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MEASUREMENT OF MUNICIPAL NEW-QUALITY PRODUCTIVE FORCES AND REGIONAL DIFFERENCES

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Abstract: Guided by the policy of developing new-quality productive forces in light of local conditions, this paper takes panel data (2015-2024) of five core cities in Jiangxi including Nanchang, Ganzhou, Jiujiang, Shangrao and Yichun as research samples. An evaluation system for municipal new-quality productive forces is constructed covering scientific-technological, green and digital dimensions. The entropy-weight improved AHP-TOPSIS model is adopted for comprehensive measurement, so as to analyze its temporal evolution and regional differentiation. The results show that the overall level of new-quality productive forces of the five cities presents a fluctuating upward trend, which can be divided into three stages: steady accumulation, accelerated improvement and adjustment-divergence. Obvious echelon gaps exist among cities. Nanchang takes the lead, Ganzhou ranks second, Shangrao shows strong late-comer momentum, while Jiujiang and Yichun suffer from remarkable fluctuation and decline. Green productivity enjoys sound intra-provincial balance yet meets promotion bottlenecks; inter-city gaps are prominent in scientific-technological and digital productivity. Most cities are confronted with insufficient S&T investment, weak digital industrial foundation and heavy pressure of industrial transformation. Targeted suggestions are put forward on consolidating industrial foundation, strengthening innovation drive, promoting digital-real economy integration, advancing differentiated green-low-carbon transition, optimizing regional coordination and institutional guarantee. It provides empirical support for fostering municipal new-quality productive forces in Jiangxi.
Keywords: New-quality productive forces; Entropy-weight improved AHP-TOPSIS; Temporal evolution; Regional difference; Jiangxi municipalities

1 INTRODUCTION

Developing new-quality productive forces serves as the core starting point for advancing high-quality development in the new era, and developing new-quality productive forces in light of local conditions points out the practical direction for local economic transformation [1-2]. Jiangxi is in a critical period of industrial iteration and upgrading. Prefecture-level cities within the province differ greatly in resource endowments and industrial foundations. Scientifically measuring the level of municipal new-quality productive forces and identifying regional development weaknesses is of practical significance for stimulating local growth momentum and promoting the economic quality improvement and expansion of Jiangxi Province during the 15th Five-Year Plan period [3-4].

Since the concept of new-quality productive forces was put forward, academic circles have carried out extensive research on its connotation interpretation, generation mechanism and index measurement. At the theoretical level, scholars have clarified the core connotation and internal logic of new-quality productive forces, and analyzed the linkage among scientific-technological innovation, digital transformation and industrial transformation [5-6]. At the empirical level, most studies construct evaluation systems from the provincial perspective and conduct measurement analysis based on dimensions such as laborers, means of labor and objects of labor, or science-technology-green-digital dimensions [7-8]. Nevertheless, existing empirical studies still have limitations. Some achievements focus on macro-comparison at China's provincial level, while long-time-series panel empirical research targeting key municipal units within central-province regions remains relatively insufficient. In-depth exploration on the temporal evolution and differentiated sub-dimensional characteristics of intra-provincial cities needs to be further strengthened [9-10].

Accordingly, this paper adopts panel data of five cities including Nanchang, Ganzhou, Jiujiang, Shangrao and Yichun from 2015 to 2024, constructs a three-dimensional indicator system covering science-technology, green and digital dimensions, and measures municipal new-quality productive forces via the entropy-weight improved AHP-TOPSIS model. The marginal contributions of this paper are as follows. First, from the prefecture-level perspective of a central province, it expands empirical research on new-quality productive forces at the meso-municipal level. Second, it analyzes echelon differentiation and restrictive weaknesses of new-quality productive forces among core cities in Jiangxi through temporal-evolution and sub-dimensional decomposition. Third, differentiated improvement paths are proposed matching cities' endowments, providing empirical references for fostering municipal new-quality productive forces in central China in light of local conditions.

