# Measurement of the Ecologization Level of New Quality Productive Forces and Obstacle Factors in the Yellow River Basin (Postprint)

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**Date:** 2025-09-17T19:45:43+00:00

## Abstract

New quality productive forces are inherently green productive forces, and green development and ecological modernization are of great significance for advancing the construction of new quality productive forces. Drawing on ecological thought from productivity theory, this study constructs an evaluation index system for the ecologicalization level of new quality productive forces that encompasses the ecologicalization of production subjects, means of labor, and objects of labor. Utilizing panel data from prefecture-level cities in the Yellow River Basin from 2012 to 2021, and employing the entropy method, Gini coefficient decomposition, and obstacle degree model, this paper examines the ecologicalization level of new quality productive forces in the Yellow River Basin and its obstacle factors. The results indicate: (1) The ecologicalization level of new quality productive forces in the Yellow River Basin exhibits an overall upward trend, with regional differences in the ecologicalization level continuously expanding, and disparities among the upper, middle, and lower reaches exerting the greatest influence on overall regional inequality. (2) The obstacle degree of production subject ecologicalization is the largest and demonstrates a year-on-year increasing trend, while the obstacle degrees of means of labor ecologicalization and objects of labor ecologicalization show declining trends; strategic emerging industries have consistently remained the primary obstacle factor impeding the enhancement of the ecologicalization level of new quality productive forces. (3) Developing new quality productive forces in the Yellow River Basin should prioritize the ecologicalization pathway, increase investment in scientific and technological innovation, endeavor to cultivate high-quality innovative talent, enhance workers' ecological awareness and capacity for ecological scientific and technological innovation, accelerate the development of ecological strategic emerging industries, promote coordinated development among the upper, middle, and lower reaches, and effectively advance the development of new quality productive forces in the Yellow River Basin.

## Full Text

# Measurement and Obstacle Factors of Ecological Level of New Quality Productive Forces in the Yellow River Basin

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**Abstract:** New quality productive forces represent a form of green productivity, making green development and ecological modernization crucial for their cultivation. Grounded in the ecological dimensions of productivity theory, this study constructs a measurement index system for the ecological level of new quality productive forces encompassing the ecological transformation of production subjects, labor materials, and labor objects. Using panel data from prefecture-level cities in the Yellow River Basin from 2012 to 2021, we employ the entropy method, Gini coefficient decomposition, and obstacle degree model to examine the ecological level of new quality productive forces and its constraining factors. The results indicate: (1) The overall ecological level of new quality productive forces in the Yellow River Basin shows an upward trend, with regional disparities continuously expanding, where differences among upstream, midstream, and downstream regions exert the greatest influence on overall regional variation. (2) The obstacle degree of production subject ecological transformation is the highest and demonstrates a 逐年上升的趋势, while obstacle degrees for labor material and labor object ecological transformation show declining trends. Strategic emerging industries consistently represent the primary obstacle impeding improvement in the ecological level of new quality productive forces. (3) Developing new quality productive forces in the Yellow River Basin should prioritize ecological pathways, increase investment in scientific and technological innovation, cultivate high-quality innovative talent, enhance workers' ecological awareness and capacity for ecological technology innovation, accelerate development of ecologically-oriented strategic emerging industries, promote coordinated development across upstream, midstream, and downstream regions, and effectively advance new quality productive forces in the Yellow River Basin.

**Keywords:** new quality productive forces; ecological; high-quality development; Yellow River Basin

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## Introduction

In September 2023, General Secretary Xi Jinping proposed accelerating the development of new quality productive forces during his inspection of Heilongjiang Province, subsequently emphasizing at the Central Economic Work Conference that "scientific and technological innovation should drive industrial innovation, particularly fostering new industries, models, and growth drivers through disruptive and cutting-edge technologies to develop new quality productive forces" [1]. In February 2024, during the 11th collective study session of the Political Bureau of the CPC Central Committee, General Secretary Xi Jinping further stated: "Green development constitutes the foundation of high-quality development, and new quality productive forces are inherently green productive forces" [2].

