

Article

Evaluation System for Agricultural and Rural Modernization in China

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Abstract: High-quality development of agricultural and rural areas is the foundation of national modernization and sustainable development in China. Therefore, the evaluation of the degree of development of modernization of China's agricultural and rural areas and the summarization of its main characteristics are crucial. However, studies on rural modernization and coordinated development are limited. Here, we developed a statistical evaluation system to effectively identify and assess the levels of agricultural and rural modernization, urban–rural integration, and agricultural rural coordination. We found that agricultural and rural modernization in China has continued to improve, but low scores were attributed to the factors of coordinated development of urban–rural areas, livable ecological environment, farmer prosperity, industrial structure upgrade, and resource allocation efficiency, limiting high-quality agricultural and rural development. Agricultural and rural modernization is lower in the central and western regions, compared to that in the eastern regions, but it is picking up the pace, indicating convergence. Rural modernization is lower than agricultural modernization and the two subsystems are not sufficiently coordinated, especially in undeveloped areas. Furthermore, the regional differences in rural modernization are greater than those in agricultural modernization. The system developed here can provide valuable experience for developing countries to open new paths toward modernization.



Citation: Yan, Z.; Peng, L.; Wu, X. Evaluation System for Agricultural and Rural Modernization in China. *Agriculture* **2023**, *13*, 1930. <https://doi.org/10.3390/agriculture13101930>

Academic Editor: Efstratios Loizou

Received: 21 June 2023

Revised: 18 July 2023

Accepted: 25 July 2023

Published: 1 October 2023



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Keywords: rural vitalization; agricultural and rural modernization; index system; coordination; convergence

1. Introduction

China is a latecomer to global modernization. The diversity in China's modernization and its prominent urban–rural gap are characteristics of its transition to modernization. Promoting urban–rural integration and agricultural and rural modernization are important for sustainable development and for narrowing the urban–rural gap [1,2]. China is a developing country and the high-quality development of agricultural and rural areas is the foundation of national modernization and sustainable development. Accordingly, China is encouraging the modernization of agricultural and rural areas. It is necessary to evaluate the degree of development of modernization of China's agricultural and rural areas and to summarize its main characteristics to provide a reference for promoting high-quality development and improving the sustainability of global modernization.

This challenge prompts several significant questions. What are the connotations of agricultural and rural modernization? How can modernization be accurately measured in combination with the national levels of development? What are the spatial patterns of agricultural and rural modernization?

To answer these questions, this study investigated agricultural and rural modernization in China and the evolutionary characteristics of the main social issues; constructed

a comprehensive, reasonable, and easy to use evaluation index system; and calculated and analyzed the results in combination with statistical data. This indicator system can effectively identify and assess the levels of agricultural and rural modernization, urban–rural integration, and agricultural rural coordination, which will help policymakers and practitioners understand the development status of China’s agricultural and rural areas, understand the weaknesses, and promote agricultural and rural development. Simultaneously, the system has great practical significance as it can provide valuable experience for developing countries to open new paths toward modernization.

2. Connotations and Evaluation of Agricultural and Rural Modernization

2.1. Connotations of Agricultural and Rural Modernization

Agricultural and rural modernization are mutually enhancing: agricultural modernization consolidates the industrial foundation and materials for rural development, while rural modernization provides better production and living spaces for industrial development. Therefore, agriculture and rural modernization are independent but closely related research objects [3,4]. Accordingly, “agricultural and rural modernization” implies each of these aspects as well as their coordinated development. That is, agricultural and rural modernization is a holistic process, although each of them have different priorities. Previous studies have extensively discussed agricultural modernization, but studies on rural modernization are lacking and studies on coordinated development have rarely been performed.

The core issue of agricultural modernization is to transform traditional agriculture. The most fundamental characteristic of agricultural activities is the use of other natural forces using structured natural forces of life [5]. Agriculture has evident seasonal, spatial, and life characteristics. Enhancing the division and the standardization of agricultural production is key to adapting to complex agricultural production and operation. Some scholars have found that introducing modern production factors and investing human capital in farmers can transform traditional agriculture, and that modern agriculture plays a significant role in narrowing the urban–rural gap [2]. Improving agricultural production technology can contribute to maintaining a balanced growth model and industry [6]. The experience of developed nations shows that agricultural modernization generally involves efficient resource allocation and establishes a factor-saving mode suitable for the country [7]. Introducing modern production factors, such as labor- and land-saving technologies [8], mechanical techniques [9], digital technologies [10], and land policy adjustments [11] can accelerate agricultural modernization.

Particularly, the basic national condition of “big country and small farmers” determines that China’s agricultural modernization should be completed through a flow of factors, the deepening of resource allocation, and the division of labor [4]. Some scholars have revealed that agricultural modernization requires strengthening the connections between small farmers and the modern service industry [12]. Accordingly, measures enabling agricultural support and protection, as well as developing social service organizations for modern agriculture, are necessary [13]. In the new era, agricultural modernization should reconstruct the modern agricultural management system, adhere to the green development concept of ecological priority, and adjust quantitative growth to place equal emphasis on quantity and quality [14,15]. Additionally, agricultural modernization should involve a modern production and operation system, achieve industrial integration, and improve the value chain while maintaining the main body of the value chain in the county, allowing for the value-added achievements of the value chain to benefit farmers more.

Rural modernization emphasizes the restoration and improvement of regional space and works to transform rural areas into rich and inclusive spaces for production and living. Rural areas are integrated systems which provide production, livelihood, ecological, and other functions outside of urban built-up areas. Thousands of years of agricultural civilization have endowed Chinese society with the characteristics and background color of “big country and small farmers,” which constitutes a historical starting point and a prerequisite of modern societal development [16]. Some scholars have discussed the connection

between Chinese village culture and the modernization trend [17]. Rural areas have the three unique functions of ensuring the supply of crucial agricultural products, providing an ecological barrier, and inheriting and maintaining culture, and the strategy for enabling the unique functions of rural areas will determine the entire process of modernization. The development method of modernization must emphasize the continuity of traditional functions and innovation. However, rural development was free from urban construction for a long time, which led to the build-up of pollutants, increasing wealth disparity between urban and rural communities, and leading to a decline in local culture, resulting in accelerated urban development and accelerated rural depression [18,19].

