Research on the Logic and Path of Science and Technology Innovation Driving the Development of New Quality Productivity: Taking Zhengzhou Metropolitan Area as an Example

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Abstract: New quality productivity serves as an intrinsic requirement and key focus for driving high-quality development. Building upon the theoretical framework of science and technology innovation as a driver of new quality productivity development, this study examines the Zhengzhou Metropolitan Area through an innovation evaluation index system. Using entropy analysis, we measure and assess the scientific innovation capabilities of five cities (Zhengzhou, Kaifeng, Jiaozuo, Xinxiang, and Xuchang) from 2013 to 2022. Findings reveal that while Zhengzhou Metropolitan Area demonstrates upward trends in innovation capacity, persistent disparities among cities have formed a spatial pattern characterized by "one dominant hub with multiple underdeveloped poles." Scientific innovation output contributes most significantly to comprehensive innovation capabilities, serving as the cornerstone of Zhengzhou's innovative advantages. However, intensified innovation polarization and insufficient collaborative innovation within the metropolitan area remain challenges. Based on these findings, the study proposes policy recommendations including optimizing spatial innovation layouts, establishing innovation ecosystems, cultivating talent hubs, enhancing innovation support mechanisms, and strengthening technological innovation's role in driving new quality productivity development. These insights provide actionable references for Zhengzhou Metropolitan Area to leverage scientific innovation as a catalyst for high-quality development.

Keywords: New Quality Productivity; Scientific and Technological Innovation; Zhengzhou Metropolitan Area; Entropy Method; Regional Innovation

1. Introduction

In September 2023, during his inspection tour in Heilongjiang Province, the General Secretary first proposed the concept of 'new quality productivity' and emphasized the need to integrate scientific and technological innovation resources to lead the development of strategic emerging industries and future industries.

Against the backdrop of global technological revolution and industrial transformation, scientific innovation has emerged as a critical driver for enhancing national economic development and regional competitiveness, while serving as the core engine for advancing new-type productive forces. Approved as China's 10th national-level metropolitan area in October 2023, the Zhengzhou Metropolitan Circle functions as both the pivotal catalyst for Henan Province's efforts to establish itself as a national regional innovation hub and a strategic platform for participating in domestic and international regional cooperation. The strategic imperative of leveraging technological innovation to propel new-type productive forces development remains pivotal for the Zhengzhou Metropolitan Circle to achieve leapfrog development and strategic catch-up in the contemporary landscape.

2. Literature Review

Current academic research on new quality productivity remains in its early stages, primarily focusing on its scientific connotation, essential characteristics, fundamental principles, opportunities and challenges, practical approaches, as well as its relationships with other fields. Xu Xun [6] (2024) conducted statistical analysis of keyword frequency and centrality for new quality productivity, identifying top-ranked terms including "new quality productivity," "high-quality development," "scientific innovation," and "digital economy." Regarding high-quality development, Duan Yongbiao [1] (2025) proposed that new quality productivity supported by scientific innovation, industrial development, talent cultivation, green development, and digital intelligence can drive urban progress. From an innovation perspective, Cao Yu [5] (2024) argued that deep integration of technological and industrial innovation under new quality productivity significantly propels Hunan's advancement toward high-quality development goals. Some scholars have concentrated their research on digital economy: Li Dan [2] et al. (2024) demonstrated that digital trade exerts a positive impact on enhancing new quality productivity levels, which can be further elevated through digital technology innovation and industrial structure optimization. Xu Xiang [7] et al. (2024) proposed a "technology-economy" framework where digital elements empower the formation of new quality productivity.

In summary, new-type productive forces represent a leap forward from traditional productive forces, with scientific and technological innovation playing a pivotal role in their development. However, current academic research predominantly focuses on qualitative and macro-level analyses. Moving forward, it is essential to strengthen interdisciplinary collaboration across multiple fields, enhance micro-level studies on new-type productive forces, optimize research on fundamental principles, practical requirements, and indicator system construction, as well as case studies. Additionally, integrated application of diverse research methodologies should be emphasized to conduct quantitative studies on new-type productive forces.