The concept of productive forces was first examined by classical economists as humanity' s capacity to conquer and transform nature to obtain greater material wealth. Regarding new quality productive forces, scholars have analyzed its conceptual connotations from multiple perspectives. Some view it as a complex system following the laws and trends of productive force modernization, comprising a "factor-function" system of new-type laborers, new labor objects, new labor tools, and new infrastructure [3]. Others emphasize that the "new" aspect represents the connection between technology and economy forming novel economic structures, while the "质" (quality) signifies high-quality development driven by innovation and technological breakthroughs [4], representing advanced productive forces aligned with green development [5]. The Yellow River Basin serves as a critical ecological security barrier and important economic region in China, where ecological fragility and urgent development needs create dual pressures on human-environment relations [6], and productive force levels exhibit significant regional disparities [7]. Therefore, solidly advancing ecological protection and high-quality development in the Yellow River Basin constitutes a major national strategy. Consequently, during the pivotal period of launching the "15th Five-Year Plan" and building new quality productive forces, evaluating and analyzing the ecological level of new quality productive forces and their obstacle factors in the Yellow River Basin holds important theoretical and practical significance for promoting both ecological protection and high-quality development in the region.

Some scholars stress that new quality productive forces should prioritize ecological transformation as the core of productivity development, grounded in promoting green transformation of production modes, technological innovation, and industrial development [8]. Additionally, existing research has explored evaluation index systems for new quality productive forces, primarily constructing them from the three constituent elements—laborers, labor materials, and labor objects [9], or based on the essential connotations from perspectives of technology, green development, and digitalization [10], as well as new technologies, production organization, data elements, and laborers [11]. While these studies have laid foundations for new quality productive force theory and evaluation, emphasizing the importance of ecological transformation, research on measuring and evaluating the ecological level of new quality productive forces and exploring ecological development pathways remains limited, particularly lacking studies on ecological transformation of new quality productive forces in regions critical for ecological protection. Therefore, this paper focuses on prefecture-level cities in the Yellow River Basin, constructs a measurement index system for the ecological level of new quality productive forces, and employs methods including the entropy method, Gini coefficient decomposition, and obstacle degree model to comprehensively measure the ecological level of new quality productive forces from 2012 to 2021, revealing regional development patterns and obstacle factors, thereby providing theoretical and practical references for ecological development of new quality productive forces in the Yellow River Basin.

## 1. Research Framework

**1.1 Study Area** The Yellow River Basin (95°53 ~119°05 E, 32°10 ~41°50 N) flows through nine provinces/autonomous regions: Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shanxi, Shaanxi, Henan, and Shandong. The main stream spans 5,464 km. Using the HeKou Town in Togtoh County, Inner Mongolia, and the Taohuayu in Zhengzhou, Henan as boundaries, the basin is divided into upstream, midstream, and downstream sections. The Yellow River Basin possesses abundant natural resources but has long relied on traditional industries, resulting in deteriorating ecological environments that constrain high-quality development. In 2021, the basin' s GDP reached 28.13 trillion yuan, with Henan and Shandong in the midstream and downstream accounting for approximately 47% of the total, indicating extreme economic imbalance. Therefore, the Yellow River Basin represents a key region for developing new quality productive forces in China. Considering data availability, continuity, and regional analytical feasibility, this study selected 30 prefecture-level cities in the upstream, 28 in the midstream, and 25 in the downstream as research objects (Fig. 1).

**1.2 Data Sources** Research data were obtained from the *China City Statistical Yearbook* (2013-2022), provincial/regional statistical yearbooks, municipal statistical bulletins, and solid waste pollution prevention information bulletins from 2012 to 2021. Missing data for individual cities were supplemented using interpolation methods, ensuring data authenticity and reliability.

