

Measuring the Development Level and Coordination of Agricultural and Rural Modernization in China: Postprint

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Abstract

Promoting agricultural and rural modernization is a major task in comprehensively building a modern socialist strong country. This study constructs an evaluation index system to measure the development level of agricultural and rural modernization in 30 Chinese provinces (municipalities and autonomous regions) from 2010 to 2020 and analyzes its spatiotemporal characteristics, introduces a coupling coordination degree model to analyze the coordination between agricultural modernization and rural modernization and explore its spatial correlation, and identifies weaknesses in agricultural and rural modernization development by determining relative lag types. The results show that: (1) From 2010 to 2020, the development levels of China's agricultural and rural modernization, rural modernization, and agricultural modernization all exhibited fluctuating upward trends; medium-high and high levels of agricultural and rural modernization were concentrated in small areas of coastal regions, while other regions remained at medium-low and low levels; there were significant differences in the spatial distribution of agricultural modernization and rural modernization development levels. (2) The coupling coordination degree between agricultural modernization and rural modernization continuously improved, but the opposing trend between high-value and low-value clusters intensified. (3) The quality of coupling coordination grades is positively correlated with the level of agricultural and rural modernization development. Among the primary coordination and above types, Shanghai, Tianjin, and Beijing exhibited relative lag in agricultural modernization development level, Shandong, Zhejiang, and Fujian exhibited relative lag in rural modernization development level, while Jiangsu and Guangdong showed relatively balanced development; other regions belong to the barely coordinated and below types, exhibiting either relative lag in rural modernization development level or dual-low levels and disharmony in both agricultural modernization and rural modernization development.

Full Text

Preamble

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Measurement and Coordination Analysis of Agricultural and Rural Modernization Development Levels in China

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Abstract: Promoting agricultural and rural modernization is a major task in building a comprehensively modern socialist country. This study constructs an evaluation index system to measure the development level of agricultural and rural modernization in 30 Chinese provinces (municipalities and autonomous regions) from 2010 to 2020 and analyzes its spatiotemporal characteristics. The coupling coordination degree model is introduced to analyze the coordination between agricultural modernization and rural modernization and explore its spatial correlation. The relative lagging types are identified to discover shortcomings in agricultural and rural modernization development. The results show: (1) From 2010 to 2020, the development levels of agricultural and rural modernization, rural modernization, and agricultural modernization in China all exhibited fluctuating upward trends. Medium-high and high levels of agricultural and rural modernization are concentrated in small areas along the coast, while other regions are at medium-low and low levels. There are significant spatial distribution differences between agricultural modernization and rural modernization development levels. (2) The coupling coordination degree between agricultural modernization and rural modernization continues to improve, but the opposing trend between high-value and low-value agglomeration areas is strengthening. (3) The quality of coupling coordination grades is positively correlated with the level of agricultural and rural modernization development. Among the primary coordination and above types, Shanghai, Tianjin, and Beijing show relatively lagging agricultural modernization development levels; Shandong, Zhejiang, and Fujian show relatively lagging rural modernization development levels; while Jiangsu and Guangdong have relatively balanced development. Other regions belong to the barely coordinated and below types, characterized by relatively lagging rural modernization development levels or “dual-low” and uncoordinated agricultural and rural modernization development levels.

Keywords: agricultural and rural modernization; development level; coupling coordination; spatiotemporal characteristics

Introduction

Agricultural and rural modernization represents the overarching goal of the rural revitalization strategy and holds a pivotal position in the process of Chinese-style modernization [1-3]. In 2021, the State Council issued the “14th Five-Year Plan for Promoting Agricultural and Rural Modernization,” which for the first time proposed the integrated design and parallel advancement of agricultural modernization and rural modernization. At the current stage, improving the development level of agricultural and rural modernization and coordinating the advancement of agricultural and rural modernization has become a top priority in the work concerning agriculture, rural areas, and farmers.

Prior to the 19th National Congress of the Communist Party of China, research on agricultural modernization dominated the academic discourse. The 19th National Congress proposed “accelerating agricultural and rural modernization” and elevated “rural modernization” alongside “agricultural modernization” as the overarching goal of the “three rural” work in the new era [4]. Experts and scholars contend that agricultural and rural modernization emerges from the organic coupling of agricultural modernization and rural modernization—two relatively independent yet interconnected subsystems that mutually promote and integrate with each other [6,8,14-16]. Separating agricultural modernization from rural modernization or emphasizing one at the expense of the other risks falling into the “polarization trap” of rapid agricultural development alongside accelerating rural decline [9].

