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Measurement and Spatiotemporal Evolution of the Development Level of New Quality Productive Forces in the Yangtze River Basin: Based on Data from Prefecture-level Cities

Yuxin Zeng, Ziyi Luo, Lisi Jiang, Yue Wang*

College of Economics, Sichuan Agricultural University, Chengdu 611130, China

*Corresponding Author

Abstract

The development of new quality productivity is an intrinsic requirement and an important focus point for promoting high-quality economic development and is of great significance for accelerating the realization of Chinese-style modernization. Based on the panel data of 110 prefecture-level cities in the Yangtze River Basin from 2018 to 2021, the article counted eight indicators under technological new quality productivity and green new quality productivity and then calculated the composite indexes of technological and green new quality productivity by using the factor analysis method, based on which, the kernel density estimation method and the global Moran indexes were applied to analyze the spatial-temporal evolution characteristics of the development of new quality productivity. The results show that, firstly, there are differences in the level of NQP among city clusters in the Yangtze River Basin, but there is a decreasing trend over time, and the NQP at the municipal level of different city clusters has a decreasing trend in general. Second, the overall differences in the development level of green and technological new quality productivity and the differences within the upper, middle, and lower reaches of the Yangtze River show an upward trend, and the development level of the upper reaches is lower than that of the lower reaches. Third, the new technological productivity in 2018-2019 shows a positive spatial correlation.

Keywords

Technological NPP; Green NPP; Regional Variation; Spatial Autocorrelation.

1. Introduction

New quality productivity, i.e. productivity led by scientific and technological innovation, strategic emerging industries and future industries, and meeting the requirements of high-quality development, can bring people a high quality of social life. Because of its emphasis on introducing and using new materials, new processes, and new technologies, it can effectively drive the innovation and development of related enterprises, effectively accelerate supply-side reform, and promote the high-quality development of the economy (Hu Hongbin, 2023). Under the deepening of economic globalization, the lack of economic strength caused by international turbulence and other factors requires new productivity to bring new changes and breakthroughs. As an important engine for the realization of high-quality development of China's economy in the new era (Lu Jiang et al., 2024), the new quality productivity is an inevitable choice to promote the construction of a modernized economic system in China and to cope with the impacts of the external environment effectively.

The Yangtze River Economic Belt, as where the center of China's economy is located and where its vitality lies (Feng Jun et al., 2024), is a key region for promoting the construction of a strong socialist modernization country. The Yangtze River basin connects the eastern coast of China

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and the inland areas of central and western China, and the cities in the region show obvious spatial heterogeneity in terms of production factors, resource endowment, and industrial structure (Zhou et al., 2021), and there are significant differences in their ability to promote high-quality development of the economy, which exacerbates the phenomenon of unbalanced and insufficient development among the cities. Therefore, scientifically assessing the development of new quality productivity in the Yangtze River Basin and measuring its development level from the spatial and temporal evolution paths can help to promote the synergistic development and economic growth of the urban agglomerations in the Yangtze River Basin, so as to drive the coordinated, stable, and sustainable growth of the country's inter-regional economy from point to point and from line to line.

At present, domestic research and discussion on new quality productivity mainly focus on the following two aspects. On the one hand, there is still some controversy among different scholars about the definition of new quality productivity. Some scholars believe that the new quality productivity is the advanced productivity quality that innovation plays a leading role, gets rid of the traditional economic growth mode and productivity development path, and has high-tech, high-efficiency, and high-quality characteristics, which is in line with the new development concept (Zhang Zhe et al., 2024). Du Chuanzhong et al. (2023), on the other hand, hold a conservative attitude, believing that the new quality of productivity still belongs to the category of productivity in essence, and it is the "leap" of productivity in the new round of scientific and technological revolution and industrial change; while Shi Jianxun and Xu Ling (2024) believe that the new quality of productivity is the new technology and digitalized machinery and equipment, which are represented by cloud computing, green and low-carbon technology, artificial intelligence and big data, and that the new technology and digitalized machinery and equipment are the new technology and digitalized machinery and equipment. New technologies and new elements such as digitalized machines and equipment, new energy, new materials, digital infrastructure, massive data, digitalized workers, arithmetic power, and other new elements are closely integrated with the new form of productivity.