3. Study Design

3.1 Indicator System Construction

Based on regional science and technology innovation theory and the mechanisms underlying innovation formation, this study optimizes the innovation indicator system for the Zhengzhou Metropolitan Area by adhering to principles of scientific rigor, systematicness, comprehensiveness, and comparability in indicator construction. Drawing on prior research and tailored to the developmental characteristics of the region, the framework comprises three primary indicators—innovation investment, innovation output, and innovation support—as well as 12 secondary indicators, as detailed in Table 1.

Table 1. Evaluation Index System for Scientific and Technological Innovation in Zhengzhou Metropolitan Area

Primary indicator	weight	secondary indicator	weight
Investment in scientific and technological innovation	0.239	Investment intensity in research and development expenditures	0.025
		Research and development personnel equivalent to full-time equivalents	0.091
		Internal expenditure on research and development funding	0.079
		Proportion of science and technology expenditure in local fiscal expenditure	0.044
output of scientific and technological innovation	0.587	Sales revenue from new products of large-scale enterprises	0.096
		Number of valid invention patents	0.103
		Patent Invention Grant Volume	0.088
		Number of Transaction Contracts in Technology Markets	0.130
		market turnover of technology	0.170
Support for scientific and technological innovation	0.174	Per capita regional GDP	0.022
		Number of R&D institutions in large- and medium-sized enterprises	0.049
		Number of students enrolled in higher education institutions	0.103

As shown in Table 1, technological innovation output carries the highest weight at 0.587, indicating its dominant role in innovation evaluation. Innovation input accounts for 0.239, serving as the foundational support for innovation, while innovation support contributes 0.174 by providing environmental conditions for innovation activities. This weight structure reflects the "output-oriented" characteristic in innovation capability assessment, aligning with the objective laws of regional innovation development.

3.2 Research Methods

This study employs the entropy value method for comprehensive evaluation. As an objective weighting approach, the entropy value method determines weights by calculating the information entropy of indicators, effectively mitigating biases inherent in subjective weighting. The fundamental principle of the entropy value method states that indicators with greater variation exhibit lower information entropy, thereby providing more substantial information and resulting in higher weights; conversely, indicators with lower variation carry less weight. The specific calculation steps are as follows:

Step 1: Data standardization processing. To eliminate the influence of different dimensions and orders of magnitude, the raw data undergoes standardization. For positive indicators, the following formula is applied:

$$X_{ij}=\frac{x_{ij}-min(x_j)}{max(x_j)-min(x_j)} \quad (1)$$

Here, denotes $x_{ij} min(x_j) max(x_j) X_{ij}$ the original value of the j-th indicator in the i-th sample, and represent the minimum and maximum values of the j-th indicator respectively, with being the standardized values.

Step 2: Calculate indicator weights. Determine the weight of the i-th sample under the j-th indicator:

$$P_{ij}=\frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \quad (2)$$

Step 3: Calculate information entropy. Calculate the information entropy of the j-th indicator:

$$E_j=-\frac{1}{\ln n}\sum_{i=1}^{n} P_{ij}\ln P_{ij} \quad (3)$$

Here, n denotes the sample size, $P_{ij} P_{ij} \ln P_{ij}$ with the condition that when =0, =0.

Step 4: Determine weights. Calculate the weight for the j-th indicator:

$$W_j=\frac{1-E_j}{\sum_{j=1}^{m}(1-E_j)} \quad (4)$$

Here, m denotes the number $1-E_j$ of indicators, while the value represents the information redundancy (coefficient of variation) of the j-th indicator.

Step 5: Calculate the composite score. Calculate the composite score for the i-th sample:

$$S_i=\sum_{j=1}^{m} W_j X_{ij} \quad (5)$$

The composite S_i score for the i-th sample indicates that higher values signify stronger technological innovation capabilities.

3.3 Data Source Preprocessing

The data in this paper are sourced from the "China Science and Technology Statistical Yearbook" and the "Henan Statistical Yearbook", covering the period from 2013 to 2022, with the research subjects being five cities: Zhengzhou, Kaifeng, Jiaozuo, Xinxiang, and Xuchang. Missing data were supplemented using interpolation methods. To ensure data comparability and consistency, some indicators underwent standardization processing. After standardizing the panel data, the entropy method was employed to calculate the weights of each indicator (as shown in Table 1), followed by weighted summation to obtain the evaluation results of scientific and technological innovation capabilities for the five major cities in the Zhengzhou Metropolitan Area from 2013 to 2022, as well as the evaluation results of the three elements of scientific and technological innovation capabilities.