China’s agricultural and rural modernization still faces numerous problems and challenges. First, a gap exists between China’s agricultural modernization and that of developed countries. China’s agricultural science and technology contribution rate still lags behind that of developed nations [7]; non-specialized, fragmented, and small-scale agricultural production and management models hinder cost reduction; and the intensity of chemical fertilizer and pesticide use exceeds both international safety thresholds and world averages [10]. Second, disparities persist between rural and urban development in China. The rural tap water penetration rate remains 10.9 percentage points lower than the urban rate [11], and significant service gaps exist in culture, education, healthcare, and elderly care, with the income gap between urban and rural residents not having fundamentally narrowed [12]. Third, the “differential speed problem” between agricultural and rural modernization development hinders coordinated advancement [13]. Provincial-level agricultural and rural modernization development levels exhibit significant regional differences, affecting the overall process of achieving agricultural and rural modernization [5,14].

Existing research has primarily focused on qualitative analyses of theoretical connotations and pathway studies, while quantitative research has mostly involved constructing evaluation index systems to assess development levels. However, the selection of indicators and calculation of weights require further consideration. Moreover, agricultural and rural modernization represents a moderniza-

tion characterized by the coupled symbiosis, coordinated interaction, and integration of agricultural and rural modernization [6,8,15-16], yet research on the coupled and coordinated development of agricultural and rural modernization in China remains insufficient. Therefore, following the principle of “integrated design and parallel advancement,” this study constructs an index system to measure the agricultural and rural modernization development level in 30 provinces (municipalities and autonomous regions) from 2010 to 2020, analyzes its spatiotemporal characteristics, introduces a coupling coordination degree model to analyze the coordination between agricultural and rural modernization and explore its spatial correlation, and identifies development shortcomings by judging lagging types, thereby providing references for coordinating the advancement of agricultural and rural modernization.

Methodology

1.1 Evaluation Index System Construction

Agricultural and rural modernization encompasses the modernization of the agricultural industrial system, production system, management system, rural infrastructure and public services, rural residents’ ideological concepts and quality of life, and rural governance system and capacity [6,8,15-16]. As the goal and core essence of the rural revitalization strategy, agricultural and rural modernization must be supported by the “twenty-character” guideline of rural revitalization [17]. Therefore, based on the connotation of agricultural and rural modernization, combined with the content of the rural revitalization strategy’s “twenty-character” guideline, and following the principle of “integrated design and parallel advancement” for agricultural and rural modernization, this study draws on previous research [10,18-19,21-25] to construct a comprehensive evaluation index system for agricultural and rural modernization development levels (Table 1).

1.2 Data Sources and Processing

Data were obtained from the China Statistical Yearbook, China Rural Statistical Yearbook, China Urban-Rural Statistical Yearbook, China Science and Technology Statistical Yearbook, China Labor Statistical Yearbook, China Civil Affairs Statistical Yearbook, China Population and Employment Statistical Yearbook, China Social Statistical Yearbook, China Tertiary Industry Statistical Yearbook, and provincial (municipal and autonomous region) statistical yearbooks. Missing data for the number of agricultural science and technology personnel were supplemented using interpolation methods, while other missing data were replaced with data from adjacent years. To address differences in dimension, magnitude, and positive/negative orientation among indicators, this study standardized the raw data [26] using the following formulas:

For positive indicators:

$$X'_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)}$$

For negative indicators:

$$X'_{ij} = \frac{\max(X_j) - X_{ij}}{\max(X_j) - \min(X_j)}$$

where X_{ij} represents the raw value; X'_{ij} represents the standardized value of indicator j for research unit i ; and $\max(X_j)$ and $\min(X_j)$ represent the maximum and minimum values of indicator j , respectively.

1.3 Methods

1.3.1 Multi-indicator Comprehensive Measurement Method The entropy method was used to assign weights to indicators based on the objective dispersion degree of the standardized data [27]. The multi-linear weighting method was then applied to calculate the development level indices for agricultural and rural modernization, agricultural modernization, and rural modernization. The specific formulas are as follows:

$$p_{ij} = \frac{X'_{ij}}{\sum_{i=1}^n X'_{ij}}$$

$$s_j = -k \sum_{i=1}^n p_{ij} \times \ln(p_{ij}), \quad k = \frac{1}{\ln(n)}$$

$$w_j = \frac{1 - s_j}{\sum_{j=1}^m (1 - s_j)}$$

$$G = \sum_{j=1}^m w_j \times p_{ij}$$

where p_{ij} represents the normalized value of indicator j for research unit i ; k is a coefficient; n is the total number of research units; s_j is the entropy value of indicator j ; w_j is the weight of the j th indicator; m is the number of evaluation indicators; and G is the final development level of the system.