### 1.3 Theoretical Basis

**1.3.1 Connotation of Ecological Development of New Quality Productive Forces** Marxist productivity theory conceptualizes productive forces as a comprehensive, concrete, and realistic concept encompassing production subjects, labor materials, and labor objects, representing the integrated development of production capacity and factors. New quality productive forces refer to advanced productive forces that meet ecological civilization construction requirements, led by high-quality innovative talent, promoted by scientific and technological revolutions and breakthroughs that facilitate innovative allocation of production factors and drive deep industrial transformation and upgrading, representing a breakthrough leap in productive forces. Protecting the ecological environment equates to protecting productive forces, while improving the ecological environment equates to developing productive forces [12]. Ecological development of new quality productive forces manifests in three dimensions:

ecological transformation of production subjects, labor materials, and labor objects. Production subjects (laborers) undergo ecological transformation when they possess ecological civilization concepts, advanced environmental protection knowledge, and innovative skills, enabling them to independently choose resource-saving and environment-friendly production modes harmonious with nature. Labor materials, bridging laborers and labor objects, undergo ecological transformation in three aspects: institutions, technology, and infrastructure—promoting systematic innovation institutions integrating science and technology with ecological civilization, building efficient ecological science and technology innovation systems; achieving innovative breakthroughs in ecological technology that integrate high technology with ecological development; and requiring green and intelligent infrastructure transformation, such as accelerating integration of ecological environmental protection infrastructure with internet development. Labor objects, the material objects processed and transformed by laborers including unprocessed natural substances, undergo ecological transformation through moderate development and utilization, pollution reduction, and rational protection of natural material labor objects, achieving positive transformation between natural and economic values to ensure stability, diversity, and sustainability of natural material labor objects; for non-material labor objects, increased scientific and technological investment should promote development of strategic emerging industries, future industries, and environmental protection industries oriented toward the future.

**1.3.2 Analytical Framework for Ecological Development of New Quality Productive Forces** Ecological development of new quality productive forces aims to comprehensively advance modernization featuring harmonious coexistence between humanity and nature, unifying scientific and technological innovation with natural ecological protection to achieve comprehensive upgrading of productivity factors, realizing ecological transformation of productivity factors throughout the entire production process, forming new-type production relations compatible with ecological civilization, and establishing a modern industrial system unified by ecological priorities and green development. Based on this connotation framework and goal orientation, this study employs a framework of production subject ecological transformation, labor material ecological transformation, and labor object ecological transformation (Fig. 2) to construct a new quality productive forces evaluation index system, using the entropy method to measure spatiotemporal patterns, Gini coefficient decomposition to analyze regional differences, and obstacle degree model to explore constraining factors, thereby analyzing advantages and problems in ecological development of new quality productive forces in the Yellow River Basin to provide new policy insights for deepening ecological protection and high-quality development.

### 1.4 Methods

**1.4.1 Entropy Method** This study employs the entropy method to calculate weights of indicators in the ecological level measurement index system for new quality productive forces, analyzing the influence degree of different indicators on the ecological level, and uses linear weighting to calculate the ecological level. The formulas are as follows:

For positive indicators:

$$x_{ij} = \frac{X_{ij} - \min X_{ij}}{\max X_{ij} - \min X_{ij}}$$

For negative indicators:

$$x_{ij} = \frac{\max X_{ij} - X_{ij}}{\max X_{ij} - \min X_{ij}}$$

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$$

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \times \ln(p_{ij})$$

$$W_j = \frac{1 - e_j}{\sum_{j=1}^{n}(1 - e_j)}$$

$$E_i = \sum_{j=1}^{n} x_{ij} \times W_j$$

Where: $X_{ij}$ is the original data of indicator $j$ for city $i$; $x_{ij}$ is the standardized value; $e_j$ is the information entropy of indicator $j$; $p_{ij}$ is the proportion of city $i$ in indicator $j$; $W_j$ is the weight of indicator $j$; $E_i$ is the ecological level of new quality productive forces for city $i$; $m$ is the number of cities; and $n$ is the number of indicators.