On the other hand, it is the propelling role of the new quality productivity there are many discussions. Wang Ke and Guo Xiaoxi (2024) point out that although the level of new quality productivity in China has been rising year by year, the overall level is not high and there are regional differences, and the jump in the level of new quality productivity has shifted more to polarization type and the hollow type and less to high-efficiency type; Xu Zheng et al. (2023) show that the new quality productivity can optimize the layout of major productive forces, promote the in-depth fusion and development of regional innovation centers and regional industrial systems, strengthen the synergy and integration between regions, and drive regional high-quality productive forces. inter-regional synergy and integration, and drive regional high-quality development. Yan Lianfu and Niu just (2024) talk about how the development of new productive forces can help empower the development of a bigger and better economy and cut the "cake" of common prosperity.

2. Methods and Data

2.1. Source of Data

This paper takes the Yangtze River Basin, Chengdu-Chongqing, and Wuhan urban agglomerations as research objects. The data in this paper come from the China Statistical Yearbook, the 2018-2021 China Yangtze River Basin Green New Quality Productivity and Science and Technology New Quality Productivity Indicator Information Database provided by the China Regional Research Data Support Platform, in which the green new quality productivity is measured by the area of green space (hectare), the area of green space in parks, and the green coverage rate of built-up areas (%); and the scientific and technological new

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quality productivity is measured by the number of Research and Experimental Development (R&D) The new quality productivity of science and technology is measured by the number of research and development (R&D) personnel (person), the number of students enrolled in general institutions of higher education (person), the number of graduates from general institutions of higher education (person), the number of patents for inventions (piece), and the number of scientific and technological papers published (piece).

Table 1. Green new mass productivity indicators

Level 1 indicators	source (of information etc)
Area of green space (hectares)	Wang Ke, Guo Xiao Xi (2024)
Green area of parks (hectares)	Wang Ke, Guo Xiao Xi (2024)
Greening coverage of built-up areas (%)	Wang Ke, Guo Xiao Xi (2024)

Table 2. New quality productivity indicators for science and technology

Level 1 indicators	source (of information etc)
Research and experimental development (R&D) personnel (persons)	Luo Shuang, Xiao Yun (2024)
Number of students enrolled in general higher education (persons)	Jue Wang (2023)
Number of general higher education graduates (persons)	Luo Shuang, Xiao Yun (2024)
Number of patents for inventions (cases)	Wang Jue (2023); Zhang Zhe et al. (2024), Wang Ke, Guo Xiaoxi (2024); Lu Jiang et al.(2024)
Scientific and technical papers published (one)	Wang Ke, Guo Xiaoxi (2024); Lu Jiang et al.(2024),Jue Wang (2023); Zhe Zhang et al. (2024)

2.2. Measurement of the Level of Development of the New Quality Productivity

Considering the space reason, this paper only shows the results of factor analysis measurement of new quality productivity of science and technology. It should be noted that a correlation between variables is a prerequisite for conducting research using factor analysis, so before using factor analysis to measure the level of new quality productivity in science and technology, the original variables of the five indicators under new quality productivity in science and technology: the number of research and experimental development RD personnel, the number of students enrolled in general higher education, the number of graduates from general higher education, the number of invention patents, and the number of published scientific and technological papers were tested by the Bartlett sphericity test and the KMO test. Bartlett sphericity test and KMO test to examine the correlation between the variables. The test results show that: (1) the P-value of Bartlett's spherical test is 0, which does not obey the spherical test and rejects the hypothesis that the variables are independent of each other, indicating that the correlation between the variables is strong. (2) The KMO value is 0.721, indicating that it is suitable for factor analysis. Taken together, the raw variables of the five indicators are suitable for conducting factor analysis.

Further, principal component analysiswas utilizedto extract the factor variables. Table 3 demonstrates the results of principal component analysis for the five raw variables. Referring to the idea of most scholars, the factors with a cumulative contribution rate of 0.8 or more are taken as public factors. Based on this, two factors with a cumulative contribution of more than

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0.8were identified using principal component analysis and therefore these two factors were used as the common factors.

