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Research on the relationship between new quality productivity and digital-real integration——Based on provincial spatiotemporal data

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ABSTRACT
The new type of productive forces is leading industrial transformation and has become a new driving force in global competition. Promoting the deep integration of the digital economy and the real economy is key to achieving high-quality development and a modern industrial system. This paper, based on the RESSET database, constructs a measurement system for the new type of productive forces and the degree of digital-real integration, and analyzes their dynamic evolution using kernel density estimation. Additionally, it explores their spatial concentration and regional differences. Furthermore, the correlation and threshold effects between the two are analyzed. The study finds the following: 1) New type productive forces are transitioning from concentration to balance; 2) Inter-provincial differences remain significant; 3) There is a spatial agglomeration effect between the two; 4) The promoting effect of new type productive forces on digital-real integration exhibits a diminishing return effect.

KEYWORDS
New-quality productive forces; Digital-real economy integration; Dynamic evolution; Moran's I index

1 Introduction

In January 2023, the 21st Century Economic Report published the 2022 China Digital-Real Integration Development Trend White Paper, which deeply analyzed the potential of digital-real integration in supply chains and industrial chains, pointing out that it will become a new driving force for promoting China's high-quality economic development. In September 2023, China's leadership introduced the concept of 'new type productive forces' during a research visit to Heilongjiang, injecting new vitality into digital-real integration[1]. In 2024, the country advocated for driving digital-real integration with new type productive forces, marking the beginning of a new phase in this field. New type productive forces are characterized by efficiency, intelligence, and innovation, not only enhancing the competitiveness of traditional industries but also driving the development of emerging industries, especially by improving efficiency and decision-making accuracy through artificial intelligence and big data. Digital-real integration combines artificial intelligence and big data to optimize resource allocation, promote industrial upgrading, and achieve sustainable development[2]. The interrelationship between new type productive forces and digital-real integration is mutually reinforcing, and studying this relationship is of great significance for promoting high-quality economic development.

2 Data Sources and Indicator Calculation

2.1 Data Sources

To ensure the authenticity and validity of the data, this study selects panel data from 31 provinces, municipalities, and autonomous regions in China from 2013 to 2022. Due to significant data gaps for some indicators in China's Hong Kong, Macau, and Taiwan regions, which cannot be meaningfully interpolated, samples from these three regions are excluded. For individual missing data, interpolation or linear trend methods are used for filling. The research data is sourced from the China Statistical Yearbook, China Transportation Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook, and the RESSET database.

2.2 Constructing the Indicator System

2.2.1 Indicator System for the Development Level of New Type Productive Forces

According to central economic principles, new type productive forces represent an advanced form of productive forces that align with the new development philosophy. The focus is on optimizing the combination of labor factors, improving productivity, while also emphasizing the comprehensive development of people and the harmonious coexistence between humans and nature. The enhancement of new type productive forces relies not only on technological innovation but also on strengthening the integration of the innovation chain, industrial chain, capital chain, and talent chain[3]. New type productive forces are the product of productivity transformation and technological breakthroughs, representing the improvement of human capacity to transform nature[4]. Therefore, in assessing new type productive forces, it is necessary to consider not only the technological foundation but also evaluate its high-quality developmental outcomes.

Based on Marxist productivity theory and modern economic thought, an evaluation system for new type productive forces has been constructed, encompassing nine characteristics and 25 indicators, specifically including: three "highs" (technology, high efficiency, high quality), three "transformations" (digital intelligence, networking, greening), and three "qualities" (innovation, sustainability, openness). Some indicators are derived through calculations, such as technological level, which is measured by the proportion of fiscal expenditure on science and technology, and asset profitability, which is calculated by the ratio of profits to total assets[5].

2.2.2 Indicator System for the Degree of Digital-Real Integration

The Chinese government attaches great importance to the integration of the digital economy and the real economy, implementing a series of policies to promote the growth of the digital economy and encouraging the deep integration of the two. This study constructs a comprehensive indicator system for the degree of digital-real integration from two perspectives: the digital economy and the real economy. From the perspective of digital industrialization and industrial digitalization, relevant indicators for the digital economy are established. From the perspective of six major sectors—industry, agriculture, construction, transportation and postal services, wholesale and retail, and accommodation and catering—indicators for the real economy are developed.