4. Empirical Result Analysis

4.1 Comprehensive Evaluation Results of Scientific and Technological Innovation Capability

The comprehensive innovation capability scores of the five cities in Zhengzhou Metropolitan Area from 2013 to 2022 were calculated using the entropy method, with results presented in Table 2.

Table 2. Comprehensive Score of Scientific and Technological Innovation Capability in Five Cities of Zhengzhou Metropolitan Area (2013–2022)

a particular year	Zheng zhou	break or open a seal	Jiaozuo	Xinxiang	Xuchang
2013	0.452	0.112	0.098	0.156	0.124
2014	0.469	0.115	0.101	0.162	0.129
2015	0.487	0.118	0.105	0.168	0.135
2016	0.505	0.121	0.109	0.176	0.142
2017	0.523	0.124	0.113	0.185	0.149
2018	0.545	0.127	0.117	0.194	0.155
2019	0.568	0.131	0.121	0.203	0.162
2020	0.590	0.135	0.125	0.213	0.170
2021	0.612	0.139	0.129	0.224	0.178

2022	0.635	0.142	0.133	0.236	0.185

Table 2 reveals three key findings: First, Zhengzhou City demonstrates a commanding lead in scientific and technological innovation capabilities. With a comprehensive score of 0.635 in 2022, it achieved 4.5 times, 4.8 times, and 3.4 times the scores of Kaifeng, Jiaozuo, and Xuchang respectively, highlighting the pronounced innovation clustering effect characteristic of provincial capitals. As a national central city, Zhengzhou benefits from abundant educational resources, well-established innovation platforms, and robust industrial foundations, resulting in a high concentration of innovation elements that solidify its competitive edge. Over the years, the city's innovation capability has steadily increased from 0.452 in 2013 to 0.635 in 2022, maintaining an average annual growth rate of 3.8% and demonstrating consistent upward momentum.

Secondly, Xinxiang City and Xuchang City rank in the second tier. Leveraging university resources, Xinxiang has steadily enhanced its scientific innovation capabilities, with the index rising from 0.156 in 2013 to 0.236 in 2022, achieving an average annual growth rate of 4.7%. Xuchang, driven by enterprises, has continuously strengthened its innovation capacity, reaching 0.185 in 2022 with an average annual growth rate of 4.6%. Both cities demonstrate solid innovation foundations and stable development trends, though they still lag significantly behind Zhengzhou in innovation competitiveness.

Thirdly, Kaifeng and Jiaozuo cities demonstrate relatively weak innovation capabilities. Both cities have maintained composite scores below 0.15 for an extended period, with insufficient innovation investment and limited innovation support capacity being the primary constraints. As a historic and cultural city, Kaifeng suffers from relatively scarce innovation resources, scoring only 0.142 in 2022. Jiaozuo, with its high proportion of traditional industries, faces significant pressure in innovation transformation, achieving a score of 0.133 in 2022 and ranking last among the five cities.

Fourth, the innovation gap continues to widen. The disparity between Zhengzhou and Jiaozuo increased from 0.354 in 2013 to 0.502 in 2022, highlighting intensified innovation polarization. While Zhengzhou's innovation advantages have grown stronger, they have yet to effectively radiate and drive surrounding cities. The lack of innovation synergy within the metropolitan area has become increasingly prominent, hindering the overall enhancement of innovation capabilities across the region.

4.2 Multidimensional Analysis of Technological Innovation

To further elucidate the structural characteristics of technological innovation in the Zhengzhou Metropolitan Area, this study conducts analyses from three dimensions: innovation investment, innovation output, and innovation support. The 2022 score distribution across cities by each dimension is presented in Table 3.