1.3.2 ArcGIS Spatial Analysis This study employs the natural breaks method in ArcGIS 10.2 software to classify different regions into four levels according to the principle of minimizing within-group variance while maximizing between-group variance [28]: low level, medium-low level, medium-high level, and high level. This approach enables exploration of the spatial distribution patterns of agricultural and rural modernization development levels, agricultural modernization, and rural modernization across China.

1.3.3 Coupling Coordination Degree Model and Lagging Type Judgment The coupling coordination model involves three metrics: coupling degree (C), coordination degree (T), and coupling coordination degree (D). The coupling degree reflects the degree of mutual dependence and constraint between systems, while the coordination degree reflects the quality of coordination. The calculation formulas are as follows [29-30]:

$$C = 2 \times \frac{\sqrt{U_1 \times U_2}}{U_1 + U_2}$$

$$T = \alpha \times U_1 + \beta \times U_2$$

$$D = \sqrt{C \times T}$$

where U_1 and U_2 represent the development level indices of agricultural modernization and rural modernization, respectively; and α and β are undetermined coefficients reflecting the contribution of each system to the overall development level. Drawing on previous research [29-30] and based on the principle of “integrated design and parallel advancement” for agricultural and rural modernization, this study sets both α and β equal to 0.5. The coupling coordination grades are divided into ten levels from extreme imbalance to premium coordination.

To further investigate the synchronization between agricultural and rural modernization development processes and identify shortcomings, this study draws on previous research [31] to judge relative lagging types based on the difference between subsystem development level indices. The relative lagging types are determined by comparing local agricultural modernization development level with local rural modernization development level. If the difference between a region’s agricultural modernization development level index and rural modernization development level index is greater than 0.1, the region exhibits a relatively lagging rural modernization development level; if the difference is less than -0.1, it shows a relatively lagging agricultural modernization development level; if the difference equals 0, it represents balanced development.

1.3.4 Exploratory Spatial Data Analysis (ESDA) This method calculates the Global Moran's I and Local Moran's I values for the coupling coordination degree of agricultural and rural modernization development levels from 2010 to 2020 to reveal global and local spatial clustering, anomalies, and significance levels [32-33]. The formulas are:

$$\text{Global Moran's I} = \frac{\sum_{i=1}^n \sum_{j=1}^n W_{ij}(X_i - \bar{X})(X_j - \bar{X})}{S^2 \sum_{i=1}^n \sum_{j=1}^n W_{ij}}$$

$$\text{Local Moran's I} = \frac{X_i - \bar{X}}{S^2} \sum_{j=1}^n W_{ij}(X_j - \bar{X})$$

where n is the total number of spatial units; X_i and X_j represent the comprehensive evaluation values of agricultural modernization development levels for units i and j ; \bar{X} is the mean value; S^2 is the variance; and W_{ij} is the spatial weight matrix. This study employs a queen contiguity spatial weight matrix.

When the Global Moran's I is positive and approaches 1 at a given significance level, it indicates higher global clustering; when negative and approaches -1, it suggests more pronounced global dispersion. The Local Moran's I greater than 0 indicates local spatial clustering, while less than 0 indicates local spatial anomaly. The Moran scatter plot derived from Local Moran's I illustrates the spatial distribution relationship between each research unit and its neighbors. A research unit falling in the first quadrant indicates high values surrounded by high values (HH clustering); the second quadrant indicates low values surrounded by high values (LH clustering); the third quadrant indicates low values surrounded by low values (LL clustering); and the fourth quadrant indicates high values surrounded by low values (HL clustering). Based on LISA analysis, local spatial clustering or anomalies can be further visualized.

Results

2.1 Analysis of Agricultural and Rural Modernization Development Levels

2.1.1 Temporal Analysis Based on formulas (1)-(4), this study calculated the development level indices for agricultural and rural modernization, agricultural modernization, and rural modernization. From 2010 to 2020, China's agricultural and rural modernization development level index increased from 0.189 to 0.621, with an average annual growth rate of 21.74%. The agricultural modernization development level index grew from 0.201 to 0.653, with an average annual growth rate of 15.59%. The rural modernization development level index rose from 0.176 to 0.588, with an average annual growth rate of 26.97%. All three indices exhibited fluctuating upward trends.