2.3 Indicator Calculation Methods and Results

2.3.1 Calculation of New Type Productive Forces Development Level

Based on the above "three highs, three qualities, three transformations" indicator system, the entropy-weight TOPSIS method is used to calculate the development level of new type productive forces in China's provinces from 2013 to 2022. This method objectively assigns weights by utilizing the information provided by the characteristic dimensions, avoiding the potential bias from subjective weighting. The specific steps are as follows:

Step 1: Differentiate between positive and negative indicators in the "three highs, three qualities, three transformations" indicator system and standardize the data.

$$x'_{ij}=\begin{cases}\dfrac{x_{ij}-\min(x_j)}{\max(x_j)-\min(x_j)} & (\text{正向指标}) \\[2ex] \dfrac{\max(x_j)-x_{ij}}{\max(x_j)-\min(x_j)} & (\text{负向指标})\end{cases} \tag{1}$$

Where i represents the province ,j represents the indicator value, and x'_{ij} is the standardized value of the j-th indicator for the i-th province after removing the dimension.

Step 2: Calculate the proportion P of each indicator among all indicators.

$$P_{ij}=\frac{x'_{ij}}{\sum_i\sum_j x'_{ij}} \tag{2}$$

Step 3: Calculate the information entropy e for each indicator.

$$e_j=-\frac{1}{\ln(mn)}\sum_i P_{ij}\ln(P_{ij}) \tag{3}$$

Where m represents the number of provinces, and n represents the number of indicators.

Step 4: Calculate the weight w of each indicator in the development level of new type productive forces for each province.

$$w_j=\frac{1-e_j}{\sum_j(1-e_j)} \tag{4}$$

Step 5: Construct the weighted matrix R for each province's new type productive forces development level indicators.

$$R_{ij}=x'_{ij}*w_j \tag{5}$$

Step 6: Calculate the optimal and worst Euclidean distances L

$$L_i^+=\sqrt{\sum_j(R_{ij}-R_j^+)^2} \tag{6}$$

$$L_i^-=\sqrt{\sum_j(R_{ij}-R_j^-)^2} \tag{7}$$

Step 7: Calculate the comprehensive score Ci for each province's new type productive forces development level.

$$C_i = \frac{D_i^-}{D_i^- + D_i^+} \tag{8}$$

Where Ci ranges from 0 to 1, with a higher value indicating a higher level of new type productive forces development in the province.

Based on the "three highs, three transformations, three qualities" indicator system, this study calculates the development level of new type productive forces for the 31 provinces, municipalities, and autonomous regions from 2013 to 2022 using the entropy-weight method. The scores range from 0.2354 to 0.6107, with the lowest being in Qinghai Province and the highest in Guangdong Province. Only five provinces and municipalities—Shanghai, Zhejiang, Beijing, Jiangsu, and Guangdong—have a score exceeding 0.5. The rest of the provinces have scores below this threshold, indicating that there is still significant potential for improving the new type productive forces in China.

2.3.2 Calculation of Digital-Physical Integration Level

First, based on the digital economy indicators and physical economy indicators, the entropy-weight TOPSIS method is used to calculate the development levels of the digital economy and physical economy in China's provinces from 2013 to 2022. Then, a coupling model is constructed to calculate the degree of integration Fi between the digital economy and the physical economy. A higher value of Fi indicates a higher degree of digital-physical integration in the province.

$$F_i = \sqrt{X_i \times Y_i} \tag{9}$$

$$X_i = \frac{2\sqrt{d_i \times s_i}}{d_i + s_i} \tag{10}$$

$$Y_i = \alpha d_i + \beta s_i \tag{11}$$

Where d_i represents the digital economy indicator value of the i province, s_i represents the physical economy indicator value of the i province, α represents the weight of the digital economy, β represents the weight of the physical economy, In this study, both α and β are set to 0.5, treating the digital economy and physical economy as equally important.