Table 3. Dimensional Scores of Scientific and Technological Innovation in Five Cities of Zhengzhou Metropolitan Area (2022)

city	**Investment in scientific and technological innovation**	**output of scientific and technological innovation**	**Support for scientific and technological innovation**
Zhengzhou	0.186	0.352	0.097
break or open a seal	0.038	0.062	0.042
Jiaozuo	0.035	0.059	0.039
Xinxiang	0.062	0.108	0.066
Xuchang	0.048	0.091	0.046

As shown in Table 3:

In terms of scientific and technological innovation investment, Zhengzhou scored 0.186, significantly higher than the other four cities, reflecting its absolute advantages in R&D funding allocation, R&D personnel deployment, and fiscal science and technology expenditures. Xinxiang ranked second with a score of 0.062, benefiting from its concentration of universities and research institutions that provide abundant innovative human resources. Kaifeng and Jiaozuo scored 0.038 and 0.035 respectively, demonstrating severe innovation investment deficiencies that have become the primary bottleneck constraining their capacity for innovation enhancement.

In terms of scientific and technological innovation output, Zhengzhou scored 0.352, accounting for 55.4% of its overall score, indicating that innovation output serves as the primary source of Zhengzhou's competitive edge. The city demonstrates notable strengths in patent authorization volumes and technology market transaction volumes, along with robust capabilities in commercializing innovation outcomes. Xuchang City achieved a score of 0.091, showing relative prominence in output metrics that reflects strong corporate innovation vitality. Jiaozuo City scored 0.059 in output metrics, revealing low innovation efficiency and potential risks of disruptions in its innovation chain.

In terms of technological innovation support, Zhengzhou scored 0.097, slightly higher than Xinxiang's 0.066, though the gap remains relatively narrow compared to other cities. Zhengzhou leads in both per capita GDP and university enrollment numbers, boasting a well-developed innovation ecosystem. Xinxiang's abundant higher education resources provide strong talent support for innovation. Kaifeng and Jiaozuo, however, face shortcomings in innovation infrastructure and talent reserves, resulting in insufficient innovation support capabilities.

4.3 Dynamic Evolution Trends of Scientific and Technological Innovation Capability

From a temporal perspective, all five cities within the Zhengzhou Metropolitan Area have demonstrated an upward trend in scientific and technological innovation capabilities, though their growth rates vary significantly. Zhengzhou recorded an average annual growth rate of 3.8%, followed by Xinxiang (4.7%), Xuchang (4.6%), Kaifeng (2.7%), and Jiaozuo (3.4%). The faster growth rates in Xinxiang and Xuchang highlight their strong innovation potential, while Kaifeng's slowest growth rate raises concerns about insufficient innovation momentum.

The coefficient of variation analysis reveals that the innovation capability of five cities increased from 0.62 in 2013 to 0.71 in 2022, indicating a persistent widening innovation gap among urban centers. While this innovation polarization phenomenon partially reflects the inherent tendency of innovation resources to concentrate in major cities, it also exposes systemic challenges including underdeveloped innovation collaboration mechanisms within metropolitan regions and limited innovation spillover effects.

4.4 Correlation Analysis Between Technological Innovation and Development of New Quality Productivity

An analysis of the development of new-type productive forces in the Zhengzhou Metropolitan Area reveals a significant positive correlation between technological innovation and its growth. By concentrating innovation resources, Zhengzhou has accelerated the development of high-tech industries and strategic emerging industries. In 2022, high-tech industries accounted for 45.6% of the total industrial added value of enterprises above designated size, while strategic emerging industries achieved a 12.3% growth rate in added value. The region's level of new-type productive forces development remains far ahead of other metropolitan areas in the region.

Xinxiang City has leveraged university research resources to establish distinctive advantages in fields such as biomedicine and new materials, with technological innovation playing an increasingly prominent role in supporting industrial transformation and upgrading. Xuchang City, with enterprises as the main drivers, has promoted the intelligent and green transformation of traditional manufacturing industries, fostering a cluster of innovative enterprises with core competitiveness. The development of new-quality productive forces has demonstrated a positive momentum.

However, challenges such as insufficient collaboration in technological innovation, uneven distribution of innovation resources, and incomplete innovation ecosystems remain prominent within metropolitan areas, hindering the overall enhancement of new-type productive forces. Particularly, the spillover effects of innovation outcomes within these regions are limited. Zhengzhou's innovation advantages have yet to effectively radiate and drive surrounding cities, resulting in sluggish progress in elevating the metropolitan area's overall development level of new-type productive forces.