2 CONSTRUCTION OF EVALUATION INDEX SYSTEM AND MEASUREMENT METHOD FOR NEW-QUALITY PRODUCTIVE FORCES

2.1 Evaluation Index System of Municipal New-Quality Productive Forces

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New-quality productive forces are characterized by high technology, high efficiency and high quality, corresponding to scientific and technological new-quality productive forces, green new-quality productive forces and digital new-quality productive forces. Combined with the actual situation of Jiangxi Province, this paper constructs a cross-municipal comprehensive evaluation system containing 3 primary indicators, 6 secondary indicators and 18 tertiary indicators. The entropy weight-improved AHP-TOPSIS method is adopted to assign weights and measure each indicator, so as to obtain the level of new-quality productive forces in five cities: Nanchang, Yichun, Ganzhou, Jiujiang and Shangrao.
Scientific and Technological New-quality Productive Forces: Innovation is the feature of new-quality productive forces, which is driven by revolutionary technological breakthroughs. Therefore, scientific and technological productive forces can be further divided into innovative productive forces and technological productive forces.
(1) Innovative productive forces. First, scientific and technological funds are the guarantee of innovation. The internal R&D expenditure of industrial enterprises above designated size can largely represent the level of regional innovation capital input. Second, the number of invention patent grants represents the latest theoretical achievements of innovation, which serves as the theoretical support for transforming into new-quality productive forces. Finally, high-tech industries are manufacturing sectors with strong innovation attributes, and their operating income can reflect the regional innovation level.
(2) Technological productive forces. First, industrial enterprises above designated size are an important source of regional economic aggregate. Advanced equipment manufacturing industry integrates advanced technologies and industries. The operating income of both can truthfully reflect the regional technological productive force level. Second, the full-time equivalent of R&D personnel in industrial enterprises above designated size is a core official statistical indicator released by the National Bureau of Statistics, which is highly suitable as an indicator for scientific and technological productive forces.
Green New-quality Productive Forces: (1) Resource-conserving productive forces. As the input side, the resource-conserving type focuses on reducing resource input and improving resource utilization efficiency, which represents a social development mode that maximizes economic and social benefits with minimum resource consumption. The ratio of energy consumption to gross domestic product, the ratio of fossil energy consumption of enterprises above designated size to gross domestic product, and the ratio of industrial water consumption to gross domestic product can well reflect resource utilization efficiency. These three are negative indicators; the smaller the value, the higher the level of resource-conserving productive forces.
(2) Environment-friendly productive forces. As the output side, the environment-friendly type focuses on reducing pollution emissions, protecting the ecological environment and promoting sustainable economic development. The ratio of comprehensive utilization amount to generation amount of industrial solid waste, the ratio of industrial wastewater discharge to gross domestic product, and the ratio of industrial SO_2 emission to gross domestic product are relatively objective measurement indicators. Among them, the ratio of industrial wastewater discharge to gross domestic product and the ratio of industrial SO_2 emission to gross domestic product are negative indicators; the smaller the value, the higher the level of environment-friendly productive forces.
Digital New-quality Productive Forces: Digital economy is the major economic form following agricultural economy and industrial economy. It is a strategic choice to seize the opportunities brought by the new round of scientific and technological revolution and industrial transformation, and also the core driving force for fostering new-quality productive forces. New-quality productive forces emphasize the innovative allocation and optimized combination leap of production factors, and digital economy is the key power to achieve this goal. Digital economy consists of digital industrialization and industrial digitalization. The two coordinate bidirectionally and jointly become an important power source for cultivating regional new-quality productive forces.
(1) Digital industrial productive forces. Digital industrialization mainly includes digital product manufacturing, software and information technology services, Internet services, etc. It provides technologies, products and infrastructure for the digital transformation of the whole society and lays the foundation for digital economy development. Digital industrialization supplies technical tools for industrial digitalization. Variables such as the manufacturing industry of computers, communications and other electronic equipment, total telecommunication business volume, and the number of Internet broadband access users are industries that provide digital technologies, hardware, software and infrastructure for the whole society, which can well reflect the level of digital industrialization.
(2) Industrial digital productive forces. Industrial digitalization refers to the improvement of digital efficiency. It embodies the deep integration of digital technology and real economy, manifested as the efficiency improvement and output growth of traditional primary, secondary and tertiary industries applying digital technology. Industrial digitalization provides broad application scenarios for digital industrialization. The income of software and information technology service industry, the number of mobile phone users at year-end, and e-commerce sales volume are application scenarios of industrial digitalization.
At present, there is no unified evaluation indicator for measuring new-quality productive forces in academia. The above evaluation indicators are selected by comprehensively considering the specific conditions of Jiangxi Province and the five cities including Nanchang, Yichun, Ganzhou, Jiujiang and Shangrao. There are inevitably limitations in both the quantity and selection of indicators, which will be the direction of further research in this paper. However, under the unified indicator system, the level of new-quality productive forces of the five cities can be reflected fairly to a certain extent, and it is expected to provide certain reference significance. The detailed index system is shown in Table 1.

