, thereby avoiding resource waste and economic structural imbalances.

On the one hand, the rapid development of the digital economy has not only enhanced the production efficiency of various resource factors but also strengthened collaboration and cooperation across production stages and among different sectors. This synergy not only makes production processes more efficient but also drives the industrial structure toward continuous evolution toward greater rationalization.

On the other hand, the digital economy has driven the development of digital, information, and intelligent technologies, a trend that has also facilitated a comprehensive upgrade of production models and efficiency in traditional industries. Through the application of digital technologies, traditional industries can achieve digitization, informatization, and intelligent transformation across all stages of production, distribution, exchange, and consumption. This enhances productivity levels, production efficiency, product quality, and overall service standards, thereby elevating the sophistication and competitiveness of the industrial structure.

Based on the above theoretical analysis, this paper proposes the following hypotheses:

Hypothesis 1: The development of the digital economy can promote the rationalization of industrial structures across cities in Anhui Province.

Hypothesis 2: The development of the digital economy can promote the upgrading of industrial structures across cities in Anhui Province.

3. Model Design and Data Sources

3.1. Variable Selection

3.1.1. Dependent Variables

Optimization and Upgrading of Industrial Structure. This paper will compare industrial structure levels from two perspectives. First, industrial structure rationalization (isu1) is used to characterize the equilibrium and efficiency of the industrial structure, reflecting changes in interactions and economic linkages among industries, thereby driving the industrial structure toward a more rational direction. Currently, the academic community typically uses the Theil Index to measure the level of

industrial structure rationalization, though some scholars employ other methods to quantify indicators of industrial structure rationalization. Given data availability, this paper adopts the method proposed by He Xiong and Fan Kexin, using the ratio of the value-added output of the secondary sector to that of the tertiary sector to represent industrial structure rationalization [8] . This indicator suggests that the smaller the isu1 value, the higher the relative growth in the value-added output of the tertiary sector, indicating that the dominant sector of the industrial structure is gradually shifting toward the tertiary sector, and the higher the degree of industrial structure rationalization. Specifically, as shown in Equation(1).

$$isu1_{i,t}=\frac{Y_{2i,t}}{Y_{3i,t}} \tag{1}$$

Where isu1i,t represents the industrial structure rationalization index for City i in year t; Y2i,t represents the industrial value added to City i's secondary sector in year t, and $Y_{3i,t}$ represents the industrial value added of City i's tertiary sector in year t.

Industrial structure upgrading (isu2) refers to the process by which an industrial structure evolves toward a higher level of development. Currently, most scholars primarily use two indicators to measure industrial structure upgrading: the ratio of the output value of the tertiary sector to that of the secondary sector, and the share of the tertiary and secondary sectors in total output value. Following the approach of most scholars, this paper uses the ratio of the output value of the tertiary sector to that of the secondary sector to indicate the level of industrial structure upgrading [9], as shown in Equation (2)

$$isu2_{i,\ t}=\frac{Y_{3i,t}}{Y_{2i,t}} \tag{2}$$

Where $isu2_{i,t}$ represents the industrial structure upgrading index for City i in year t; $Y_{2i,t}$ represents the output value of City i's secondary industry in year t, and $Y_{3i,t}$ represents the output value of City i's tertiary industry in year t.

3.1.2. Explanatory Variables

Level of digital economic development (dig). To date, the academic community has not yet established a unified and comprehensive standard for measuring the level of digital economic development. Overall, the statistics and calculations for digital economic development evaluation indicators are primarily constructed based on infrastructure construction and improvement, the digital industry, and inclusive finance. Different research focuses also lead to the establishment of different indicator systems. For example, the Tencent Research Institute evaluates the "Internet Plus" digital economy index from the perspectives of four different domains: government affairs, daily life, culture, and the economy. The Digital China Development Report (2020) establishes a digital development evaluation system based on the digital foundation, comprehensive digital empowerment, key digital capabilities, the digital development environment, and organizational implementation safeguards. Drawing on the work of Liu Jun, Yang Yuanyun, and Zhang Sanfeng (2020), this paper centers on internet development as the core evaluation indicator. It constructs an indicator system in accordance with the needs and requirements of the digital economy, measuring the level of the digital economy from two aspects: digital internet development and digital inclusive finance [10] .To measure digital internet development across prefecture-level cities in Anhui Province, we adopt the methodology of Huang Qunhui et al. (2019), utilizing four indicators: internet penetration rate, employment in related sectors, related output, and mobile phone penetration rate [11] . The method for calculating the level of digital economic development (dig) involves using principal component analysis to determine the digital economic development index for each prefecture-level city, as shown in Table (1).