**1.4.2 Gini Coefficient Decomposition** The Dagum Gini coefficient decomposition method can resolve cross-overlapping issues among samples and measure the causes of regional disparities [13]. A larger Gini coefficient indicates greater spatial imbalance. The overall Gini coefficient ($G$) for the ecological level of new quality productive forces in the Yellow River Basin is calculated as:

$$G = \frac{1}{2u}\sum_{q=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{m_q}\sum_{r=1}^{m_h}|y_{qi} - y_{hr}|$$

Where: $u$ is the mean ecological level across all cities; $k$ is the number of basin zones; $y_{qi}$ and $y_{hr}$ represent ecological levels in zones $q$ and $h$; and $m_q$ and $m_h$ are the numbers of cities in zones $q$ and $h$.

The Gini coefficient can be decomposed into: $G = G_w + G_{nb} + G_t$, where $G_w$ represents intra-regional differences, $G_{nb}$ represents net inter-regional differences, and $G_t$ represents the contribution of transvariation between regions.

**1.4.3 Obstacle Degree Model** To further analyze key obstacles constraining the ecological level, this study constructs an obstacle degree model to identify limiting factors. The formulas are:

$$C_{ij} = \frac{x_{ij} \times W_j}{\sum_{j=1}^{n} x_{ij} \times W_j} \times 100\%$$

Where: $C_{ij}$ is the obstacle degree of indicator $j$ for city $i$; a larger $C_{ij}$ indicates greater obstruction.

**1.5 Indicator System Construction** Integrating the connotation and characteristics of ecological transformation across the three productivity factors, this study constructs a measurement index system for the ecological level of new quality productive forces based on production subject ecological transformation, labor material ecological transformation, and labor object ecological transformation, adhering to scientific rationality and operability principles (Table 1).

**Table 1** Index system for measuring the ecological level of new quality productive forces

| Criterion Layer | Dimension Layer | Indicator Layer | Unit | Attribute |
|---|---|---|---|---|
| **Production Subject Ecological Transformation** | High-quality talent | Education level ($X_1$) | Proportion of regular higher education institution students | + |

| Criterion Layer | Dimension Layer | Indicator Layer | Unit | Attribute |
|---|---|---|---|---|
| | | Knowledge-intensive personnel ($X_2$) | Employees in information transmission, software, IT services, and scientific research/technical services | + |
| | Ecological awareness | Environmental protection investment ($X_3$) | Energy conservation and environmental protection expenditure | + |
| **Labor Material Ecological Transformation** | Energy utilization ecology | Energy conservation ($X_4$) | Energy consumption per unit GDP | - |
| | Facility advancement | Digital infrastructure ($X_5$) | Internet broadband access users | + |
| | | Digitalization level ($X_6$) | Digital economy index | + |

| Criterion Layer | Dimension Layer | Indicator Layer | Unit | Attribute |
|---|---|---|---|---|
| | Scientific and technological innovation | Green innovation level ($X_7$) | Total green patent authorizations | + |
| **Labor Object Ecological Transformation** | Ecological technology industries | Strategic emerging industries ($X_8$) | Number of AI enterprises | + |
| | | Industrial structure advancement ($X_9$) | Ratio of tertiary to secondary industry value-added | + |
| | Ecological production process | Green clean production ($X_{10}$) | Comprehensive utilization rate of industrial solid waste | + |
| | Ecological environment | Greening condition ($X_{11}$) | Built-up area green coverage rate | + |

Note: "+" indicates positive indicators; "-" indicates negative indicators.

## 2. Results and Analysis

**2.1 Comprehensive Ecological Level and Development Trends** Overall, the comprehensive ecological index of new quality productive forces in the Yellow River Basin showed a 逐年上升趋势 from 2012 to 2021, with the index ranging from 0.0631 to 0.1459, a mean of 0.1045, and median of 0.1015, surpassing the average from 2015 onward (Fig. 3). Among the three criterion layers, the labor material ecological transformation index was largest and showed the most significant increase, ranging from 0.0237 to 0.0595 and exceeding the average from 2013. The labor object ecological transformation index also rose 逐年上升 with substantial growth, ranging from 0.0186 to 0.0454 and surpassing the average from 2016. The production subject ecological transformation index increased 逐年上升 but with the smallest growth 幅度, indicating relatively weak development of production subject ecological transformation in the Yellow River Basin and a shortage of high-quality talent. In summary, the ecological development of new quality productive forces in the Yellow River Basin shows favorable trends, particularly since the 19th Party Congress when ecological transformation and upgrading of productive forces have been prioritized, with noticeable improvements in infrastructure and industrial scientific and technological innovation and ecology.