Table 1 Evaluation Index System of Urban New-Quality Productive Forces

Primary Indicator	Secondary Indicator	Tertiary Indicator	Unit	Property
Scientific and Technological Productive Forces	Innovative Productive Forces	A1 Number of invention patent grants	piece	+
		A2 Operating income of high-tech industries	ten thousand yuan	+
		A3 Internal R&D expenditure of industrial enterprises above designated size	trillion yuan	+
	Technological Productive Forces	A4 Per capita operating income of industrial enterprises above designated size	ten thousand yuan/person	+
		A5 Full-time equivalent of R&D personnel in industrial enterprises above designated size	person-year	+
		A6 Per capita income of equipment manufacturing industry	ten thousand yuan	+
Green Productive Forces	Resource-conserving Productive Forces	B1 Energy consumption / gross domestic product	%	-
		B2 Fossil energy consumption of enterprises above designated size / gross domestic product	%	-
		B3 Industrial water consumption / gross domestic product	%	-
	Environment-friendly Productive Forces	B4 Comprehensive utilization amount / generation amount of industrial solid waste	%	+
		B5 Industrial wastewater discharge / gross domestic product	%	-
		B6 Industrial SO_2 emission / gross domestic product	%	-
Digital Productive Forces	Digital Industrial Productive Forces	C1 Industrial operating income of computer, communication and other electronic equipment manufacturing	ten thousand yuan	+
		C2 Total telecommunication business volume	100 million yuan	+
		C3 Number of Internet broadband access users	ten thousand households	+
	Industrial Digital Productive Forces	C4 Income of software and information technology service industry	ten thousand yuan	+
		C5 Number of mobile phone users at year-end	ten thousand households	+
		C6 E-commerce sales volume	ten thousand yuan	+

2.2 Measurement Method of Municipal New-Quality Productive Forces

Standardization of Indicator Data: (1) Positive indicators

$$x_{ij}^{'}=\frac{x_{ij}-min(x_j)}{max(x_j)-min(x_j)} \tag{1}$$

(2) Negative indicators

$$x_{ij}^{'}=\frac{max(x_j)-x_{ij}}{max(x_j)-min(x_j)} \tag{2}$$

To avoid zero values after standardization which cause problems in subsequent calculation, the results are usually translated:

$$x_{ij}^{''}=x_{ij}^{'}+a \tag{3}$$

where a is a tiny positive constant (such as 0.0001), ensuring that $x_{ij}^{''}$ will not be zero and avoiding meaningless calculation when taking $\ln p_{ij}$ in the follow-up.

Entropy Value and Difference Coefficient: (1) Calculate indicator weight

$$p_{ij}=\frac{x_{ij}^{''}}{\sum_{i=1}^{n} x_{ij}^{''}} \tag{4}$$

(2) Calculate information entropy

$$e_j=-k\sum_{i=1}^{n} p_{ij}\ln p_{ij} \tag{5}$$

Where $k = \ln \frac{1}{n}$ (3) Calculate difference coefficient

$$g_j=1-e_j \tag{6}$$

Improved AHP Weighting: (1) Maximum difference coefficient ratio D and adjustment coefficient α

$$D=\frac{\max(g_j)}{\min(g_j)},\quad \alpha=\begin{cases}\text{round}(D), D\le 9\\ 9, D>9\end{cases} \tag{7}$$

$$R=\left(\frac{D}{\alpha}\right)^{1/(\alpha-1)} \tag{8}$$

(2) Scale mapping value: $k \cdot R^{(k-1)}$, k = 1,2, ..., 9 (see Table 2)

Table 2 Scale and Mapping Values of Analytic Hierarchy Process

Scale k	Mapping Value $k \cdot R^{(k-1)}$
1	$1\times R^0$
2	$2\times R^1$
3	$3\times R^2$
4	$4\times R^3$
5	$5\times R^4$
6	$6\times R^5$
7	$7\times R^6$
8	$8\times R^7$
9	$9\times R^8$

(3) Solve weights from judgment matrix: Calculate the ratio of difference coefficients between each pair of indicators:

$$r_{jk}=\frac{g_j}{g_k} \tag{9}$$

Take the closest value in Table 2; take the reciprocal if r < 1.

