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How Digital-Real Integration Drives the Development of New-Quality Industries

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Abstract

The deep convergence between the digital economy and the real economy has increasingly emerged as the core driver of high-quality economic development. Amid the efforts to develop new-quality productive forces, new-quality industries are experiencing rapid growth. Using panel data covering 198 prefecture-level cities in China over the period 2010–2024, this paper empirically explores the impact and underlying mechanism of digital-real integration on the advancement of new-quality industries. The results demonstrate that digital-real integration exerts a significantly positive stimulative effect on the growth of new-quality industries, and this conclusion holds steady after multiple robustness checks. Further mechanism tests suggest that digital patent innovation acts as a mediating variable in the linkage between digital-real integration and new-quality industry development. Specifically, digital-real integration enhances the dynamism of digital patent creation, while the technological upgrading and commercialization of digital patents further fuel the expansion of new-quality industries. Heterogeneity analysis shows that the promotional impact of digital-real integration is more pronounced in eastern China and regions southeast of the Hu Huanyong Line. This study enriches the academic literature on digital-real integration and new-quality productive forces, and offers meaningful references for policy design to advance digital-real integration and foster the growth of new-quality industries.

Keywords

Digital-real Integration; New-quality Industries; Digital Patents; Mediating Effect.

1. Introduction

At present, the scientific and technological revolution and industrial transformation driven by artificial intelligence are evolving globally, reshaping the national competition pattern and economic development model. Based on the needs of high-quality development, China has identified digital-real integration as the core path to build strategic advantages for future development. Relevant documents propose fostering new-quality productive forces and expanding new-quality industries through digital-real integration. Digital-real integration gives birth to new-quality productive forces, which is reflected in the vigorous development of new-quality industries. As the core pillar of the modern industrial system, new-quality industries determine a country's position in the global industrial and value chains, and are a key carrier to consolidate the material and technological foundation of Chinese-style modernization. Therefore, exploring the impact of digital-real integration on the development of new-quality industries has important theoretical and practical value.

At its core, digital-real integration means digital technologies penetrate, empower, and restructure the real economy, and its economic impacts have drawn wide academic attention. At the macro level, such integration helps lift total factor productivity and advance industrial structure upgrading, acting as a key engine for high-quality development. At the micro level,

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tech-driven integration between digital and real sectors strengthens firms' innovation output and production efficiency, while accelerating manufacturing transformation[1]. Moreover, the influence of digital-real integration on regional economic growth differs noticeably across regions.

Although prior research has confirmed the positive economic outcomes of digital-real integration, studies on how it propels the growth of new-quality industries and the underlying mechanism remain limited. Digital patents serve as a critical bridge linking digital-real integration and new-quality industries, yet existing research has rarely highlighted their unique function or treated them as a core mediating variable, making the findings less targeted for guiding the cultivation of new-quality industries in practice[2]. In light of this gap, this paper takes digital patents as the starting point, uses panel data from 198 prefecture-level cities during 2010–2024 to examine how digital-real integration affects new-quality industry development, and explores the mediating role of digital patents as well as the regional heterogeneity of such effects.

2. Theoretical Analysis and Hypothesis Formulation

China's economy has entered a period of high-quality development transformation, and fostering new-quality productive forces centered on strategic emerging industries is a core strategy to break through the growth bottleneck and build new international competitive advantages. Digital-real integration has been clearly listed as a key path to empower industrial upgrading. Combined with China's domestic reality and the needs of new-quality industries, this paper analyzes and puts forward research hypotheses from three dimensions: direct driving effect, mediating transmission mechanism and regional heterogeneity[2].

2.1. Digital-Real Integration and the Development of New-Quality Industries

Digital-real integration refers to the multi-dimensional deep coupling and collaborative evolution of digital technologies and the real economy, providing a soil for new-quality industries. Firstly, it broadens the supply of technical knowledge and promotes real technological innovation. Secondly, it improves the accuracy and efficiency of factor allocation, solves the pain points of factor shortage, and removes obstacles to factor flow. Thirdly, it gives birth to new industrial organization forms and impetus for transformation and upgrading[3]. Based on this, Hypothesis H1 is proposed:

H1: Digital-real integration can significantly promote the development of new-quality industries.