Table 1. Indicators of Digital Economic Development Level.

Primary Indicators	Second-Level Indicators	Indicator Attribute
Digital Internet Development	Number of mobile phone users per 100 people	+
	Percentage of Employees in Computer Services and Software	+
	Number of Internet users per 100 people	+
	Total telecommunications services per capita	+
Digital Finance	Digital Inclusive Finance Index	+

3.1.3. Control Variables

Drawing on the research by Shen Yunhong and Huang Heng (2020), this study sets government expenditure (gov) and economic development level (eco) as control variables. Specifically, government expenditure (gov) is represented by the ratio of fiscal expenditure to GDP in each prefecture-level city, while economic development level (eco) is represented by the logarithm (ln) of per capita regional GDP in each prefecture-level city [12].

3.2. Model Construction

This paper constructs a panel regression model to test Hypothesis 1, namely, that the development of the digital economy can promote the rationalization of industrial structures across cities in Anhui Province. The model is constructed as shown in Equation (3)

$$isu1_{i,t}=\alpha+\beta dig_{i,t}+\tau\sum control+\mu_i+\varepsilon_{i,t} \quad (3)$$

In Equation (3), $ius1_{i,t}$ is the dependent variable, representing the industrial structure rationalization index for City i in year t; $dig_{i,t}$ is the independent variable, representing the level of digital economic development for City i in year t; control are control variables, namely government expenditure (gov) and economic development level (eco); μ_i represents the city fixed effect; and $\varepsilon_{i,t}$ is the random error term.

To test Hypothesis 2—that the digital economy can drive the upgrading of industrial structures across cities in Anhui Province—we construct a panel regression model as shown in Equation (4):

$$isu2_{i,t}=\alpha+\beta dig_{i,t}+\tau\sum control+\mu_i+\varepsilon_{i,t} \quad (4)$$

3.3. Data Sources and Descriptive Statistics of Variables

3.3.1. Data Sources

This study selected panel data from prefecture-level cities across Anhui Province and constructed a corresponding indicator system based on the needs and requirements of digital economic development.

Industrial structure upgrading is measured from two dimensions: industrial structure upgrading and industrial structure rationalization [13]. These indicators involve the output value and value-added of the secondary and tertiary industries in various prefecture-level cities of Anhui Province, for which raw data can be obtained from the Anhui Statistical Yearbook.

The development of the digital internet can be measured through four indicators: mobile phone penetration rate, internet penetration rate, employment in the sector, and related output. A comprehensive analysis of these indicators provides a more holistic understanding of the development status of the digital internet, specifically including the number of mobile phone users per 100 people,

the proportion of employees in the computer services and software industry, the number of broadband internet subscribers per 100 people, and the total volume of telecommunications services per capita. Raw data for these indicators can be obtained from the China Urban Statistical Yearbook.

To assess the level of digital finance development, the China Digital Inclusive Finance Index was adopted. This index was jointly compiled by the Digital Finance Research Center at Peking University and Ant Financial Group. The comprehensive digital economy development index was derived using principal component analysis. The construction and analytical methods of this indicator system aim to comprehensively consider multiple aspects of digital economic development, evaluating various dimensions ranging from internet penetration and the availability of communication infrastructure to the adoption of digital financial services, in order to fully and objectively reflect the level of digital economic development. Such an evaluation system not only helps understand the development status of the digital economy across cities in Anhui Province but also provides a scientific basis for the government to formulate corresponding development strategies and policies [14].

3.3.2. Descriptive Statistics of Variables

This study selected panel data from 16 prefectures in Anhui Province, China, covering the period from 2011 to 2022. Using STATA software, regression analysis was performed on these data to conduct descriptive statistics for industrial structure rationalization (isu1), industrial structure upgrading (isu2), digital economy development level (dig), government expenditure (gov), and economic development level (eco). The results are shown in Table 2.

Table 2. Descriptive Statistics of Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
isu1	208	1.327	0.533	0.133	3.198
isu2	208	0.88	0.072	0.398	0.982
dig	208	0.254	0.032	0.18	0.335
gov	208	0.201	0.056	0.107	0.355
eco	208	10.594	0.587	9.113	11.742

4. Empirical Analysis of the Digital Economy's Impact on Industrial Structure Upgrading

4.1. Model Specification

In Stata, this study used the Variance Inflation Factor (VIF) to test multicollinearity among all variables. The results show that among all variables (isu1, isu2, dig, gov, eco), the maximum VIF value is 2.68, the minimum is 1.31, and the average is 2.2. Since the VIF values for all variables are less than 10, it can be concluded that there is no multicollinearity among the variables selected in this study.