(4) Weight and consistency test — Eigenvector method to solve the eigenvector corresponding to the maximum eigenvalue and normalize it.

Evaluation Using Technique for Order Preference by Similarity to an Ideal Solution: TOPSIS is a widely used objective comprehensive evaluation method that highlights overall differences. It emphasizes the discriminability principle and free competition principle of schemes and can complement advantages with methods such as entropy weight method.

(1) Construct weighted normalized matrix according to the weights determined by entropy weight method

$$V=P\cdot W=\begin{bmatrix} w_1P_{11} & w_2P_{21} & \cdots & w_nP_{m1} \\ w_1P_{12} & w_2P_{22} & \ddots & w_nP_{m2} \\ \vdots & \vdots & \ddots & \vdots \\ w_1P_{1n} & w_2P_{2n} & \cdots & w_nP_{mn} \end{bmatrix} \tag{10}$$

(2) Calculate the optimal scheme and worst scheme. For positive indicators, the optimal scheme and worst scheme are:

$$V^+=maxv_{ij} \mid i=1,2,\ldots,n \tag{11}$$

For negative indicators, the optimal scheme and worst scheme are:

$$V^-=minv_{ij} \mid i=1,2,\ldots,n \tag{12}$$

(3) Calculate the distance from indicators to the optimal scheme and worst scheme

$$d_i^+=\sqrt{\sum_{j=1}^{n}(v_{ij}-V_j^+)^2} \tag{13}$$

$$d_i^-=\sqrt{\sum_{j=1}^{n}(v_{ij}-V_j^-)^2} \tag{14}$$

where i = 1,2, ..., m.

(4) Calculate relative closeness

$$c_i=\frac{d_i^-}{d_i^+ + d_i^-} \tag{15}$$

The relative closeness c_i reflects the proximity degree between the evaluated object and the optimal solution, namely the final score.

Comprehensive Score: According to the measurement results of scientific and technological productive forces, green productive forces and digital productive forces of the five cities in each year, the average value of each year is calculated, which represents the level of new-quality productive forces of the five cities in different years.

3 NEW-QUALITY PRODUCTIVE FORCE MEASUREMENT RESULTS

3.1 Comprehensive Analysis of Temporal Evolution

Overall, as shown in Figure 1, the new-quality productive forces of Nanchang, Ganzhou, Shangrao, Jiujiang and Yichun generally showed an upward trend from 2015 to 2024. The time sequence can be divided into three stages: (1) Steady accumulation stage (2015–2018): the scores of each city rose slowly, and the gaps between cities gradually widened. (2) Accelerated promotion stage (2019–2022): policy-driven, the new-quality productive force level of each region increased rapidly. (3) Adjustment and differentiation stage (2023–2024): some cities witnessed score decline, and the internal regional development differentiation became more obvious.