### 2.2 Regional Patterns and Evolution

**2.2.1 Regional Patterns and Changes** Using the natural breaks method and considering actual conditions of high-quality ecological development in the Yellow River Basin, ArcGIS was employed to classify ecological levels into five categories: low, relatively low, medium, relatively high, and high. Visualization analysis was conducted at three time points (2012, 2016, 2021) (Fig. 4). The overall regional pattern shows an "east-high, west-low" disparity, though upstream-midstream-downstream patterns are becoming increasingly balanced. High-level cities evolved from only Xi' an (midstream) in 2012 to nine cities by 2021: Jinan, Zhengzhou, Qingdao, Weifang, and Yantai (downstream), plus Xi' an (midstream). Relatively high-level cities included Taiyuan (midstream) and Lanzhou (upstream) in 2012, expanding to 13 cities by 2021: Jinan, Zhengzhou, and Qingdao (downstream), Luoyang, Xianyang, Jinzhong, and Yulin (midstream), and Lanzhou, Hohhot, and Yinchuan (upstream). Medium-level cities increased from 16 in 2012 to 23 by 2021, while low and relatively low-level cities decreased significantly. The ecological level of new quality productive forces in the Yellow River Basin generally develops around urban agglomerations—the Guanzhong Plain, Lanzhou-Xining, Shandong Peninsula, and the Yellow River "Ji" character bend metropolitan area—showing clear urban agglomeration patterns.

Examining criterion layers separately, production subject ecological transformation shows a centralization trend focused on provincial capitals and major cities, with minimal temporal change. In 2012, high-level cities included Xi' an (midstream) and Jinan and Qingdao (downstream); by 2021, high-level cities remained concentrated in Shandong Province and other provincial capitals. Labor material ecological transformation demonstrates downstream urban agglomeration. In 2012, high-level cities included Xi' an (midstream) and Jinan and Qingdao (downstream); by 2021, high-level cities showed clear agglomeration in the downstream region, reflecting stronger capabilities in energy utilization, scientific and technological innovation, and infrastructure. Labor object ecological transformation also shows agglomeration, primarily in Shandong Province cities and other provincial capitals. In 2012, high-level cities included Xi' an (Shaanxi) and Zhengzhou (Henan); by 2021, relatively high-level cities included Jinan, Qingdao, and Yantai (Shandong), with medium-level cities including Taiyuan (Shanxi) and Linyi and Weifang (Shandong). Shandong' s vigorous promotion of traditional industry upgrading and development of characteristic industries has effectively achieved high-level agglomeration of labor object ecological transformation.

**2.2.2 Regional Decomposition and Evolution** To better understand regional disparities, Gini coefficient decomposition was applied to measure the overall Gini coefficient from 2012 to 2021 and calculate coefficients for upstream, midstream, and downstream regions (Fig. 5).

**Intra-regional differences:** The overall Gini coefficient ranged from 0.3209 to 0.4233, with a mean of 0.3719, showing an upward trend and increasing inter-city disparities. The midstream Gini coefficient showed the most pronounced upward trend, peaking in 2021, indicating widening gaps among midstream cities, with Shaanxi and Shanxi cities outperforming Henan cities. The downstream Gini coefficient also increased, gradually expanding inter-city gaps. The upstream Gini coefficient remained relatively balanced, indicating consistent development across upstream cities.

**Inter-regional differences:** The inter-regional Gini coefficient showed an overall upward trend. The upstream-downstream Gini coefficient was largest, indicating growing disparities between upstream and downstream regions. The upstream-midstream coefficient was relatively low, as was the midstream-downstream coefficient, suggesting the most balanced development occurs between midstream and downstream.