Table 3. Principal component analysis of raw variables

variable name	eigenvalue (math.)	Difference in eigenvalues	variance contribution	Cumulative variance contribution
Number of RD personnel in research and experimental development	3.91355	3.27503	0.7827	0.7827
Number of students enrolled in general higher education	0.638515	0.405076	0.1277	0.9104
Number of graduates from general higher education institutions	0.233439	0.476837	0.0467	0.9571
Number of patents for inventions	0.185755	0.157012	0.0372	0.9943
Number of scientific papers published	0.287425		0.0057	1.0000

After extracting the common factors, the scores of Common Factor 1 and Common Factor 2 were further calculated and expressed as F1 and F2respectively.On this basis,based on the factor score equation, the composite index of the level of new quality productivity of science and technology is calculated and used to measure the degree of the level of development of new quality productivity of science and technology. The formula is y=(0.787×F1+0.1277×F2)/0.9104.Where y is thescore of the composite indexof the level of scientific and technological new quality productivity development, whichis usedto characterize the degree of the level of scientific and technological new quality productivity development.

2.3. Kernel Density Estimation Non-parametric Method

2.3.1. Overview of the Methodology

This paper will employ the Kernel density estimation non-parametric method to investigate the spatial imbalanced distribution dynamics of supply chain resilience among enterprises in the 12 city clusters of the Yangtze River Basin (including the Basin itself). Kernel density estimation is a commonly used method for studying spatial imbalance by comparing the differences in sample distributions at different time points. It assumes that the density function of the random variable x is f(x), and the probability density at point x is represented by Equation (1):

$$f(x) = \frac{1}{N_h} \sum_{i=1}^{N} K(\frac{X_i - x}{h}) \quad (1)$$

Where N is the number of observations, h is the bandwidth, K(·) is the Kernel function, and X_i are the observed values. The Kernel density function has various expressions such as uniform kernel, quadratic kernel, and Gaussian kernel, among which Gaussian kernel is most commonly used. Therefore, this paper also adopts a Gaussian kernel to estimate the dynamic evolution process of the distribution of supply chain resilience of high enterprises in 12 urban agglomerations in the Yangtze River Basin (including the Yangtze River Basin). The expression of Gaussian kernel function is shown in equation (2).

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$$f(x)=\frac{1}{\sqrt{2\pi}}\exp(-\frac{x^2}{2}) \quad (2)$$

2.3.2. Time Evolution Characteristics of New Quality Productivity in Urban Agglomerations in the Yangtze River Basin

To further reveal the time evolution characteristics of the changes in the development levels of technological new quality productivity and green new quality productivity among the cities of the six city clusters in the Yangtze River Basin, this paper plots the density distributions of the development levels of technological new quality productivity and green new quality productivity among the cities of the six city clusters in the Yangtze River Basin in the period of 2018-2021 by using the kernel density estimation method (Figures 1 to 6).

First, the kernel density estimation maps of these six city clusters show the probability distribution characteristics of the development levels of technological novelty productivity and green novelty productivity among the cities in the Yangtze River Basin. The center of the kernel density estimation curves of the development levels of technological novelty productivity in the Yangtze River Basin as well as the change intervals in the Yangtze River Basin from 2018 to 2021 gradually shifted to the left, whereas the estimated curves of the green novelty productivity only shifted marginally. It indicates that the development level of technological new quality productivity in the Yangtze River Basin has an obvious downward trend, i.e., the technological new quality productivity in the Yangtze River Basin is declining. The development level of green NQP is still to be improved. This leftward shift reflects that the cities in the Yangtze River Basin may not yet have adapted to the new technological changes, and thus have not yet significantly promoted regional economic development.

Second, the change in the width of the distribution curve reveals regional differences in the level of new quality productivity development among city clusters. Over time, the width of the distribution curves for the Chengdu-Chongqing and Wuhan clusters decreases, suggesting that the differences in new productivity within these clusters are narrowing. Analyzing the overall Yangtze River Basin may imply that there are significant differences between different city clusters in terms of the level of green development management and technological innovation capacity, leading to unbalanced development of new quality productivity.

Through further analysis, the distribution curves of city clusters do not show obvious single-peak or double-peak characteristics, which may indicate that the polarization of the new quality productivity is not significant. These changes suggest that urban environmental protection, the optimization of science and technology policies, and the application of technological innovation may play a key role in this process.