The objectives of studying rural issues in China is to discuss the phenomena and laws that are involved in the transition of rural areas from traditional to modern societies. The contents of rural modernization should include population, environment, social capital, traditions and customs, and organizational governance [4]. The promotion of rural culture, environment, farmers' livelihoods, and social governance should be prioritized [20–22]. Promoting rural modernization is vital for urbanization and the internal endowment of rural areas. The logic of urban–rural coordinated development is incorporated into the strategic framework of rural revitalization [23]. Scholars' interpretations of rural modernization are basically unified. A comprehensive realization of rural modernization requires special consideration of positioning, functioning, transformation, and urban and rural integration [4]. By 2035, China's rural areas should be a "Four High Space" integrating production space for high-quality agricultural products, high-vitality space for innovation and entrepreneurship, high-quality living space, and high ecology space with a high appearance level.

To summarize, the different characteristics indicate the need to have a different focus for agricultural and rural modernization: agricultural modernization requires growth and efficiency while rural modernization requires sharing and equity. However, agricultural and rural modernization are interconnected, and rural revitalization is required to strengthen the linkages.

2.2. Evaluation Logic of Agricultural and Rural Modernization

Early studies tended to concentrate on a single part of the theme "agriculture, rural areas, and farmers" and focused on the development goals of different periods [24,25]. With the change in development stage, relevant research began to examine the comprehensive impact of multiple factors on agricultural and rural development [20–22]. These studies largely adhered to the development law of urban–rural connections and the characteristics of the rural development stage [26,27]. The evaluation content expanded from the local to the wider situation and the evaluation objectives became increasingly diversified. However, the development of modernization is a process of continuous sublation, and some indicators that are no longer applicable need to not be included in the scope of the evaluation. Moreover, the change in development stage requires the understanding of "agriculture, rural areas, and farmers" to be deepened continuously based on inheritance.

At a stage when the focus of the work on "agriculture, rural areas, and farmers" needs to be considered and adjusted, some indicators from the past may no longer be applicable, and the relevant evaluation index may have some bias when considering a comprehensive investigation of modernization. Some studies have attempted to examine rural revitalization strategies from a more comprehensive perspective. The pertinent literature is typically broken down into three groups: (1) horizontal comparative research from a macroscopic perspective [28], (2) horizontal comparative research with a micro-level perspective [29], (3) longitudinal comparative research of different periods of development [30].

Previous studies provide guidance for this paper but have shortcomings. First, most studies focused on the rural interior when selecting evaluation indicators, ignoring the urban–rural relationship. The "integration", "sharing", and "high quality" factors should be integrated into the scope of investigation of the evaluation index system. Second, the relevant evaluation systems cannot effectively identify agricultural and rural modernization

and the coordinating relationship between these has received little attention. Finally, some studies incorporated single-factor productivity into the evaluation system as this is easier to calculate. The implications of improving single-factor productivity will strengthen the “extensive growth” but reduce the leadership of the index system. This study aimed to address the deficiency or absence of existing literature pertaining to these aspects.

3. Evaluation Index System and Evaluation Method

3.1. Constructing the Index System

The evaluation system should abide by the following guidelines. First, the index selection should respect history, reflect continuity, highlight the general logic of agricultural and rural development, and improve comparability at the regional level. Second, it should demonstrate foresight. The index selection should reflect the implications of the new stage of development and corresponding new concepts and should consider the success of the country. Third, the system should reflect changes in the principal contradictions of social problems. Whether the main social contradiction can be solved effectively is one of the assessment criteria for judging the quality of agricultural and rural modernization. Fourth, the system should ensure that the indicators are comprehensive. Agricultural and rural modernization are systematic processes, which need to be balanced and implemented with the most representative indicators in the key areas. Fifth, the index should ensure that the evaluation is easy to execute. It is important to improve the practical value of the evaluation system by selecting existing and quantifiable indicators and reduce the difficulty of collecting and processing indicators.

Previous analyses have revealed that the developmental focus of agricultural and rural modernization is different, but that they are interconnected and jointly contribute to their respective success. Due to industrial development, resource allocation is the foundation of agricultural modernization [2,4], and agricultural product supply is the fundamental aim of agriculture. Agricultural modernization is therefore measured according to four criteria: vitality of industrial development, upgrading of industrial structure, efficiency of resource allocation, and food security. Providing ecological barriers and inheriting and promoting excellent culture are unique functions of rural areas [31]. Improving public services and coordinating urban–rural development are important guarantees for building a beautiful countryside [32,33]. The ultimate goal of rural construction is to increase farmers’ income and improve their living standards [12]. Therefore, rural modernization is measured according to six aspects: livability of ecological environment, improvement of rural civilization, effectiveness of rural governance, level of perfection of public services, coordination of urban–rural development, and prosperity of farmers. Farmers, as a key component of rural revitalization, are integrated into the processes of agricultural and rural modernization.

1. The vitality of industrial development consists in the conditions of agricultural production and the momentum of industrial development. High-quality cultivated land, technological progress, agricultural insurance, and financial development are increasingly becoming drivers of agricultural development. The conditions and drivers of agricultural production are measured by the above variables. By fostering drivers of new growth and improving the conditions of agricultural production, we can further consolidate the foundation of agricultural development.
2. Upgrading industrial structure consists in the optimization of industrial structure and the opening level. The optimization of industrial structure is measured by the proportion of high-value agriculture, the value of all agricultural output, and added value of agriculture, forestry, animal husbandry, and fishery services. The opening level is determined by dividing the entire volume of agricultural product imports and exports by the added value of the primary industry.
3. Efficiency of resource allocation consists in factor allocation rationalization and efficiency. Factor allocation rationalization is measured by comparing labor productivity between agricultural sectors and non-agricultural sectors. Factor allocation efficiency

is measured by three indicators: total factor productivity, gross domestic product (GDP) to total output ratio, and energy consumption of GDP. Owing to the high correlations between labor, land, and capital productivity, the total factor productivity can comprehensively reflect the level of productivity. As GDP is the greater between the total output and the intermediate input, when the difference is larger, the intermediate input is lower, the added value is higher, and the efficiency of the factor conversion is higher. The lower the energy consumption of GDP, the lower the undesirable output.