Additionally, based on the F-test results, F (15, 173) = 5.98 and F (15, 109) = 19.36, with p-values of 0.000 for both—far below 0.05—indicating that the null hypothesis is rejected at the 1% significance level. Based on the results of the Hausman test, the p-values are 0.0193 and 0.0000, respectively, which are also less than 0.05, indicating that at the 1% significance level, the null hypothesis is rejected. Considering the results of both the F-test and the Hausman test, it can be concluded that a fixed-effects model, rather than a random-effects model, should be used to analyze the enabling effect of the digital economy on industrial structure upgrading in this study. Therefore, this study adopts a fixed-effects model to analyze the enabling effect of the digital economy on industrial structure upgrading.

4.2. Regression Analysis

A regression analysis was conducted on industrial structure rationalization (isu1), industrial structure upgrading (isu2), digital economy indicators (dig), government expenditure (gov), and economic

development level (eco). The results of the fixed-effects model regression are shown in Table (3). Column (1) presents the regression results for the dependent variable industrial structure rationalization (isu1) and the independent variable digital economy development level (dig), with a coefficient of 6.481, which is highly significant at the 1% level. Column (2) presents the regression results obtained after adding two control variables, government expenditure (gov) and level of economic development (eco), to the regression model. The coefficient for the dependent variable level of digital economic development (dig), is 2.205, which is statistically significant. This indicates that an increase in the level of digital economic development can significantly drive the value-added output of the tertiary sector to exceed that of the secondary sector, leading to a gradual shift in the industrial focus toward tertiary sector dominance. Therefore, an increase in the level of digital economic development promotes the rationalization of the industrial structure, and Hypothesis 1 is supported. Column (3) presents the results of a separate regression analyzing the two variables—level of digital economic development and industrial structure upgrading—with a coefficient of 0.877. At the 1% significance level, the coefficients for these two variables are positive. Column (4) presents the regression results obtained after incorporating the two control variables—government expenditure (gov) and economic development level (eco)—into the model. The coefficient for the digital economy development level (dig), i.e., the independent variable, is 0.618. At the 10% significance level, the coefficients for both variables are greater than 0, confirming Hypothesis (2).

Table 3. Model Regression Results.

	(1)	(2)	(3)	(4)
	isu1	isu1	isu2	isu2
dig	6.481***	2.205*	0.877***	0.168*
	(6.576)	(1.663)	(10.539)	(1.816)
gov		-4.006***		1.647***
		(-3.213)		(2.949)
eco		-0.618***		0.574***
		(-4.988)		(10.392)
_cons	2.968***	9.260***	0.498***	-5.613***
	(11.621)	(7.352)	(11.837)	(-8.973)
N	192	192	192	192
R2	0.198	0.303	0.388	0.633
F	43.241	25.027	111.063	99.577
***p<0.01", "**p<0.05", "*p<0.10				

Note: ***p<0.01", "**p<0.05", "*p<0.10 indicate significance at the 1%, 5%, and 10% levels, respectively.

4.3. Robustness Tests

Since industrial restructuring takes time, the impact of the digital economy is not immediately apparent and may exhibit a certain degree of lag [15]. That is, an increase in the current level of digital economic development may have a relatively small direct impact on the optimization and upgrading of the current industrial structure, but it may significantly influence the industrial structure in the next period. Therefore, this paper adjusts the level of digital economic development to the explanatory variable L.dig for the next period [16].

Regression analysis of the adjusted explanatory variable yields the results shown in Table (4). The core explanatory variable — the level of digital economic development — continues to exert a significant influence on the dependent variables of industrial structure rationalization and industrial structure upgrading at the 1% significance level. It is worth noting that the coefficient for industrial structure rationalization (isu1) is negative, while the coefficient for industrial structure upgrading (isu2) is positive. This indicates that the improvement in the level of digital economic development has indeed significantly promoted the rationalization and upgrading of industrial structures across

various cities in Anhui Province. This result further validates the reliability of the empirical findings discussed earlier.

Table 4. Robustness Test Results

	(1)	(2)
	isu1	isu2
ldig	4.247***	1.217**
	(3.210)	(1.987)
gov	-3.344**	2.099***
	(-2.420)	(3.282)
eco	-0.497***	0.624***
	(-3.688)	(9.987)
_cons	8.333***	-6.465***
	(5.694)	(-9.544)
N	176	176
R^2	0.296	0.620
F	21.961	85.425
***p<0.01", "**p<0.05", "*p<0.10		

Note: ***p<0.01", "**p<0.05", "*p<0.10 indicate significance at the 1%, 5%, and 10% levels, respectively

In summary, the improvement in the level of digital economic development can significantly promote the optimization and upgrading of industrial structure, which further underscores the important role of the digital economy in driving economic structural transformation. The findings of this study provide important references for government departments and enterprises to accelerate digital transformation, enabling them to formulate more effective policies and strategies to promote the sustained and healthy development of the digital economy.