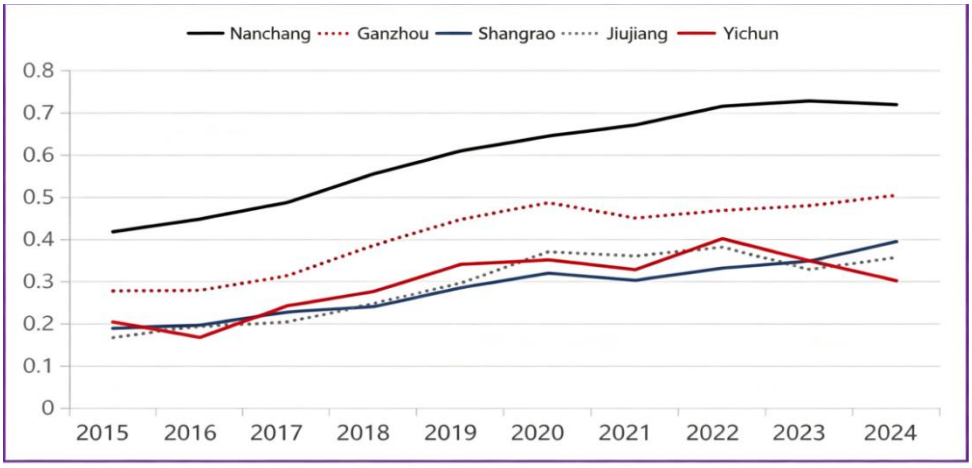


Figure 1 Temporal Evolution of New-Quality Productive Forces from 2015 to 2024

From the perspective of individual cities, there are obvious differences in growth paths and fluctuation characteristics among cities: (1) Nanchang consistently ranked first in comprehensive score with continuous overall growth. It reached the peak of 0.7288 in 2023 and had a slight drop in 2024. As the provincial capital, its status as the core pole of new-quality productive forces is stable. (2) Ganzhou maintained the second place, with an overall rising score and only a small decline in 2021, followed by recovery growth, showing remarkable late-development catching-up characteristics. (3) Shangrao started at a low level but kept rising steadily without sharp decline. Its score in 2024 exceeded Jiujiang and Yichun, and the late-development growth potential was gradually released. (4) Jiujiang achieved rapid improvement from 2020 to 2022, followed by a significant decline in 2023, ranking fourth in 2024. (5) Yichun had a short-term drop in 2016, peaked at 0.4022 in 2022 and then declined for two consecutive years, ranking fifth in 2024. The gaps among Shangrao, Jiujiang and Yichun are small, while the gaps between them and Nanchang and Ganzhou are obvious.

3.2 Ten-Year Average Value and Comprehensive Analysis

The ten-year sub-dimensional analysis and comprehensive scores for new-quality productivity are presented in Table 3.

Table 3 Ten-Year Sub-Dimensional and Comprehensive Scores of New-Quality Productive Forces

Dimension	Nanchang	Ganzhou	Yichun	Jiujiang	Shangrao
Scientific and Technological Productive Forces	0.501995	0.169700	0.211582	0.260467	0.197600
Green Productive Forces	0.770340	0.831760	0.560752	0.485335	0.500821
Digital Productive Forces	0.530260	0.230410	0.118753	0.129804	0.154547
New-quality Productive Forces	0.600865	0.410623	0.297029	0.291869	0.284323

It can be seen from Figure 2 that the ranking of average values of the five cities changed slightly during the decade of 2015–2024. Nanchang still took the lead, Ganzhou ranked second, and Yichun surpassed Jiujiang and Shangrao to rank third. It can be specifically seen from Table 3 that Yichun performed better in green productive forces than Jiujiang and Shangrao. Jiujiang and Shangrao ranked relatively low, while the overall level gaps among Yichun, Jiujiang and Shangrao were small.

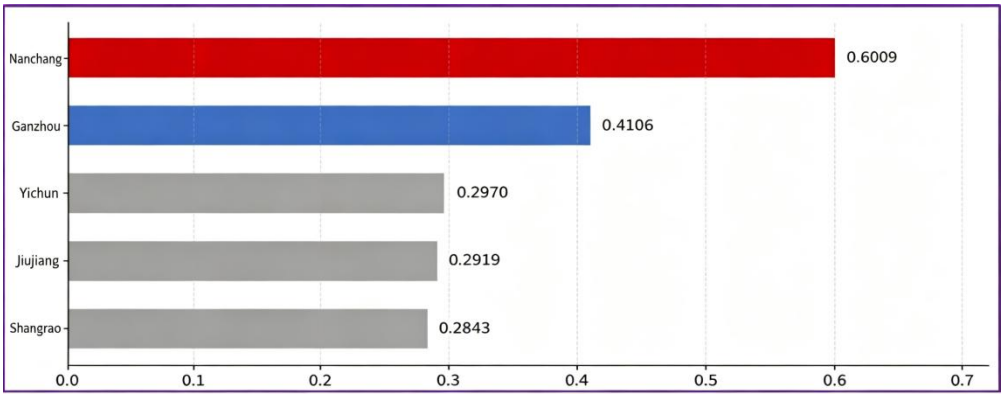


Figure 2 Ranking of Comprehensive Scores of New-Quality Productive Forces from 2015 to 2024