4. Food security is the main goal of agricultural modernization. It consists in cultivated land stock, food self-sufficiency rate, and food quality and safety. Cultivated land stock is determined by the proportion of the current and prior year's grain sowing areas. The food self-sufficiency rate is measured by the comprehensive self-sufficiency rate of the six important agricultural products: grain, oil, sugar, meat, milk, and aquatic products. Food quality and safety is measured by the qualified rate of food safety and quality.
5. The livability of an ecological environment consists in ecological resource endowment, intensity of pollution, and pollution control level. Ecological endowment is measured by the excellence of the ambient air quality and the coverage of village greening. Pollution intensity is measured by the amounts of chemical fertilizer and pesticide applied per hectare. Pollution control includes the centralized treatment of household garbage and the standard treatment of domestic sewage.
6. Improvement of rural civilization consists in educational development and cultural construction. The promotion of rural civilization should simultaneously adhere to material and spiritual civilization, improve the cultural quality and spiritual outlook of farmers, and cultivate civilized local customs, family traditions, and folk customs. Educational development is measured by the retention rate of compulsory education. Cultural construction is measured by the quantity of village cultural centers and proportion of affluent towns and villages that are at or above the county level.
7. The effectiveness of rural governance is an important aspect of the modernization of the national governance system. Enhancing rural autonomy and financial resources is a trend in rural government, which is reflected by rural autonomy and collective economy. The mode of rural governance is mostly manifested as family governance or multi-family governance, and the common beliefs of the family gradually evolve into village rules and people's contract and family-style organization training. Rural autonomy is measured according to three factors: formulating village rules and the people's contract, regulating villagers' supervision, and setting up an overall plan. The collective economy is measured by the completion rate of collective property rights reform and the proportion of strong villages in the collective economy.
8. An essential component of rural development is improving public services. This is measured by the improvement of hardware facilities, software facilities, and the equalization of public services. Hardware facilities are measured by four indicators: disaster prevention and resistance ability, rural internet penetration rate, village road hardening rate, and the prevalence of clean toilets. Disaster prevention and resistance ability is defined as the disparity between the region's overall impacted area and its agricultural affected area. Improvement of software facilities is measured by the percentage of full-time instructors in compulsory education institutions who hold a bachelor's degree or higher, as well as the per-person availability of beds in medical and healthcare facilities. Public service equivalence is measured by the proportion of spending on education, the ratio of the basic standard of living for city and rural residents, and the basic standard of living to the per capita consumption expenditure on food, clothing, housing, transportation, and consumption.
9. Urban development requires the support of rural elements, rural development requires the driving force of cities, and rural and urban areas are interdependent and interactive. The coordination of urban–rural development is a notable symbol of rural revitalization measured by urban–rural openness, sharing development outcomes,

and income distribution equalization. Urban–rural openness is measured by the fraction of rural migration rate divided by the urbanization rate. Sharing development outcomes is measured by the ratio of per capita GDP of urban and rural and the per capita consumption between urban and rural. Income distribution equalization is measured by the Gini coefficient of income.

10. The prosperity of farmers is the foundation of rural revitalization and is measured by their income level and quality of life. Income level is measured based on the percentage of per-person disposable income and non-agricultural income. Quality of life is measured by the Engel coefficient and family car ownership per 100 households.

Table 1 provides an evaluation index system composed of 10 primary indicators, 24 secondary indicators, and 49 tertiary indicators. The data were mainly collected from the China Statistical Yearbook, China Rural Statistical Yearbook, China Agricultural Yearbook, China Agricultural Machinery Industry Yearbook, China Agricultural Products Processing Industry Yearbook, China Population and Employment Statistical Yearbook, China Environmental Statistical Yearbook, China City Statistical Yearbook, China Education Statistical Yearbook, and China Insurance Yearbook. The data missing from the yearbooks, such as the Digital Inclusive Finance Index, were obtained from the Digital Finance Research Center of Peking University, and the data pertaining to the civilized villages and towns at or above the county level are from the China Civilization Network. Following the definitions of agricultural and rural modernization, this study calculated some of their indicators, including the human capital index, total factor productivity, and the Gink coefficient.

Table 1. Evaluation index system and weight distribution.

Primary Indicators	Secondary Indicators	Tertiary Indicators	Effect
Development vitality (0.262)	Production conditions (0.448)	Proportion of high-quality cultivated land (0.302)	+
		Comprehensive mechanization rate (0.317)	+
		Rural human capital index (0.381)	+
	Development momentum (0.552)	Contribution rate of agricultural technology (0.353)	+
		Agricultural insurance depth (0.322)	+
		Digital financial inclusion index (0.325)	+
Structure upgrading (0.260)	Structure optimization (0.513)	High-value agriculture ratio (0.331)	+
		Agricultural product processing value/Total agricultural output value (0.314)	+
		Proportion of added value of agriculture service (0.355)	+
	Opening level (0.487)		
		Total import and export of agricultural products/ Added value of primary industry (1.000)	+
Resource allocation (0.233)	Rationalization (0.496)	Labor productivity compared between agriculture and non-agricultural industries (1.000)	+
		Total factor productivity (0.329)	+
	Allocation efficiency (0.504)	GDP to total output ratio (0.318)	+
		Energy consumption per CNY 10,000 GDP (0.353)	–
Food security (0.245)	Cultivated land stock (0.353)	Grain sown area of current year/Grain sown area of previous year (1.000)	+
	Food self-sufficiency rate (0.318)	Self-sufficiency rate of grain, oil, sugar, meat, milk, and aquatic products (1.000)	+
	Food quality and safety (0.329)	Qualified rate of good quality and safety (1.000)	+

Table 1. Cont.