**Contribution sources:** Intra-regional contribution rates remained most stable, fluctuating minimally from 33.44% to 34.95%. Inter-regional contribution rates and transvariation density contribution rates showed opposite trends. Inter-regional contributions fluctuated upward from 29.65% to 36.28%, while transvariation density contributions fluctuated downward from 36.90% to 28.76%. Since 2016, inter-regional differences among upstream, midstream, and downstream have contributed most to overall disparities.

**2.3 Diagnosis of Obstacle Factors** To further analyze influencing factors, the obstacle degree model was applied to identify primary constraints on ecological level improvement, focusing on criterion layer obstacle degree changes and high-obstacle factors.

**2.3.1 Criterion Layer Obstacle Degree Changes** From 2012 to 2021, production subject ecological transformation showed the highest obstacle degree, followed by labor object ecological transformation, with labor material ecological transformation showing the lowest. Production subject obstacle degree increased markedly, while labor object and labor material obstacle degrees declined overall. This indicates the primary constraint on ecological development of new quality productive forces lies in production subject ecological transformation, manifested in the shortage of ecologically-qualified, higher-education talent, and in labor object ecological transformation. Regional differences in criterion layer obstacle degrees are significant, with production subject ecological transformation showing the largest gap (3.09%) among regions. Downstream production subject ecological transformation consistently showed the highest obstacle degree, indicating that cultivating high-quality talent and enhancing workers' ecological awareness in downstream cities are critical for production subject ecological development in the basin. Labor object ecological transformation obstacle degree was most prominent in downstream regions in 2021, while remaining relatively stable upstream. Labor material ecological transformation obstacle degree maintained a pattern of highest upstream and lowest downstream, all declining over time, with the slowest decline upstream and faster declines midstream and downstream, indicating relatively low levels of scientific and technological innovation and facility advancement upstream.

**2.3.2 Analysis of Primary Obstacle Factors** Strategic emerging industries ($X_8$) consistently ranked as the primary obstacle factor across upstream, midstream, and downstream regions, with obstacle degrees reaching 25.97% in 2021. This reflects the unreasonable industrial structure in the Yellow River Basin and weak driving force from strategic emerging industries [14], making it a key constraint. Green innovation level ($X_7$) and knowledge-intensive personnel ($X_2$) showed fluctuating obstacle degrees. By 2021, knowledge-intensive personnel became the second obstacle factor for midstream and downstream regions, while green innovation level became the second obstacle factor for upstream regions. Education level ($X_1$) obstacle degrees exceeded 15.00%, ranking third. Digital infrastructure ($X_5$) obstacle degrees exceeded 5.98%, ranking fourth, though showing a declining trend. By 2021, environmental protection investment ($X_3$) became the fourth obstacle factor for midstream and downstream regions. Overall, constraints primarily manifest in two aspects: scientific and technological innovation development and high-quality talent cultivation (Table 2).

**Table 2** Main obstacles to improving ecological level of new quality productive forces in the Yellow River Basin

| Region | 1st Obstacle Factor (Degree) | 2nd Obstacle Factor (Degree) | 3rd Obstacle Factor (Degree) | 4th Obstacle Factor (Degree) |
|---|---|---|---|---|
| Upstream | Strategic emerging industries (27.31%) | Green innovation level (18.05%) | Education level (15.23%) | Digital infrastructure (6.12%) |

| Region | 1st Obstacle Factor (Degree) | 2nd Obstacle Factor (Degree) | 3rd Obstacle Factor (Degree) | 4th Obstacle Factor (Degree) |
|---|---|---|---|---|
| Midstream | Strategic emerging industries (25.18%) | Knowledge-intensive personnel (17.89%) | Education level (15.67%) | Environmental protection investment (5.98%) |
| Downstream | Strategic emerging industries (25.97%) | Knowledge-intensive personnel (18.32%) | Education level (15.00%) | Environmental protection investment (6.23%) |

## 3. Discussion

This study constructs an evaluation index system for the ecological level of new quality productive forces in the Yellow River Basin from three dimensions—production subject, labor material, and labor object ecological transformation—based on analysis of ecological development connotations, existing research, and Yellow River Basin characteristics. The measurement results reveal significant regional disparities in the ecological level of new quality productive forces in the basin, consistent with Lu et al.' s [10] findings on China' s new quality productive forces and Liu et al.' s [7] measurement analysis of new quality productive forces in the Yellow River Basin. The production subject ecological transformation index is relatively low with slow growth, representing the greatest obstacle; the labor object ecological transformation index is relatively low but grows rapidly, representing the second major obstacle; the labor material ecological transformation index is highest with the fastest growth, representing the smallest obstacle. These findings align with objective realities, demonstrating the representativeness of selected indicators.