3.3 Scientific and Technological Productive Force Dimension

As the provincial capital, Nanchang maintained medium-high and stable growth and played a “ballast stone” role, and regional differentiation intensified, see Figure 3. The Science and Technology Productivity Scores for the period 2015–2024 are presented in Table 4. Overall, the scientific and technological productive forces of the five cities maintained growth in the past decade. In particular, 2021, the opening year of the 14th Five-Year Plan, became an “acceleration turning point”. Among them, Nanchang increased by 29.4%, Jiujiang by 28.9%, Yichun by 22.6%, Shangrao by 56.9%, and Ganzhou by 52.7%, as shown in Table 4. The growth momentum showed a pattern of “southward and eastward advancement” (Ganzhou and Shangrao). Traditional industrial cities (Jiujiang and Yichun) lacked staying power.

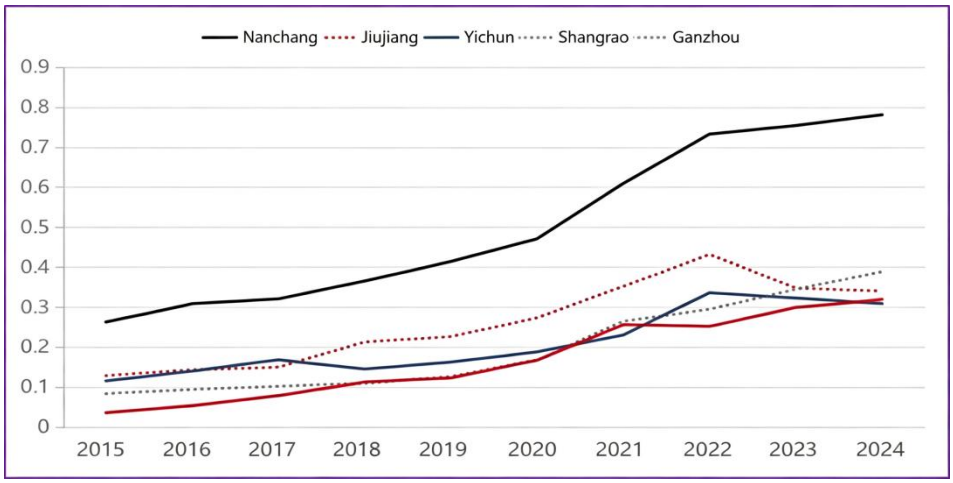


Figure 3 Score Trend of Scientific and Technological Productive Forces from 2015 to 2024

Table 4 Scores of Scientific and Technological Productive Forces from 2015 to 2024

Scientific and Technological Productive Forces	Nanchang	Jiujiang	Yichun	Shangrao	Ganzhou
2015	0.262749	0.128236	0.115837	0.083838	0.036293
2016	0.308138	0.143274	0.139467	0.094095	0.053501
2017	0.320596	0.149838	0.16781	0.102084	0.078521
2018	0.365014	0.212718	0.144929	0.109865	0.112704
2019	0.413991	0.226134	0.162592	0.126134	0.122972
2020	0.471416	0.273205	0.188059	0.168274	0.167539
2021	0.609835	0.352202	0.230559	0.263998	0.25582
2022	0.732866	0.431768	0.335647	0.294649	0.251888
2023	0.754056	0.347445	0.322288	0.344808	0.298877
2024	0.781286	0.339851	0.308627	0.388257	0.318889
Ten-year Average	0.5019947	0.2604671	0.2115815	0.1976002	0.1697004

From the perspective of individual cities: (1) Nanchang took the lead exclusively and was the only city continuing to reach new highs with the strongest growth resilience. Nanchang ranked first for ten consecutive years, with a score of 0.781 in 2024, 2.01 times that of Shangrao (0.388), the second place. Nanchang’s ten-year CAGR was 12.87%, with an absolute increment of 0.519, more than twice that of other cities. (2) Shangrao rose strongly. Its ranking rose from the 4th (0.084) in 2015 to the 2nd (0.388) in 2024, increasing by 4.63 times in ten years. Shangrao’s CAGR was 18.57%, the second highest among the five cities. Especially, its CAGR reached 23.2% from 2020 to 2024, making it the fastest-growing city in the second half of the decade, and its second-place position has been basically stabilized. (3) Ganzhou had the highest growth rate, with a CAGR of up to 27.31%, ranking first among the five cities, increasing by 8.79 times in ten years, the highest multiple. However, its starting point was too low, only 0.036 in 2015 (the lowest among the five cities). Even after ten years of rapid growth, its score of 0.319 in 2024 still ranked 4th. Ganzhou’s CAGR reached 35.8% from 2015 to 2020 (outbreak period), and decreased to 17.5% from 2020 to 2024, indicating that its growth momentum is marginally diminishing. (4) Jiujiang and Yichun “rose high and fell low”. After peaking in 2022, they declined for two consecutive years, lacking transformation capacity in scientific and technological productive forces. Jiujiang reached 0.432 in 2022, close to Shangrao’s current level, but plunged by 19.5% in 2023 and decreased slightly by 2.2% in 2024, dropping from the 2nd to the 3rd place. Yichun also achieved negative growth for two consecutive years after peaking in 2022, ranking 5th in 2024.