Primary Indicators	Secondary Indicators	Tertiary Indicators	Effect
Ecological livability (0.169)	Ecological endowment (0.349)	Excellent rate of ambient air quality (0.491)	+
		Village green coverage rate (0.509)	+
	Pollution release intensity (0.326)	Amount of chemical fertilizer applied per hectare (0.486)	—
		Amount of pesticide applied per hectare (0.514)	—
	Pollution control level (0.325)	Proportion of villages that centrally treat domestic waste (0.551)	+
		Standard treatment rate of domestic sewage (0.449)	+
Rural civilization (0.153)	Educational development (0.488)	Consolidation rate of compulsory education (1.000)	+
	Cultural construction (0.512)	Number of cultural stations in towns and villages per 10,000 people (0.576)	+
		Proportion of civilized villages and towns at or above the county level (0.424)	+
Rural governance (0.157)	Rural autonomy (0.507)	Proportion of villages with village regulations (0.309)	+
		Coverage of villagers' supervision committee (0.333)	+
		Proportion of villages with overall planning (0.358)	+
	Collective economy (0.493)	Completion rate of collective property right restructuring (0.518)	+
		Proportion of strong villages in collective economy (0.482)	+
Public services (0.179)	Hardware facility (0.338)	Agricultural disaster prevention and resistance capability (0.244)	+
		Internet penetration rate in rural areas (0.243)	+
		Hardening rate of village roads (0.316)	+
		Penetration rate of harmless toilets (0.197)	+
	Software facilities (0.326)	Percentage of full-time teachers with a bachelor's degree or higher in compulsory education schools (0.506)	+
		Per capita number of beds in medical institutions (0.494)	+
	Public services equalization (0.336)	Proportion of spending on education (0.352)	+
		Ratio of rural to urban inhabitants' minimum monthly allowances (0.373)	—
		Ratio of minimum living guarantee standard and per capita consumption expenditure on clothing, food, housing, and transportation (0.275)	+
Coordinated development (0.162)	Urban–rural openness (0.317)	Rural migration rate/urbanization rate (1.000)	+
	Sharing development outcomes (0.347)	Ratio of per capita GDP of urban–rural areas (0.471)	—
		Ratio of per capita consumption of urban–rural areas (0.529)	—
	Income distribution equalization (0.336)	Gini coefficient of urban–rural areas (0.485)	—
		Gini coefficient between different rural areas (0.515)	—

Table 1. Cont.

Primary Indicators	Secondary Indicators	Tertiary Indicators	Effect
Prosperity (0.180)	Income level (0.510)	Per capita disposable income of rural residents (0.515)	+
		Ratio of non-farm revenue (0.485)	+
	Quality of life (0.490)	Engel coefficient of rural residents (0.503)	−
		Family car ownership per 100 households (0.497)	+

3.2. Evaluation Method

This study used the improved TOPSIS method to evaluate China's agricultural and rural modernization. Compared with the traditional TOPSIS method, this method can overcome interference from random factors, such as subjective empowerment, and has the advantages of computational science and reasonable results.

First, with reference to some scholars, the logarithmic power function method was adopted for dimensionless processing [34]. Second, the index weight was determined. To avoid interference from random factors of subjective empowerment and the issue of missing variables of objective empowerment, this study adopted a combination of the hierarchical analysis method and the coefficient of variation method. The specific weights are shown in Table 1. Third, according to the resulting standard matrix and the index weights, a weighted normalized matrix was constructed to determine the ideal solutions. Then, we calculated the difference between the value of an index and the ideal solution. Fourth, we divided the development stages. Some scholars divided economic development into six stages based on the level of productivity development: traditional society, creating prerequisites for takeoff, take-off, advancement toward maturity, high consumption, and pursuing quality of life [35]. Among them, creating prerequisites for takeoff can be viewed as a slow development stage, while takeoff and advancement toward maturity can be rapid development stages. High consumption and the pursuit of quality of life suggest transformation and high-quality development. According to the lifecycle of rural development, some studies divided rural development into five stages: primary, growth, prosperity, stability, and transformation [36]. Other scholars divided rural development into three stages based on the level of development of agricultural modernization: the initial, development, and mature stages [37]. Referring to previous research, combined with the general laws of structural transformation, we divided the development of modernization into six stages: the initial, slow development, rapid development, transformation and leap, preliminary implementation, and basic implementation stages (Table 2).

Table 2. Classification of agricultural and rural modernization stages.

Agricultural and Rural Modernization Score	Correspondence to Development Stage
0.300–0.499	Initial
0.500–0.599	Slow development
0.600–0.699	Rapid development
0.700–0.799	Transformation and leap
0.800–0.899	Preliminary realization
0.900–1.000	Basic realization

The coordinated advancement of agricultural modernization and rural modernization is a prerequisite for effective agricultural and rural modernization. With reference to some studies [38], we constructed the dual system coupling a coordination degree model of agricultural modernization and rural modernization as follows:

$$C = \left\{ \frac{S_1 * S_2}{((S_1 + S_2)/2)^2} \right\}^{1/2} \quad (1)$$

$$T = \alpha * S_1 + \beta * S_2 \quad (2)$$

$$D = \sqrt{C * T} \quad (3)$$

where S_1 and S_2 represent agricultural modernization and rural modernization obtained by improved TOPSIS method, respectively, C represents the level of coordination of agricultural and rural modernization, T represents the combined development level of agricultural and rural modernization, and α and β are the weights of each subsystem. D reflects the coupling coordination level, which can effectively assess the level of coordination of agricultural and rural modernization in different regions. This study concluded that agricultural and rural development are equally important, so both α and β were taken as 0.5. Based on previous research [39], we identified 10 types of coupling coordination (Table 3).

Table 3. Classification of coupling compatibility.

Negative Coupling (Disordered Development)		Forward Coupling (Coordinated Development)	
D	Type	D	Type
0.000–0.099	Extreme dysregulation and decline	0.500–0.599	Forced coordinated development
0.100–0.199	Severe dysregulation and decline	0.600–0.699	Primary coordinated development
0.200–0.299	Moderate dysregulation and decline	0.700–0.799	Intermediate coordinated development
0.300–0.399	Mild dysregulation and decline	0.800–0.899	Good coordinated development
0.400–0.499	Tiny dysregulation and decline	0.900–1.000	High-quality coordinated development

4. Results

4.1. Agricultural and Rural Modernization

Agricultural and rural modernization in China increased from 0.524 in 2015 to 0.633 in 2019 (Table 4). However, some key factors which remain little developed constitute weaknesses in agricultural and rural modernization that will seriously affect the development process, especially the following: the coordinated development between urban–rural areas, the livability of ecological environment, prosperity, upgrading industrial structure, and resource allocation. Accelerating high-quality development of agricultural and rural areas requires sustained efforts to address these weak links.