The constructed index system emphasizes ecological transformation of the three productivity factors, though further development should strengthen connotation interpretation and index construction regarding new quality states and new drivers of ecological transformation. At the indicator selection level, data availability limitations prevented complete isolation of indicators for ecologically-qualified talent, ecological technology, and ecological industries, warranting future research on indicator selection and data acquisition. Additionally, this study examined 83 prefecture-level cities, not covering the entire basin completely, and at a relatively large spatial scale. Future research should conduct deeper analyses based on basin attributes, topographic units, and industrial/enterprise levels to provide theoretical foundations for new progress in ecological protection and high-quality development.

## 4. Conclusions and Recommendations

### 4.1 Conclusions

(1) From 2012 to 2021, the overall ecological level of new quality productive forces in the Yellow River Basin showed an upward trend, with labor material ecological transformation increasing most significantly, labor object ecological transformation developing well, and production subject ecological transformation growing relatively slowly. Particularly since the 19th Party Congress, when ecological protection and high-quality development became national strategies, the effects of ecological transformation and upgrading of productive forces have been remarkable.

(2) Ecological development of new quality productive forces in the Yellow River Basin exhibits an "east-high, west-low" pattern characterized by urban agglomeration development. Downstream development has achieved notable success, with production subject ecological transformation centered on provincial capitals and major cities, while labor material and labor object ecological transformation show agglomeration trends in downstream cities.

(3) Regional disparities among upstream, midstream, and downstream continue expanding. Since 2016, inter-regional differences have become the primary contributor to overall regional disparities, indicating increasingly prominent coordination challenges among basin segments.

(4) The greatest obstacle to ecological development is production subject ecological transformation, with obstacle degrees rising. Strategic emerging industries constitute the primary obstacle factor, followed by green innovation level and knowledge-intensive personnel, reflecting that ecological awareness, technological development, and innovative talent are foundational for improving the ecological level of new quality productive forces.

### 4.2 Recommendations

(1) **Prioritize ecological pathways for new quality productive forces and strengthen innovative supply of ecological elements.** The Yellow River Basin is rich in ecological resources but with significant regional variations. New quality productive force development must secure land, water, biological, and other utilizable natural elements while deepening the "lucid waters and lush mountains are invaluable assets" concept, integrating ecological elements into innovative factor supply to continuously enhance environmental support capacity and green development momentum.

(2) **Increase scientific and technological investment to enhance ecological technology innovation leadership.** Governments should seize the critical opportunity of new quality productive force development, deepen the national strategy for ecological protection and high-quality development in the Yellow River Basin, accelerate breakthroughs in key core technologies in biotechnology, new materials, and new energy, further promote green technology innovation, develop ecological strategic

emerging industries, and build a modern green industrial system achieving harmonious coexistence between humanity and nature.

(3) **Deeply implement new development concepts and strengthen production subject ecological transformation training.** Centered on new quality productive force development, strengthen ecological environmental protection publicity in the Yellow River Basin, develop specialized and professional innovative talent education and training tailored to different regions and industries, improve incentive policies for green innovation, and promote societal engagement in new quality productive force development.

(4) **Improve regional policy systems for new quality productive force development and promote coordinated basin development.** Fully recognize urban agglomeration trends and upstream-midstream-downstream differences, formulate targeted policies for new quality productive force development, deepen exchange and cooperation mechanisms for talent, technology, and industries, and achieve open collaboration across regions to jointly cultivate new quality productive forces.

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*Note: Figure translations are in progress. See original paper for figures.*