2.1.2 Spatial Analysis In 2020, low and medium-low levels of agricultural and rural modernization were widely distributed across various regions, while high and medium-high levels were concentrated in small areas along the coast, including Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Guangdong, and Fujian [Figure 2: see original paper]. Low and medium-low levels of agricultural modernization were mainly distributed in northwestern, northeastern, and southwestern regions, whereas high and medium-high levels were primarily found in eastern coastal and central regions. Notably, Xinjiang, as a well-established base for animal husbandry and signature fruit forestry, and Heilongjiang, as the nation's top grain producer, both belong to the medium-high level category for agricultural modernization.

The spatial distribution of medium-high and high levels of rural modernization in 2020 covered Beijing, Tianjin, Jiangsu, Shanghai, Zhejiang, Fujian, and Guangdong—similar to the pattern for agricultural and rural modernization. All other provinces (municipalities and autonomous regions) exhibited low and medium-low levels. Rural modernization demonstrates strong associations with economic zoning principles [34], showing a gradient transition from high levels in southeastern coastal areas to low levels in inland regions.

2.2 Coupling Coordination Analysis

2.2.1 Coupling Coordination Results and Spatial Correlation Based on formulas (5)-(7), this study calculated the coupling degree and coupling coordination degree. From 2010 to 2020, the coupling degree between agricultural and rural modernization development levels in China remained close to 1.0, indicating strong mutual influence and constraint between agricultural and rural modernization. The coupling coordination degree increased from 0.408 in 2010 to 0.621 in 2020, with all three metrics showing fluctuating growth trends. The 19th National Congress report placed rural modernization on an equal strategic footing with agricultural modernization, emphasizing coordinated development between the two.

Significant regional disparities exist in the spatial distribution of provincial agricultural and rural modernization development levels in China, necessitating further exploration of internal differences and spatial distribution characteristics of provincial coupling coordination degrees. Therefore, this study employs ESDA methods to explore spatial clustering and differentiation in the coordinated development of agricultural and rural modernization. The Global Moran's I values ranged from 0.491 to 0.522, indicating significant clustering of similar values in the coupling coordination degree between agricultural and rural modernization development levels.

Based on formula (9), Local Moran's I values were calculated and Moran scatter-LISA distribution maps were generated [Figure 3: see original paper] to analyze local spatial clustering. From 2010 to 2020, the distribution of significant HH clustering remained in eastern coastal areas, while significant LL clustering was

locked in northeastern, western, and central regions, with the number of significant LL clusters increasing and showing a northward shift. HL and LH clustering types, representing spatial anomalies, were distributed in transition zones between high and low coupling coordination degree areas. In 2020, the transition zones between high and low coupling coordination degree areas expanded compared with 2010, particularly in northern China and especially in northeastern regions.

2.2.2 Coordination Type and Lagging Type Analysis Provincial coordination types were mostly barely coordinated and below, corresponding to medium-low and low levels of agricultural and rural modernization development. Primary coordination and above types corresponded to relatively high and high levels of agricultural modernization development. Shanghai exhibited high-level agricultural and rural modernization development with premium coordination .

By calculating the difference between agricultural modernization development level indices and rural modernization development level indices, this study identified relative lagging types in agricultural and rural modernization development [Figure 4: see original paper]. Among primary coordination and above types, Shanghai, Tianjin, and Beijing showed relatively lagging agricultural modernization development levels. In 2020, Shanghai ranked first nationally in agricultural and rural modernization development level, agricultural modernization development level, and rural modernization development level, with its agricultural science and technology contribution rate exceeding the national average by 10.8 percentage points [35]. However, Tianjin and Beijing had agricultural modernization development level indices only 61.63% and 70.51% of Shanghai's level, respectively. Both cities had lower proportions of agricultural service industry output value than the national average, and their low-input, low-efficiency, high-energy-consumption agricultural production models hinder agricultural modernization development.

Fujian, Zhejiang, and Shandong exhibited relatively lagging rural modernization development levels. Although these provinces ranked in the top 10 nationally in agricultural and rural modernization development level, agricultural modernization development level, and rural modernization development level, their development indices ranged between 50%-65%, possibly due to failing to find optimal ways for agricultural-rural synergistic development, resulting in coupling coordination degrees remaining at primary and medium coordination stages.

Barely coordinated and below types were mostly characterized by relatively lagging rural modernization development levels, including 13 major grain-producing areas where agricultural modernization development levels significantly exceeded rural modernization development levels. Due to this imbalance, overall agricultural and rural modernization development levels remained low. Some regions, such as Shaanxi, Guangxi, Hainan, and Yunnan, exhibited balanced but uncoordinated types, facing challenges like poor hydrothermal conditions, limited land types and cultivated land area, economic

underdevelopment, shortages of high-quality agricultural talent, and capital outflow, resulting in consistently low rural modernization development levels and a “dual-low 困境” (dual-low predicament) where agricultural and rural modernization development levels are both low and mutually inhibiting.