2.2. The Mediating Role of Digital Patents

The empowerment of digital-real integration to new-quality industries needs to be realized through technological innovation transformation, and digital patents are the key mediator. On the one hand, digital-real integration provides cultivation conditions for digital patent innovation, including innovation cooperation, policy incentives and application scenarios. On the other hand, digital patents are the core support for value creation of new-quality industries, forming a complete transmission chain. Based on this, Hypothesis H2 is proposed:

H2: Digital-real integration drives the development of new-quality industries by promoting digital patent innovation[2].

2.3. Regional Heterogeneity

The release of digital-real integration dividends depends on regional "absorptive capacity" and "transformation foundation", and China's inter-regional development differences determine the heterogeneity of its driving effect. First, differences in regional development levels and marketization degrees lead to the differentiation of integration effects. The eastern region is a

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demonstration zone for digital-real integration, with high integration levels and marketization degrees, advantages in digital infrastructure, talent reserve and industrial supporting facilities, and can efficiently transform integration potential, making the promoting effect of digital-real integration more significant. In contrast, the central and western regions are constrained by weak digital infrastructure and insufficient innovation capacity, with limited driving effects[3]. Second, differences in geographical and economic patterns and resource agglomeration exacerbate the differentiation of integration effects. The Hu Huanyong Line defines the spatial differences in China's population and economy. Urban agglomerations and consumer markets are concentrated on the southeast side of the line, with strong infrastructure connectivity, convenient factor flow, and rapid implementation of technology spillover effects. The northwest side is restricted by geographical conditions and low population density, with limited coverage of digital infrastructure, poor factor flow, slow technology diffusion, and low matching degree between integration and new-quality industry development[4]. This is consistent with the research logic that the economic effects of digital-real integration have spatial spillover characteristics and are more likely to be released in regions with high agglomeration. Based on this, Hypothesis H3 is proposed:

H3: The promoting effect of digital-real integration on new-quality industries is heterogeneous, and is more significant in the eastern region and the southeast side of the Hu Huanyong Line.

3. Research Design

3.1. Model Specification and Variable Definition

To test the impact of digital-real integration on the development of new-quality industries, the following econometric model is established:

$$\text{nq\_rev}_{it} = \alpha + \beta \cdot \text{dig\_real}_{it} + \gamma \text{Controls}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{1}$$

In Formula (1), subscripts i and t represent the city and year respectively. The explained variable nq_rev_{it} is the development of new-quality industries in the city, the core explanatory variable dig_real_{it} is digital-real integration , Controls_{it} is a series of control variables,μ_i and $\lambda_t$are city and year fixed effects respectively, and ε_{it} is the random disturbance term. The specific definitions of each variable are as follows.

The explained variable nq_rev_{it} dig_real_{it} (digital-real integration degree) is calculated by referring to Zhou Mi et al. (2024), using China's patent application data and patent-industry matching information, and adopting the patent co-classification method to depict the integration characteristics of the digital economy and the real economy from four dimensions: time, industry, region and network, and then calculate the integration level of the digital economy and the real economy. Control variables include human capital level (human), economic development level (gdp), market size (pop), entrepreneurial activity (ent_act), industrial structure (ind3_share) and other variables. The mechanism variable digital patents is measured by the number of digital invention patent applications, which is obtained by screening and summing up the total number of digital invention patent applications of each prefecture-level city over the years from the full amount of patents according to the mapping relationship between the *Key Digital Technology Patent Classification System* and the International Patent Classification (IPC).

3.2. Sample Selection and Data Sources

This paper takes the panel data of China's prefecture-level cities from 2010 to 2024 as the research sample. The core consideration for selecting this time span is that after 2010, the penetration and application of digital technologies in the real economy have gradually

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deepened in China, and the state has successively issued a series of policy documents such as the Digital Economy Development Plan and the 14th Five-Year Plan for Digital Economy Development to promote the integration of the digital economy and the real economy. As the core task of high-quality development, the cultivation of new-quality productive forces has gradually formed a clear industrial form and development path during this period. This time span can not only cover the key practical stage of policy implementation, but also ensure the observation timeliness of the sample[5]. All original data come from the China City Statistical Yearbook and the statistical yearbooks and statistical bulletins of each prefecture-level city, and individual missing data are supplemented by interpolation. This paper eliminates observations with missing key variables and major administrative division adjustments (such as city-to-district conversion, merger and split), and finally obtains a balanced panel data including 198 cities and a 15-year observation period, with a total of 2970 observations.