3.4 Green Productive Force Dimension

Overall, see Table 5 for details. (1) Green productive forces are the dimension with the highest overall score, the smallest inter-city gap and the slowest growth among the three dimensions. The scores of the five cities were all above 0.35. The ten-year average of Ganzhou (0.832), the highest, was only 1.7 times that of Jiujiang (0.485), the lowest, far smaller than the 3.8 times gap of digital productive forces and 2.5 times gap of scientific and technological productive forces. This indicates that green development (ecological environment, green industries, energy conservation and

emission reduction, etc.) has formed a sound basic balance within Jiangxi Province. (2) The growth momentum of green productivity is also the weakest. The decade-long CAGR for all five cities was below 5%; among these five cities, three—Yichun, Jiujiang, and Ganzhou—experienced stagnation or negative growth between 2020 and 2024, while only Shangrao maintained stable growth and Nanchang saw modest growth. This indicates that, after a period of improvement from 2015 to 2020, green productivity has overall entered a bottleneck phase—where easily achievable energy conservation, emission reduction, and ecological restoration projects have been largely completed; further advancement now requires more profound industrial green transformation.

Table 5 Scores of Green Productive Forces from 2015 to 2024

Green Productive Forces	Ganzhou	Nanchang	Yichun	Shangrao	Jiujiang
2015	0.720565	0.674095	0.454061	0.454406	0.350403
2016	0.704734	0.689072	0.344305	0.443348	0.40654
2017	0.745298	0.707137	0.51843	0.465658	0.425697
2018	0.815231	0.74738	0.587009	0.488472	0.427398
2019	0.866241	0.775683	0.674098	0.49857	0.467125
2020	0.878751	0.792768	0.637821	0.502245	0.594294
2021	0.883632	0.821087	0.683123	0.520628	0.630241
2022	0.9144	0.834275	0.67853	0.544202	0.543977
2023	0.888541	0.826536	0.574103	0.544772	0.46852
2024	0.900203	0.835363	0.456039	0.545911	0.539157
Ten-year Average	0.8317596	0.7703396	0.5607519	0.5008212	0.4853352

4 CONCLUSIONS

This paper constructs a three-dimensional evaluation system covering scientific-technological, green and digital productive forces, and adopts the entropy-weight improved AHP-TOPSIS model to measure the municipal new-quality productive forces of five core cities in Jiangxi Province from 2015 to 2024. The empirical results reveal that the overall new-quality productive forces of the sample cities show a fluctuating upward trend with obvious phased characteristics and prominent echelon differentiation. Nanchang acts as the core growth pole, Ganzhou maintains steady progress, while Shangrao demonstrates strong late-comer advantages; Jiujiang and Yichun suffer from frequent performance fluctuations. Among the three dimensions, green productivity achieves sound intra-provincial equilibrium yet meets development bottlenecks, whereas scientific-technological and digital productivity face large inter-city gaps caused by insufficient innovation input and weak digital industrial foundation. The indicator system and measurement framework proposed in this paper can be applied to assess new-quality productive forces at the prefecture-level city scale. It can provide quantitative reference for local governments to identify development weaknesses, formulate differentiated industrial, science-technology and digital economy policies, and advance the implementation of the strategy for developing new-quality productive forces in light of local conditions.

Limited by data accessibility, only five cities in Jiangxi are included in the sample, and several influencing factors are not covered in the indicator system. Future research will expand the sample size, optimize evaluation indicators, and further explore the driving mechanisms of municipal new-quality productive forces.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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