Table 4. Scores of agricultural and rural modernization subsystems.

System/Year	2015	2016	2017	2018	2019
Development vitality	0.548	0.568	0.604	0.646	0.670
Structure upgrading	0.505	0.532	0.553	0.581	0.618
Resource allocation	0.523	0.547	0.562	0.593	0.620
Food security	0.621	0.653	0.688	0.701	0.720
Ecological livability	0.503	0.521	0.546	0.569	0.587
Rural civilization	0.556	0.571	0.594	0.618	0.630
Rural governance	0.563	0.586	0.614	0.637	0.654
Public services	0.558	0.573	0.596	0.623	0.634
Coordinated development	0.508	0.526	0.536	0.558	0.572
Prosperity	0.506	0.536	0.556	0.571	0.604
Agricultural and rural modernization	0.524	0.550	0.578	0.606	0.633

Agricultural and rural modernization showed different distribution characteristics between different regions (Table 5). First, the levels of agricultural and rural modernization showed significant regional differences. The levels of agricultural and rural modernization in the eastern, central, and western regions were 0.725, 0.606, and 0.567, respectively, indicating high development in the east, flat in the central regions, and low development in the west. On one hand, the high level of urbanization in the eastern region has attracted a large

amount of rural labor to seek employment, which helps to optimize resource allocation efficiency, increase farmers' income, and improve their living conditions. On the other hand, the improvement in the urban development level in the eastern region helps to feed-back rural areas, strengthen rural infrastructure, improve public services, and ultimately form a situation of coordinated urban–rural development. Second, agricultural and rural modernization showed a certain convergence trend among regions. The spatial distribution of the speed of agricultural and rural modernization was fast in the west, flat in the central area, and slow in the east. With the promotion of regional balanced development strategies such as Western Development, the comprehensive revitalization of Northeast China, and the rise in the central region, decision-making departments have provided a large amount of financial support for the central and western regions, promoting the development of agricultural and rural areas in the central and western regions. Different development speeds show that the agricultural and rural areas of China have potential for convergence and balanced development. Third, the level of development of the 10 subsystems varies significantly by area, which could be related to various regional resource endowments and development methods. To accelerate agricultural and rural modernization, we should follow the characteristics of regional resource endowment, adapt measures to local conditions, classify different policies, and consider regional comparative advantages.

Table 5. Scores of agricultural and rural modernization in different regions and provinces.

Region/Year		2015	2016	2017	2018	2019
Eastern	Beijing	0.757	0.803	0.837	0.853	0.867
	Tianjin	0.666	0.689	0.699	0.720	0.732
	Hebei	0.524	0.549	0.564	0.588	0.609
	Liaoning	0.536	0.559	0.586	0.617	0.638
	Shanghai	0.779	0.816	0.845	0.854	0.869
	Jiangsu	0.684	0.709	0.717	0.747	0.765
	Zhejiang	0.715	0.724	0.749	0.759	0.793
	Fujian	0.559	0.608	0.637	0.655	0.684
	Shandong	0.591	0.601	0.618	0.631	0.643
	Guangdong	0.574	0.627	0.649	0.691	0.716
	Hainan	0.533	0.560	0.579	0.618	0.661
Eastern		0.629	0.659	0.680	0.703	0.725
Central	Shanxi	0.455	0.483	0.513	0.545	0.570
	Jilin	0.491	0.515	0.538	0.565	0.582
	Heilongjiang	0.526	0.557	0.585	0.602	0.623
	Anhui	0.512	0.552	0.570	0.595	0.620
	Jiangxi	0.493	0.521	0.555	0.580	0.605
	Henan	0.485	0.513	0.546	0.568	0.583
	Hubei	0.537	0.552	0.596	0.628	0.647
	Hunan	0.511	0.532	0.553	0.596	0.617
Central		0.501	0.528	0.557	0.585	0.606
Western	Inner Mongolia	0.477	0.503	0.514	0.540	0.570
	Guangxi	0.465	0.483	0.522	0.544	0.577
	Chongqing	0.556	0.570	0.595	0.634	0.668
	Sichuan	0.467	0.483	0.530	0.566	0.604
	Guizhou	0.430	0.471	0.521	0.549	0.584
	Yunnan	0.401	0.424	0.453	0.503	0.528
	Tibet	0.397	0.409	0.435	0.470	0.499
	Shaanxi	0.498	0.519	0.537	0.567	0.611
	Gansu	0.356	0.375	0.416	0.458	0.499
	Qinghai	0.421	0.453	0.488	0.526	0.574
	Ningxia	0.451	0.490	0.520	0.537	0.566
	Xinjiang	0.393	0.421	0.453	0.486	0.532
Western		0.442	0.466	0.498	0.531	0.567

The stage of agricultural and rural modernization in each province and region is shown in Table 6. Agricultural and rural modernization in Shanghai and Beijing were close to 0.87 in 2019 and can be considered nearly fully realized. According to their current development rate, these two cities take the lead and will realize agricultural and rural modernization by approximately 2023. Agricultural and rural modernization in Tibet and Gansu was lower than 0.50, which indicates that development is in the initial stages. The average value of agricultural and rural modernization in Jilin, Henan, Shanxi, Guizhou, Guangxi, Qinghai, Inner Mongolia, Ningxia, Xinjiang, Yunnan, and other provinces was 0.566; the stage of slow development. The average value of agricultural and rural water modernization in Fujian, Hainan, Shandong, Liaoning, Hebei, Hubei, Heilongjiang, Anhui, Hunan, Jiangxi, Sichuan, Chongqing, Shaanxi, and other provinces was 0.633, entering the stage of rapid development. Agricultural and rural modernization in Zhejiang, Jiangsu, Tianjin, Guangdong, and other provinces reached 0.751, indicating a crossing into the transformation and leap development stage. According to the current development rate, these four provinces should realize agricultural and rural modernization in the next 5–10 years.

Table 6. Development stages of agricultural and rural modernization in 2019.