4. Empirical Results and Analysis

4.1. Benchmark Regression

The benchmark regression results of digital-real integration on the development of new-quality industries show that Model (1) only controls the core explanatory variables, and Model (2), Model (3) and Model (4) gradually add control variables and city fixed effects and year fixed effects. The results of Model (4) show that the estimated coefficient of digital-real integration is 3.599, which is significantly positive at the 1% level, indicating that digital-real integration significantly promotes the development of new-quality industries.

4.2. Robustness and Endogeneity

Based on the above benchmark regression results, robustness and endogeneity analyses are conducted next.

(1) Logarithmic form test. The core variables in the benchmark regression are estimated using original values, which may affect the stability of the results due to the non-linear characteristics of variable distribution or dimensional differences. Therefore, this paper performs logarithmic processing on continuous variables such as new-quality industry operating income, digital-real integration index, per capita GDP and permanent resident population (logarithm after adding 1 to new-quality industry operating income and digital-real integration index), and re-regresses to test the variable relationship.The results indicate that the coefficient of the logarithmically processed digital-real integration variable is significantly positive at the 1% level, which proves that the positive influence of digital-real integration on the development of new-quality industries remains valid after changing the variable form.

(2) Replacement of explained variables. The benchmark regression measures the development level of new-quality industries by the operating income of new-quality industries, which may have a single indicator measurement bias. This paper replaces the explained variable with the employment scale of new-quality industries (i.e., the number of employees in strategic emerging industries) for re-regression. Results indicate that the regression coefficient of the digital-real integration index remains significantly positive at the 1% level. This demonstrates that the boosting effect of digital-real integration on the development of new-quality industries is not dependent on the specific measurement of the dependent variable, confirming the robustness of the regression outcomes.

(3) Lagged one-period model test. The benchmark regression may have a reverse causality problem, that is, cities with a higher development level of new-quality industries often have stronger resource endowments and technological foundations, which may further increase investment in digital-real integration, leading to a two-way causal relationship between the core explanatory variable and the explained variable.To address the potential endogeneity

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issue, this study introduces the first-order lag term of the core independent variable, the digital-real integration index, into the regression framework. This setup enables an examination of how the lagged level of digital-real integration influences the current period's revenue generated by new-quality industries. The estimation results indicate that the coefficient of the one-period lagged integration index remains significantly positive at the 1% level. This finding suggests that even after accounting for the possibility of reverse causation, the positive impetus exerted by digital-real integration on the development of new-quality industries remains robust and statistically significant. Consequently, the core conclusions of the analysis are not undermined by endogeneity concerns.

(4) Elimination of extreme value interference. The operating income of new-quality industries or digital-real integration index of some cities in the sample may have extreme values, which may distort the real relationship between core variables. This paper adopts the tail shrinking method to adjust the new-quality industry operating income and digital-real integration index at the 1% and 99% quantiles, and re-regresses after replacing the original extreme values. The results show that the adjusted digital-real integration index coefficient is still significantly positive at the 1% level, indicating that the core conclusion is not affected by extreme values.

4.3. Mechanism Test

Digital-real integration directly stimulates digital patent output by breaking technical barriers and integrating innovation resources (digital_patentit). As a special technological achievement, the commercial application and technological transformation of digital patents can inject direct impetus into the development of new-quality industries, forming a transmission chain of "digital-real integration → digital patent innovation → new-quality industry development". This paper uses the two-step mediating effect model to test this mediating effect, and the specific model specifications are as follows:

$$\text{digital\_patent}_{it} = \alpha_1 + a \cdot \text{dig\_real}_{it} + \gamma_1 \mathbf{X}_{it} + \mu_i + \lambda_t + \varepsilon_{1it} \tag{2}$$

$$\text{nq\_rev}_{it} = \alpha_2 + b \cdot \text{digital\_patent}_{it} + \gamma_2 \mathbf{X}_{it} + \mu_i + \lambda_t + \varepsilon_{2it} \tag{3}$$

Firstly, the impact of digital-real integration on the mediating variable (digital patents) is tested. Taking the number of digital patent applications as the explained variable, the digital-real integration index and control variables such as human capital and economic development level are included in the regression. The results reveal that the regression coefficient of digital-real integration is 6.146, significantly positive at the 1% level. This suggests that digital-real integration effectively promotes the growth of digital technology innovation patents and provides solid support for digital patent output.We then examine the influence of digital patents on the development of new-quality industries. The regression results show that the coefficient of digital patents stands at 0.114, also significantly positive at the 1% level. This implies that digital patent innovation directly boosts the development of new-quality industries, verifying that digital patents serve as an effective channel for transforming technological achievements into industrial value.