Based on the digital-physical integration indicator system, this study calculates the degree of integration for the 31 provinces, municipalities, and autonomous regions from 2013 to 2022 using the entropy-weight method and coupling model. The scores range from 0.2066 to 0.9051, with Guangdong at the highest (0.9051) and Tibet at the lowest (0.2066). Eastern regions, like Shanghai (0.6271), Zhejiang (0.7928), and Jiangsu (0.8341), show higher integration, while western regions, such as Qinghai (0.2699) and Xinjiang (0.4619), have lower levels, reflecting significant regional disparities. The gap between coastal eastern and inland western provinces indicates large differences in digital-physical integration development across China.

3 Spatial and Temporal Characteristics of China's New Quality Productivity Development Level

3.1 Dynamic Evolution Analysis

To analyze the dynamic evolution trend of China's new quality productivity, this study employs kernel density estimation and divides the 31 provinces, municipalities, and autonomous regions into three major regions—Eastern, Central, and Western—based on the regional classification from the National Bureau of Statistics for comparative analysis.

Overall, from 2013 to 2022, the development of new-quality productivity in China showed both strengthening and weakening centralization trends. The kernel density curve's main peak gradually widened, signaling increased balance.

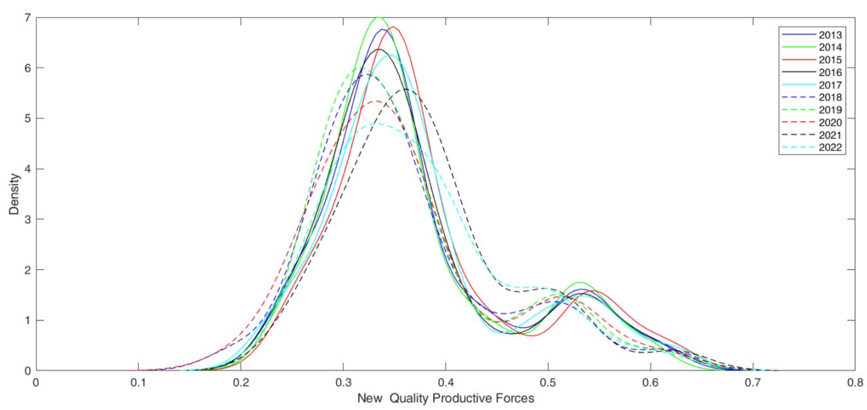

Figure 1 Dynamic Evolution Trajectory of National New Quality Productivity Development Level (2013-2022)

Since 2018, the curve has flattened with an extended right tail, indicating faster development in provinces like Guangdong, Jiangsu, and Shanghai. Before 2020, the main and side peaks showed polarization, which weakened after 2020, though some provinces continued rapid growth.

At the regional level, the Eastern region's curve shows enhanced centralization with a single peak, indicating imbalance without polarization. The Central region's curve shifted rightward each year, with a decreasing, widening peak, signaling reduced centralization and increased balance. From 2021 onwards, the curve flattens with an extended right tail, suggesting narrowing regional disparities. In the Western region, new-quality productivity grew, with the curve shifting right, a decreasing peak, and widened base, showing less disparity and alleviated polarization.

3.2 Spatial Agglomeration Effect Analysis

Based on Tobler's First Law of Geography, this study calculates the global Moran's I index using a spatial adjacency matrix to analyze new-quality productivity from 2013 to 2022. The results show a significant positive spatial correlation, with high-level regions clustering together and low-level regions also showing a similar pattern. The Moran's I index fluctuated between 0.314 and 0.431, confirming stable spatial agglomeration, with a significant P-value of 0.

Local spatial agglomeration analysis, using Moran scatter plots, reveals that most data points fall in the high-high and low-low quadrants, indicating clear spatial agglomeration in new-quality productivity development. This suggests that provinces with similar levels tend to form spatial clusters, offering key insights for regional economic dynamics and coordinated development strategies.