Region/Type	Initial Stage	Slow Development	Rapid Development	Transformation and Leap	Preliminary Realization
Eastern	—	—	Fujian, Hainan, Shandong, Liaoning, Hebei	Zhejiang, Jiangsu, Tianjin, Guangdong	Shanghai, Beijing
Central	—	Jilin, Henan, Shanxi	Hubei, Heilongjiang, Anhui, Hunan, Jiangxi	—	—
Western	Tibet, Gansu	Guizhou, Guangxi, Qinghai, Inner Mongolia, Ningxia, Xinjiang, Yunnan	Sichuan, Chongqing, Shaanxi	—	—

4.2. Agricultural Modernization and Rural Modernization

At the national level, from 2015 to 2019, the agricultural modernization index increased by 0.117 points, from 0.547 to 0.664. In the same period, the rural modernization index increased by 0.102 points, from 0.500 to 0.602. Therefore, both agricultural and rural modernization have been improving but rural modernization lags behind agricultural modernization and has more weaknesses. As key locations for production and livelihoods, rural areas should work to accelerate both types of modernization and pay attention to strengthening rural modernization and enhancing the degree of coordinated development. See Table 7.

At the regional level, the distribution patterns of agricultural and rural modernization mainly present the following characteristics. First, agricultural modernization showed spatial distribution characteristics of “high in the east, flat in the central, and low in the west” and the geographic features of “rapid in the west, flat in the central region, and slow in the east”. On one hand, the process of capital replacing scarce labor in the eastern region has been hastened by the rapid progress of urbanization, which promotes agricultural modernization. On the other hand, the varying pace of agricultural modernization in

different regions combined with their levels of development indicate the possibility of convergence of rates of agricultural modernization.

Table 7. Scores of agricultural modernization and rural modernization.

Province	Agricultural Modernization					Rural Modernization				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Beijing	0.760	0.820	0.853	0.861	0.872	0.753	0.786	0.820	0.845	0.862
Tianjin	0.688	0.706	0.723	0.753	0.771	0.644	0.672	0.674	0.687	0.693
Hebei	0.545	0.567	0.573	0.597	0.622	0.503	0.531	0.554	0.578	0.595
Liaoning	0.563	0.582	0.597	0.639	0.652	0.508	0.536	0.574	0.595	0.623
Shanghai	0.781	0.825	0.856	0.863	0.874	0.777	0.806	0.834	0.845	0.864
Jiangsu	0.698	0.744	0.753	0.788	0.810	0.670	0.674	0.681	0.705	0.720
Zhejiang	0.764	0.769	0.796	0.802	0.843	0.665	0.679	0.702	0.716	0.742
Fujian	0.601	0.613	0.640	0.659	0.696	0.516	0.602	0.634	0.650	0.671
Shandong	0.597	0.606	0.620	0.629	0.645	0.584	0.596	0.615	0.632	0.640
Guangdong	0.604	0.633	0.649	0.701	0.719	0.543	0.621	0.648	0.680	0.712
Hainan	0.546	0.562	0.581	0.622	0.661	0.519	0.558	0.576	0.613	0.660
Eastern	0.650	0.675	0.695	0.719	0.742	0.607	0.642	0.665	0.686	0.707
Shanxi	0.484	0.517	0.553	0.592	0.607	0.425	0.448	0.472	0.498	0.533
Jilin	0.517	0.533	0.543	0.574	0.601	0.465	0.496	0.533	0.555	0.562
Heilongjiang	0.579	0.606	0.627	0.636	0.663	0.472	0.508	0.542	0.568	0.583
Anhui	0.504	0.555	0.574	0.600	0.633	0.519	0.548	0.566	0.589	0.606
Jiangxi	0.506	0.530	0.575	0.605	0.641	0.480	0.512	0.534	0.555	0.568
Henan	0.495	0.519	0.555	0.575	0.596	0.474	0.507	0.536	0.561	0.569
Hubei	0.558	0.568	0.625	0.663	0.679	0.515	0.536	0.567	0.593	0.614
Hunan	0.534	0.559	0.575	0.630	0.659	0.488	0.505	0.530	0.562	0.575
Central	0.522	0.548	0.578	0.609	0.635	0.480	0.508	0.535	0.560	0.576
Inner Mongolia	0.544	0.589	0.604	0.645	0.659	0.410	0.417	0.423	0.435	0.480
Guangxi	0.481	0.503	0.530	0.557	0.589	0.448	0.462	0.513	0.530	0.564
Chongqing	0.629	0.630	0.653	0.690	0.709	0.483	0.509	0.536	0.578	0.627
Sichuan	0.470	0.486	0.549	0.606	0.651	0.463	0.479	0.511	0.525	0.556
Guizhou	0.438	0.475	0.535	0.577	0.623	0.421	0.467	0.506	0.521	0.544
Yunnan	0.410	0.446	0.484	0.547	0.569	0.392	0.402	0.421	0.458	0.486
Tibet	0.409	0.424	0.464	0.521	0.557	0.385	0.393	0.406	0.419	0.440
Shaanxi	0.503	0.521	0.552	0.584	0.635	0.492	0.516	0.522	0.550	0.587
Gansu	0.370	0.383	0.439	0.488	0.529	0.342	0.367	0.393	0.427	0.468
Qinghai	0.493	0.530	0.590	0.617	0.625	0.348	0.375	0.386	0.435	0.522
Ningxia	0.480	0.533	0.575	0.604	0.631	0.422	0.446	0.465	0.470	0.501
Xinjiang	0.403	0.425	0.480	0.518	0.559	0.383	0.417	0.425	0.453	0.504
Western	0.469	0.495	0.538	0.580	0.611	0.416	0.438	0.459	0.483	0.523
Country	0.547	0.573	0.604	0.637	0.664	0.500	0.528	0.552	0.575	0.602

Second, rural modernization showed spatial distribution characteristics of “high in the east, flat in the central, and low in the west” and a faster rate in the west than in the central and eastern regions. This shows that the development of rural modernization not only depends on the internal resource endowment of rural areas but must also be promoted within the scope of urban–rural integrated development. After years of development, the circulation of factors and commodities in the eastern region is smoother and public services are relatively better, so the eastern rural areas take the lead in development. Additionally, western rural modernization is progressing at a higher pace than in the central and eastern regions, indicating that there is a trend of convergence of rural modernization among regions. However, this convergence rate is slower than the rate of agricultural modernization.