Discussion

Compared with most existing studies that measure and analyze agricultural and rural modernization development levels [17,22-24,35], this paper considers agricultural and rural modernization as an organic coupling of two interrelated yet independent subsystems—agricultural modernization and rural modernization [6,8,15-16]. Drawing on Qin et al. [18], this study constructs a comprehensive evaluation index system encompassing both agricultural and rural modernization systems, measures their respective development levels, and further explores their coordination degree and impact on overall agricultural and rural modernization development using a coupling coordination degree model. The results demonstrate positive correlation between coupling coordination grade quality and agricultural and rural modernization development level.

Based on the measurement and spatiotemporal analysis results, this paper discusses countermeasures for promoting agricultural and rural modernization across different regions:

- (1) **Eastern coastal regions** should extend agricultural industrial chains based on their well-developed secondary and tertiary industries, develop export-oriented agriculture leveraging superior geographical locations and convenient transportation, but must address issues of high fertilizer, pesticide, and energy consumption per unit land to ensure sustainable agricultural development. **Northeastern regions** have relatively low industrial management system levels and should actively cultivate new types of agricultural business entities and develop agricultural socialized service systems. **Northwestern regions** should strengthen agricultural infrastructure construction and vigorously develop animal husbandry and fruit forestry. **Southwestern regions**, with special topographical features like forests and wetlands, should emphasize ecological environmental protection while developing ecological agriculture.
- (2) **Developed regions** have better rural infrastructure but need to improve rural civilization construction by enhancing public services in culture and education. **Other regions** commonly face poor rural infrastructure, low living standards, and weak rural governance. They should gradually establish a basic pattern of government-led rural construction with social capital investment, particularly in northwestern and northeastern regions that need to improve rural household waste and sewage treatment levels.

Based on coupling coordination grades and lagging types, this paper discusses

strategies for synergistically advancing agricultural and rural modernization:

- (1) For regions with primary coordination and above, **Beijing and Tianjin** (relatively lagging agricultural modernization) should abandon expansive growth relying on urban sprawl and resource conversion, and instead leverage technological, talent, and capital advantages to develop suburban agriculture that ensures urban food supply and high-value creative agriculture. **Fujian, Zhejiang, Shandong, Jiangsu, and Guangdong** (relatively lagging rural modernization) should ensure agricultural industries match regional characteristics to avoid “industry copying” and “one-size-fits-all villages.”
- (2) For regions with barely coordinated and below grades, those with relatively lagging rural modernization should ensure the effectiveness of rural development policies while guaranteeing food and agricultural product supply to avoid disconnect between agricultural and rural modernization. Regions with “dual-low” but uncoordinated development should correctly understand the relationship between agricultural and rural modernization, and develop new rural industries, business forms, and models based on current conditions and regional advantages.

However, agricultural and rural modernization is an evolving concept, and its main contradictions change over time. Therefore, future research should continuously improve the evaluation index system for agricultural modernization development levels. Additionally, specific reasons affecting the coordination between agricultural and rural modernization require further verification through reliable empirical analysis to provide strong evidence for comprehensively and efficiently promoting agricultural and rural modernization.

Conclusion

From 2010 to 2020, the development levels of agricultural and rural modernization, agricultural modernization, and rural modernization in China all showed fluctuating upward trends. In 2020, high and medium-high levels of agricultural and rural modernization and rural modernization were concentrated in eastern coastal regions, while high and medium-high levels of agricultural modernization were distributed in eastern coastal and central regions, plus Xinjiang and Heilongjiang. All other regions exhibited medium-low and low levels, with significant spatial distribution differences between agricultural and rural modernization development levels.

From 2010 to 2020, the coupling coordination degree between agricultural and rural modernization continued to increase, with Global Moran's I values ranging from 0.491 to 0.522, showing significant clustering of similar values. High-value clustering types slowly expanded from coastal areas inland, while low-value clustering types showed a northward trend, with transition zones between high and

low coupling coordination degree areas decreasing and opposing trends strengthening.

The quality of coupling coordination grades is positively correlated with agricultural and rural modernization development levels. Among primary coordination and above grades, Beijing, Shanghai, and Tianjin exhibited relatively lagging agricultural modernization development; Shandong, Zhejiang, and Fujian showed relatively lagging rural modernization development; while Jiangsu and Guangdong demonstrated balanced development. Barely coordinated and below grades were mostly characterized by relatively lagging rural modernization or “dual-low” and uncoordinated agricultural and rural modernization development levels.

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