5. Research Conclusions and Policy Recommendations

5.1. Research Conclusions

This paper aims to analyze, from an empirical perspective, the impact of the digital economy in various prefecture-level cities of Anhui Province on industrial structure upgrading. It defines the specific connotations of industrial structure upgrading in terms of both industrial structure upgrading and rationalization. By collecting panel data from various prefecture-level cities in Anhui Province from 2011 to 2022 and conducting empirical analysis on this data, the following conclusions are drawn:

First, through model regression analysis and robustness tests, the results indicate that improvements in the level of digital economic development across Anhui's prefecture-level cities significantly promote both the rationalization and upgrading of industrial structures. The digital economy development level index comprises five sub-indicators. Therefore, increases in the number of mobile phone users, the number of internet users, and the per capita total volume of telecommunications services in Anhui's prefecture-level cities, along with an increase in the proportion of relevant employees and an improvement in the digital inclusive finance index, can elevate the level of digital economy development. This, in turn, drives the rationalization and upgrading of the industrial structure, thereby promoting the optimization and upgrading of the industrial structure.

Second, the empirical results of this study show that the control variables—government expenditure (gov) and economic development level (eco)—also have a significant impact on the rationalization and upgrading of the industrial structure. The study found that both increased government expenditure and higher economic development levels can drive the industrial structure toward greater sophistication and rationalization. This trend not only helps promote the transformation and

upgrading of the industrial structure but also plays a positive role in the healthy development of the overall economy.

5.2. Policy Recommendations

The digital economy has a significant impact on the upgrading of Anhui Province's industrial structure. The development of the digital economy has fostered the emergence and growth of emerging industries. Emerging industries represented by big data, artificial intelligence, and cloud computing are on the rise, becoming key engines driving industrial structure upgrading and spurring the development of more high-tech, high-value-added industries. The rapid development of the digital economy has also given rise to new industrial and business models, driving the restructuring and upgrading of industrial and value chains, and further promoting the optimization and upgrading of the industrial structure. The digital economy's impact on the industrial structure upgrade in Anhui Province is multifaceted, including driving the transformation and upgrading of traditional industries and promoting the growth of emerging industries, thereby providing crucial support and momentum for the province's high-quality economic development. Therefore, the government and enterprises should increase their support for the development of the digital economy, actively promote the widespread application of digital technologies across various industries, and unlock the potential of the digital economy. Accordingly, this paper offers the following three recommendations:

First, all cities and prefectures in Anhui Province should strengthen the development of digital economy infrastructure, increase the penetration of digital technologies, and advance the processes of industrial digitization and the digitalization of industries. Municipalities can also use this opportunity to continuously improve the digitalization and intelligentization levels of their industries, conduct in-depth research on the application of digital technologies across various industrial sectors, and thereby promote the transformation, optimization, and upgrading of industrial structures. Particularly against the backdrop of the "new normal" in economic development and the rapid growth of the digital economy, it is even more critical to recognize the potential of the digital economy and accelerate the pace of digital transformation. This will enable better adaptation to increasingly fierce industrial competition and market changes, ultimately achieving the goal of sustained and healthy economic development.

Second, during the digital transformation process, it is also essential to prioritize talent development, expand the pool of digital technology professionals, and increase the proportion of workers in computer services and software. Governments at all levels and enterprises should strengthen the training and recruitment of talent related to the digital economy, establish robust talent development systems and mechanisms for scientific and technological innovation, and provide strong talent and technical support for the development of the digital economy. The development of the digital economy has become a key engine driving Anhui Province's economic growth. All cities and prefectures should fully recognize the importance of digital talent to the digital economy and inject more sustainable momentum into the province's continued and vigorous economic development.

Third, municipal government departments can adopt effective policy measures and industry guidance to increase fiscal spending on the digital economy, expand investment and support for related sectors, and promote the widespread application of digital technologies in traditional industries and sectors. This will better leverage the driving role of the digital economy, injecting new momentum and vitality into Anhui's economic development. Additionally, enterprises can be encouraged to increase R&D investment, advance digital technologies, enhance their competitiveness in the market, and boost market vitality.

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