4 Spatial and Temporal Characteristics of the Degree of Digital-Real Economy Integration in China

4.1 Dynamic Evolution Analysis

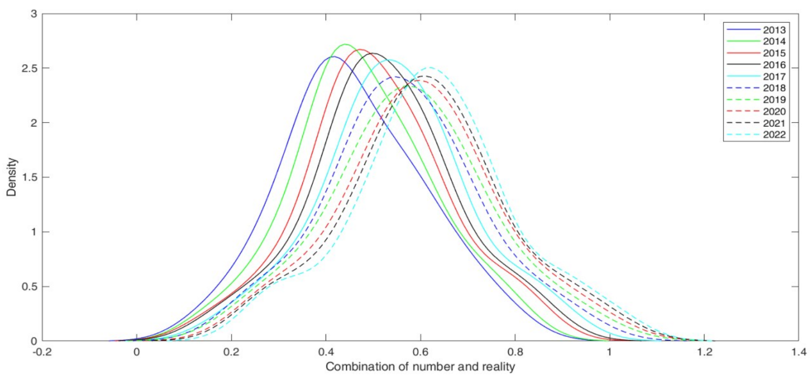

Figure 2 Dynamic Evolution Trajectory of National Digital-Real Economy Integration Degree (2013-2022)

From 2013 to 2022, the degree of national digital-real economy integration continued to improve, with the kernel density curve shifting to the right each year. The main peak first rose and then fell, indicating a weakening of the centralization trend. Some provinces, such as Guangdong, Beijing, and Shanghai, demonstrated outstanding integration, though no polarization was observed, and the overall development was relatively balanced, promoting healthy economic growth.

At the regional level, integration in the Eastern region continued to improve, with the curve shifting right, centralization weakening, and balance enhancing. The Central region showed steady improvement in integration, with widening gaps. After 2018, the balance increased, and regional polarization weakened. In the Western region, integration rose with scattered data, and since 2018, a trend of multipolarization emerged.

4.2 Spatial Agglomeration Effect Analysis

This study calculates the global Moran's I index for digital-real economy integration across China's provinces from 2013 to 2022. The results show a consistently positive Moran's I index, indicating strong spatial correlation in integration across provinces, with this correlation strengthening over time. The index fluctuated between 0.280 and 0.315, reflecting a gradual intensification of spatial agglomeration. The P-value was 0, confirming result reliability.

Local spatial analysis shows most provinces' data points cluster in high-high and low-low agglomeration quadrants, indicating a clear positive spatial agglomeration effect. This suggests significant spatial dependence in the distribution of integration, with related provinces forming agglomeration areas.

5 Exploration of the Relationship Between New-Quality Productive Forces and the Degree of Digital-Real Economy Integration

Analysis of scatter plots from 2013, 2016, 2019, and 2022 shows a positive correlation between new-quality productive forces and digital-real economy integration, with a correlation coefficient ranging from 0.796 to 0.871. Threshold effect regression analysis reveals that the impact of new-quality productive forces on integration varies. At lower levels of productive forces, a 1-unit increase results in a 2.56-unit improvement in integration. At higher levels, the effect weakens, with the regression coefficient dropping to 1.49, indicating diminishing returns. When new-quality productive forces are below 0.38, the promoting effect is stronger; above this level, it weakens.

6 Conclusion and Recommendations

China's new-quality productive forces show dynamic evolution: the eastern region leads, the central region steadily improves, and the western region stabilizes, with an overall trend toward balance. Digital-real economy integration is rising, with the eastern region most balanced, the central region improving annually, and the western region holding great potential, though regional disparities remain. Spatial agglomeration analysis shows positive autocorrelation between new-quality productive forces and integration, with high-development areas agglomerating and low-development areas following a similar trend. The synchronization between the two is high, with correlation coefficients of 0.825 and 0.874 for the east and central regions, and 0.747 for the west. Threshold effect analysis reveals that as new-quality productive forces grow, their impact on integration weakens.

It is recommended to increase support for new-quality productive forces and digital-real economy integration, encourage R&D and innovation, improve digital infrastructure, and offer tax and financial incentives. Industrial digitalization should be accelerated through standardization and the fostering of digital industry clusters[6]. Regions should create tailored strategies based on local advantages, and the government should support industrial upgrades in central and western regions, promote infrastructure development, and ensure policy implementation via technology transfer and talent support[7].

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