Third, agricultural modernization was higher and progressed at a faster pace than rural modernization. The disparity between rural and agricultural modernization narrowed in the eastern area but continued to widen in the central and western regions. With a growth-oriented development strategy with more emphasis on agricultural modernization, rural construction did not receive as much attention as agricultural production and faced the impacts of urbanization, causing the deterioration of rural non-point source pollution and the disintegration of traditional rural culture, leading to uncoordinated development.

It should be pointed out that the regional development of rural modernization differs more than that of agricultural modernization, and the degree of unbalance is higher. Therefore, to properly solve the urban–rural development imbalance, it is crucial to consider how these factors play out in different regions.

4.3. Coupling Agricultural and Rural Coordination

Figure 1 depicts the shifts in the degree of agricultural and rural coupling cooperation, subfigure (a) represents 2015 and subfigure (b) represents 2019. At the national level, the degree of coupling coordination between agricultural and rural modernization improved greatly from 0.730 in 2015 to 0.797 in 2019. However, coupling remains at the intermediate coordination stage. The degrees of coupling coordination in the eastern, central, and western regions in 2019 were, respectively, 0.833, 0.781, and 0.758. While other regions are still in the intermediate coordination stage, the eastern region has moved past this and into good coordination. Although the western region's rural development has a weak basis, its level of coordinated development has been effectively improving through various national policies.

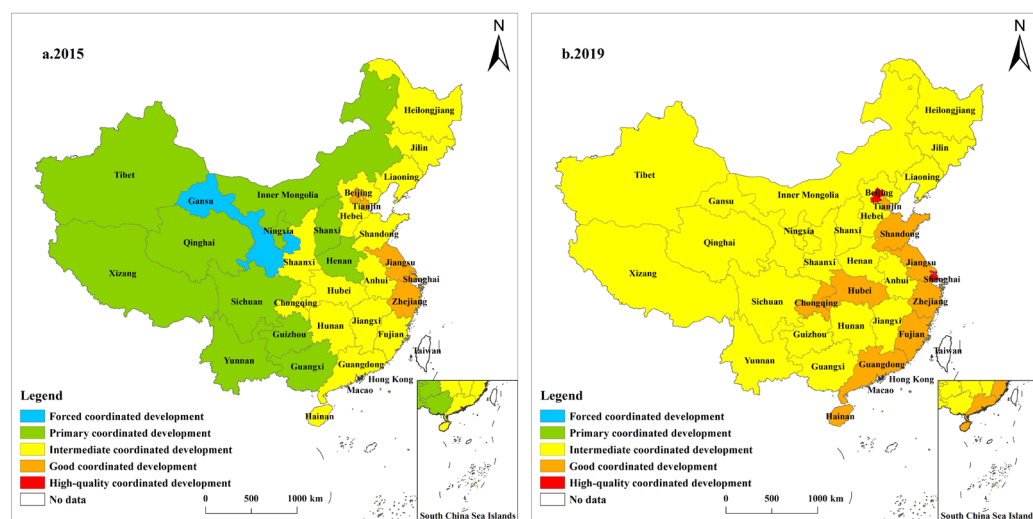


Figure 1. Level of agricultural and rural modernization coupling coordination.

In different provinces, the level of coordinated agricultural and rural development in all provinces continued to increase from 2015 to 2019. The number of provinces with good or better coordination increased from 5 to 12 and the number of provinces in primary coordination or below decreased from 14 to 1. By 2019, except for Liaoning (intermediate coordination), all provinces in the eastern region had good coordination or better. In the central region, except for Hubei (good coordination), all provinces had intermediate coordination. In the western region, except for Chongqing (good coordination) and Gansu (primary coordination), all provinces had intermediate coordination. As a result, the eastern provinces had a higher level of coupling coordination between agricultural and rural areas, which indicates that the coordinated growth of agriculture and rural areas is contingent upon the full development of cities.

5. Convergence Test

5.1. σ Convergence Test

We used the coefficient of variation to examine the convergence of agricultural and rural modernization (Equation (4)).

$$\sigma_t = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_{i,t} - \bar{x}_t)^2 / \bar{x}_t} \quad (4)$$

where n is the quantity of provinces, $x_{i,t}$ indicates the agricultural and rural modernization of province i in period t , and the coefficient of variation for agricultural and rural modernization is given by the symbol σ_t . If $\sigma_{t+1} < \sigma_t$, the coefficient of variation is shrinking and there is σ convergence; otherwise, the difference in agricultural and rural modernization development shows a divergent trend and σ convergence does not exist.

Table 8 displays the results of the σ value calculation. Nationally, σ decreased from 0.201 to 0.150 from 2015 to 2019 and agricultural and rural modernization showed σ convergence, demonstrating that the differences in agricultural and rural modernization in China's provinces have been gradually closing. By region, the eastern, central, and western regions saw a decline in σ from 0.148, 0.050, and 0.123 in 2015 to 0.125, 0.042, and 0.086 in 2019, respectively. The σ of the different regions generally showed a downward trend, demonstrating a gradual decrease in the internal inequalities in the development of agricultural and rural areas.

Table 8. Convergence test of agricultural and rural modernization.

Year	Country	Eastern Region	Central Region	Western Region
2015	0.200	0.150	0.052	0.123
2016	0.195	0.146	0.048	0.115
2017	0.180	0.145	0.048	0.102
2018	0.162	0.132	0.044	0.091
2019	0.148	0.124	0.043	0.086

5.2. Absolute β Convergence Test

Absolute β convergence can assess whether agricultural and rural modernization approaches the same steady state equilibrium value. The estimation model for absolute β convergence is as follows:

$$(\ln x_{i,t} - \ln x_{i,0}) / T = \alpha + \beta \ln x_{i,0} + \varepsilon_{i,t} \quad (5)$$

where $x_{i,t}$ and $x_{i,0}$ indicate the scores of reporting-period and base-period of agricultural and rural modernization of province i , respectively, T is the time span of the base period and the reporting period, α and β are the estimated coefficient. If the β value is significantly negative, it indicates that the province shows an absolute convergence trend. The absolute β convergence rate λ can be expressed as in Equation (6), which refers to the speed at which the poor level of agricultural and rural modernization catches up with that of developed areas.

$$\lambda = -\frac{1}{T} \ln(1 + \beta) \quad (6)$$

Table 9 displays the results of coefficient β . Nationally, the estimated β_1 was significantly negative, showing β absolute convergence at a rate of 1.88%. Thus, the regions with lower levels of agricultural and rural modernization have a higher growth rate than those with higher levels. Thus, the development gap between regions is narrowing and agricultural and rural modernization will eventually reach a steady level. Regionally, the β_1 of the eastern, central, and western regions were negative at the statistical levels of 5%, 10%, and 1%, respectively, demonstrating a “catch-up effect” of provinces with lower levels of agricultural and rural modernizing development to those with higher levels. This means

that agricultural and rural modernization in various regions will converge to the steady state equilibrium, followed by national level convergence.