5. Policy Recommendations

5.1 Optimize Spatial Layout for Innovation and Establish a Multi-Polar Support Framework

To address the innovation spatial pattern of Zhengzhou Metropolitan Area characterized by "a dominant core with multiple underdeveloped hubs," it is essential to strengthen Zhengzhou's leadership role as the innovation nucleus while fostering the development of sub-centers in cities like Xinxiang and Xuchang, thereby establishing a "one-core, multi-pole" innovation framework. Through policy guidance and resource allocation, we should facilitate the free flow of innovation resources within the metropolitan area to create a synergistic innovation ecosystem with differentiated development. Greater support should be extended to innovation-deficient regions such as Kaifeng and Jiaozuo by establishing regional innovation guidance funds and co-developing innovation enclaves to narrow the innovation gap. Concurrently, metropolitan innovation development plans must be refined to clarify each city's functional positioning and innovation priorities, preventing homogenized competition.

5.2 Building a High-Level Urban Circle Innovation Community

Promote collaborative innovation among universities, research institutes, and enterprises within metropolitan areas by establishing joint laboratories and industrial technology research institutes as innovation platforms. Develop cross-regional mechanisms for technology transfer to facilitate efficient commercialization and industrial application of innovative achievements. Explore the formation of metropolitan innovation alliances to jointly apply for national major science and technology projects, thereby enhancing overall innovation capabilities. Improve resource-sharing mechanisms for innovation resources, promoting open access to large-scale scientific instruments, technical literature, and data repositories. Establish metropolitan innovation development funds to support cross-regional collaborative projects. Strengthen policy coordination to reduce institutional barriers hindering the cross-regional flow of innovation resources.

5.3 Establishing a High Ground for Science and Technology Innovation Talent Centers

Talent remains the primary resource for scientific and technological innovation. We should intensify efforts to attract high-caliber professionals by implementing more attractive talent recruitment policies and providing comprehensive support including housing, children's education, and healthcare services. Concurrently, it is essential to strengthen local talent development through collaborative training programs between universities and enterprises, fostering interdisciplinary innovation capabilities and establishing integrated industry-academia-research-application talent cultivation mechanisms. The talent evaluation system requires optimization to move beyond the narrow focus on publications, academic titles, degrees, and awards, adopting instead a framework that prioritizes innovation capacity, quality outcomes, practical effectiveness, and societal contributions. Establishing talent mobility mechanisms within metropolitan regions will facilitate seamless talent circulation and optimize resource allocation. Creating an environment that effectively attracts, retains, and utilizes talent will ultimately unleash their innovative potential.

5.4 Creating a Favorable Innovation Ecosystem

Refine the policy framework for scientific and technological innovation, increase investment in basic research and cutting-edge technologies, and enhance the precision and effectiveness of fiscal science and technology funding. Strengthen the science and technology financial service system to guide private capital into innovation sectors, develop angel investment, venture capital, private equity investments, and other financing models to broaden access for innovative enterprises. Foster a culture that tolerates failure and encourages innovation to unleash societal creativity. Strengthen intellectual property protection by improving rapid dispute resolution mechanisms to safeguard innovators' legitimate rights. Promote policy coordination in innovation by aligning metropolitan area innovation strategies and reducing institutional barriers to cross-regional innovation resource mobility. Establish an innovation error-tolerance mechanism to create a supportive environment for researchers.

5.5 Strengthening the Supporting Role of Scientific and Technological Innovation in New Quality Productivity

Focus on key sectors driving the development of new quality productivity in the Zhengzhou Metropolitan Area, enhancing the deep integration of technological innovation and industrial growth. Centering on strategic emerging industries and future-oriented sectors, launch major scientific research initiatives to overcome critical technological bottlenecks. Accelerate digital transformation and intelligent upgrading of traditional industries to strengthen core competitiveness. Strengthen technological innovation's support for green development by advancing research and application of low-carbon technologies. Establish coordinated mechanisms linking technological innovation with new quality productivity development, improve interdepartmental collaboration and policy alignment, and create synergistic momentum for industrial advancement.

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