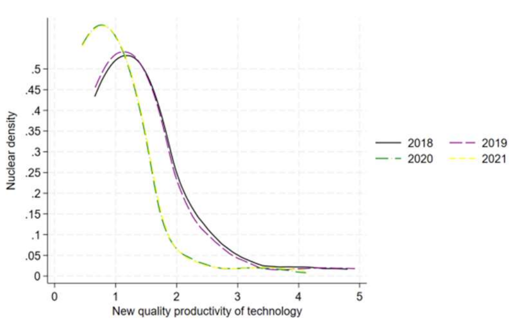

Figure 1. Yangtze River Basin

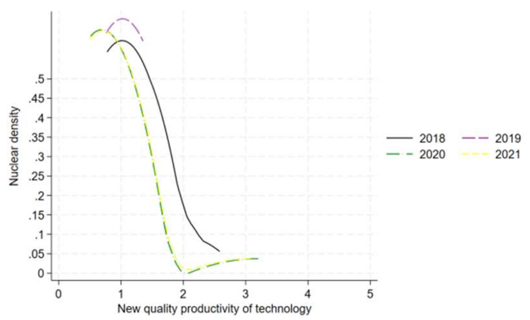

Figure 2. Chengdu-Chongqing city cluster

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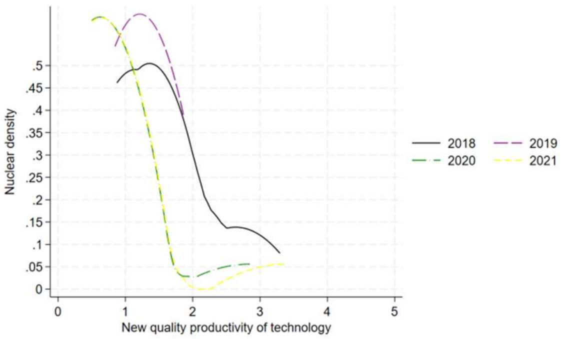

Figure 3. Wu Han

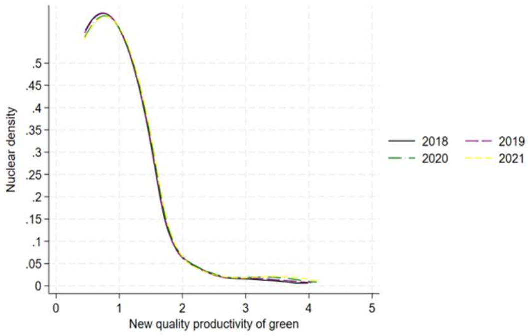

Figure 4. Yangtze River Basin

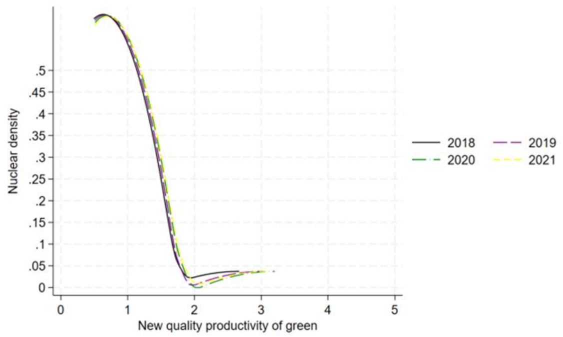

Figure 5. Chengdu-Chongqing city cluster

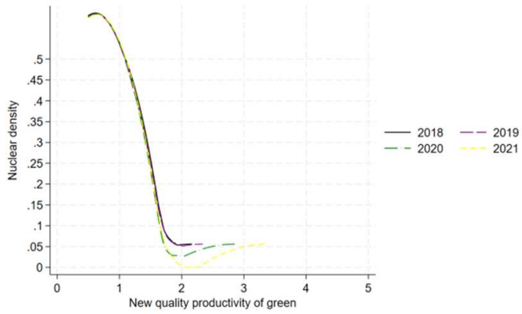

Figure 6. Wu Han

2.4. Spatial Autocorrelation Tests

2.4.1. Overview of the Methodology

(1) Spatial autocorrelation tests

The first law of geography states that everything is correlated with everything else and the closer the distance, the stronger the correlation. Before constructing the spatial measurement model, Moran's I proposed by Anselin is usually chosen to test whether the variables have spatial autocorrelation or not, and Moran's index can be divided into global Moran's I and local Moran's I (Zhan Lei et al., 2022).