To further verify the statistical significance of the mediating effect, this paper conducts the Sobel test. The calculation shows that the Sobel Z value is 8.138 and is significant at the 1% level ($p<0.01$), indicating that the mediating effect is statistically reliable. Considering the dependence of the Sobel test on the normality assumption of variables, this paper further adopts the more robust Bootstrap method with 1000 repeated samplings for testing. The results show that the 95% confidence interval of the digital patent mediating effect is [0.548,

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1.064], and 0 is not included in the interval, which further confirms the robustness of the mediating effect and eliminates the interference of sampling errors on the results.

4.4. Heterogeneity Analysis

The dividends of digital-real integration are unevenly released, depending on the regional "absorptive capacity" and "transformation foundation", and the promoting effect on new-quality industries is heterogeneous, more significant in the eastern region and the southeast side of the Hu Huanyong Line. Combined with the characteristics of unbalanced regional development in China, this paper conducts grouped regression from two dimensions: regional development level and geographical and economic pattern.

(1) Regional development level heterogeneity: prominent effect in the eastern region. After grouping according to the regional classification standards of the National Bureau of Statistics, the regression results show a "prominent eastern" characteristic. The regression coefficient of digital-real integration on the development of new-quality industries in the eastern region is the largest and highly significant. Although the central and western regions pass the significance test, the values are lower than those in the eastern region. This is related to regional basic conditions and policy environment. The eastern region is a demonstration zone for digital-real integration, with policy dividends, full coverage of digital infrastructure first, and agglomeration of a large number of high-end talents and venture capital, which can quickly transform technological potential. Although the central and western regions have policies supporting digital transformation, they are constrained by the digital divide and other factors, and the industrial catalytic effect has not been fully released, with small coefficients.

(2) Geographical and economic pattern heterogeneity: significant effect on the southeast side of the Hu Huanyong Line. Grouped regression by the "Hu Huanyong Line" shows that the promoting effect of digital-real integration on new-quality industries is significantly positive on the southeast side and not significant on the northwest side. A large number of urban agglomerations are concentrated on the southeast side, with inclined digital infrastructure, forming a technology and knowledge diffusion network and factor flow channel. Digital-real integration can be implemented with the help of agglomeration effect to meet the conditions of new-quality industries. The northwest side is restricted by geographical and other factors, with insufficient economic agglomeration and low matching efficiency. Support policies focus on filling shortcomings, and have not formed industrial-level integration ecological conditions, so the industrial promoting effect has not been effectively manifested.

5. Conclusion and Policy Implications

Using panel data covering 198 prefecture-level cities over 2010–2024, this paper explores the influence, transmission mechanism, and regional heterogeneity of digital-real integration on the advancement of new-quality industries, offering empirical support for pathways to foster new-quality productive forces. The primary conclusions are summarized below:(1) Benchmark regression and robustness tests show that digital-real integration significantly promotes the development of new-quality industries; (2) Digital patent innovation is the driving mediating variable. Digital-real integration increases digital patent output, and its commercial application transforms into new-quality industrial competitiveness, forming a transmission chain; (3) The industrial promoting effect of digital-real integration has regional heterogeneity, with a higher driving coefficient in the eastern region than in the central and western regions, and a significantly positive effect on the southeast side of the Hu Huanyong Line and no significant effect on the northwest side.

Based on the research conclusions and reality, policy implications are put forward: First, implement a differentiated regional promotion strategy. The eastern region focuses on high-

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end integration and innovation to build industrial clusters, while the central and western regions and the northwest side fill shortcomings and cultivate an integration ecology. Second, build a full-chain support system for integration-innovation-transformation, set up special funds to support patent R&D, build a docking platform, and develop pledge financing. Third, strengthen the original innovation and patent layout of digital technologies, support key fields, improve the protection system, and encourage enterprises to develop special patents.

This study has limitations: The measurement of digital-real integration focuses on the technical level, not covering dimensions such as business collaboration, which may have measurement bias. In the future, a multi-dimensional index system can be constructed; the research sample focuses on the macro level of prefecture-level cities, lacking enterprise micro data, making it difficult to investigate the heterogeneous responses of enterprises and differences in transformation paths; the mechanism analysis only focuses on digital patents, not exploring other potential transmission paths, which may omit important channels.

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