(2) Space weight settings

In testing the spatial correlation of variables, a spatial weight matrix is needed to reflect the relationship between spatial units. Taking this into consideration, it is proposed to use inverse distance matrix spatial weights to measure the spatial correlation of variables.

$$W_{ij} = \begin{cases} 1/d_{ij}, i \neq j \\ 0, i = j \end{cases}$$

(3) Spatial correlation measures

Global Moran's Index. Generally, Moran's index I (Moran's I), Geary's index C (Geary's C), and Getis-Ord index Gare used to conduct preliminary tests of spatial effects. In this paper, Moran's index I is used.

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} \times (x_i - \bar{x}) \times (x_j - \bar{x})}{Z^2 \times \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{3}$$

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Equation (3), $Z^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}$ is the sample variance difference, Wij is the (i, j) element of the spatial weight matrix (measuring the distance between region i and region j), $\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}$ is the sum of all spatial weights. After performing the normalization, the $\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}$, Moran index I can be simplified as:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} \times (x_i - \bar{x}) \times (x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{4}$$

The normalized Moran's index generally takes values between -1 and 1. A value greater than 0 indicates positive autocorrelation; less than 0, negative autocorrelation; and close to 0, no autocorrelation.

2.4.2. Global Spatial Autocorrelation Test

(1) Global spatial autocorrelation test for new quality productivity in science and technology

To accurately examine whether there is a significant spatial correlation in the development level of scientific and technological new quality productivity in the Yangtze River Basin from 2018 to 2022, the inverse distance spatial weight matrix is selected here to carry out the spatial autocorrelation test, and the results are shown in Table 1. It can be seen that the global Moran's I is greater than 0 in 2018-2019, and the P-value is less than 0.1, indicating that there is a significant positive spatial correlation in the development level of new quality productivity of science and technology in the Yangtze River basin.

Table 4. The whole picture of new quality productivity of science and technology in the Yangtze River Basin, 2018-2021Moran's I

year	Moran's I	p
2018	0.015*	4
2019	0.021**	7
2020	-0.005	5

(2) A global spatial autocorrelation test for green new quality productivity

To accurately examine whether there is a significant spatial correlation in the development level of new quality productivity of science and technology in the Yangtze River Basin from 2018 to 2022, the inverse distance spatial weight matrixes chosen here to carry out the spatial autocorrelation test, and the results are shown in Table 2. It can be seen that the global Moran's I except in 2018-2019 are all greater than 0, but the P-value is greater than 0.1, indicating that there is no significant spatial positive correlation in the development level of green new quality productivity in the Yangtze River Basin.

3. Conclusion and Implications

This paper provides an in-depth analysis of the regional differences and dynamic evolution of the development levels of municipal green NPS and STNPS among six city clusters in the Yangtze River Basin from 2018 to 2021.Its main conclusions are as follows:

(1) There should be significant differences in the level of new quality productivity among city clusters, but there is a downward trend over time.

(2) Interregional differences are the main cause of overall regional differences. Both less-developed city clusters and developed city groups tend to decrease intra-regional differences in the level of development of new quality productivity, which may be related to various factors such as environmental regulation and policy support.

(3) The dynamic evolutionary characteristics of NPP indicate that NPP at the municipal level in different city clusters is generally on a downward trend and that there are differences in the rate and level of development between different city clusters.

Based on the above conclusions, this study provides the following insights:

(1) The state should pay attention to the differences in new-quality productivity among city clusters, formulate corresponding support policies for less developed city clusters, improve the policy environment, and raise the requirements for environmental regulation and the level of support for new-technology talents, to promote the balanced development of the regional economy.

(2) Encourage localities to adopt the introduction of innovative technologies such as 5G digitization and artificial intelligence to improve the development of new quality productivity in science and technology.

(3) Promote inter-regional cooperation and exchanges through resource sharing and information exchange to improve the overall level of new quality productivity development in city clusters.

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