Table 9. Absolute β convergence test of agricultural and rural modernization.

	Country	Eastern Region	Central Region	Western Region
β_1 estimated value	−0.0724 ***	−0.0548 **	−0.0545 *	−0.0876 ***
Standard error	0.0079	0.0215	0.0267	0.0206
Number of provinces	31	11	8	12
Convergence rate	0.0188	0.0141	0.0140	0.0229
F statistic	84.39 ***	6.50 **	4.15 *	18.00 ***

Note: ***, **, and * indicate that the coefficients are significant at 1%, 5%, and 10%, respectively.

5.3. Conditional β Convergence Test

Unlike absolute convergence, conditional convergence assesses whether different economies can approach different steady state levels under their specific economic conditions. Generally, there are two methods for testing conditional convergence. One is to add explanatory variables to the convergence regression model to test whether the estimated value is less than 0, which would indicate β conditional convergence. The other is the panel data fixed effect model, which allows for a correlation between random error terms and explanatory variables to be compared with the random effects model. Based on the data structure and reliability of the regression results, the second research method was chosen to test the conditional β convergence using the two-way fixed effect model. The regression model for the conditional β convergence test was as follows:

$$\ln x_{i,t+1} - \ln x_{i,t} = \alpha + \beta \ln x_{i,t} + \varepsilon_{i,t} \quad (7)$$

where $x_{i,t}$ and $x_{i,t+1}$ indicate the scores of agricultural and rural modernization in the current and later periods, respectively; α is the fixed effect term, corresponding to the steady state level of different economies; and β is the key parameter of the study. If the estimated β value is less than 0 and can pass the significance test, there is conditional β convergence, that is, the agricultural and rural modernization level score in the province is close to its steady state value.

Table 10 displays the results of parameter β . Nationally, the estimated β_2 value was significantly negative, indicating that agricultural and rural modernization had a trend of convergence to the steady state level. By region, the estimated β_2 values in the eastern, central, and western regions were significantly negative at statistical levels of 5%, 5%, and 1%, respectively, indicating that agricultural and rural modernization in the different regions had a trend of convergence to their own steady state level. However, owing to the heterogeneity of economic environment and resource availability, different regions have different steady state levels, which agricultural and rural modernization is gradually converging toward.

Table 10. Conditional β convergence test of agricultural and rural modernization.

	Country	Eastern Region	Central Region	Western Region
	FE	FE	FE	FE
β_2 estimated value	−0.1977 **	−0.4126 **	−0.7776 **	−0.3862 ***
Standard error	0.0841	0.1432	0.2495	0.1226
Sample capacity	124	44	32	48
F statistic	3.78 **	5.27 **	9.53 ***	5.16 **

Note: *** and ** indicate that the coefficients are significant at 1% and 5%, respectively.

6. Conclusions

This study comprehensively, objectively, and truthfully presented the level of agricultural and rural modernization in China, clarified the advantages and disadvantages of different regions, and provided reference for the continuous promotion of agricultural and rural modernization. The main findings are as follows:

First, there are significant regional differences in the development of agricultural and rural areas in China. The modernization level of agricultural and rural areas in the eastern region is the highest, but the modernization speed in the central and western regions is relatively fast, and there is a trend of convergence in the modernization level of agricultural and rural areas in different regions. On the way to comprehensively realizing China's agricultural and rural modernization, it is necessary to promote regional coordinated development as well as study and formulate agricultural and rural development policies and support for underdeveloped regions. We also need to recognize the objective differences in different regions, fully leverage the characteristics of local resource endowments, adapt to local conditions, promote classification, and improve the effectiveness, accuracy, and sustainability of the policies.

Second, the coordinated development of urban–rural, livable ecological environment, farmer prosperity, industrial structure upgrade, and resource allocation efficiency is lagging, highlighting the weakness of high-quality agricultural and rural development. The modernization of agriculture and rural areas is the result of a combination of multiple factors. On one hand, it is necessary to continuously tap into the potential for internal development in rural areas, drive agricultural and rural development through innovation, and improve the weak links. On the other hand, the modernization of agricultural and rural areas needs to fully leverage the driving role of cities. Urban development cannot be separated from the support of rural elements, and rural development cannot be separated from the drive of Kaesong. Agricultural and rural development and urbanization are interdependent and interactive, and the status and rights of cities and villages are equal.

Third, the development of agriculture and rural areas is uncoordinated, slowing the process of modernization. At present, the development of rural modernization lags behind the development of agricultural modernization, and narrowing the gap between the development of agriculture and rural areas deserves great attention. Agricultural modernization has laid a material foundation for rural development, and rural modernization provides inclusive production and living spaces for agricultural development. The coordinated development of agricultural and rural modernization jointly promotes their improvement.

China has significant regional differences and each region has a different modernization development path. Future research should summarize the general laws of local agricultural and rural modernization in combination with the development characteristics of each region.

In addition, China and many leading developed countries have encountered some common problems in the process of rural construction, such as weak rural infrastructure, declining agricultural economic status, environmental pollution, and resource shortage. The indicator design of this study integrates the agricultural and rural development experiences of leading developed countries. However, as China is a developing country with a large population, there are also typical personalized issues in its agricultural and rural development. Therefore, this study mainly focused on the agricultural and rural development of China and lacks a comparison with other regions, which is a shortcoming of this study. Subsequent research should design a concise, inclusive, and actionable evaluation system for the common issues of agricultural and rural development in different regions and compare the modernization of various countries.

Author Contributions: Methodology, Z.Y.; Data curation, Z.Y. and L.P.; Writing—original draft, Z.Y. and L.P.; Writing—review & editing, Z.Y. and X.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (grant number 72103134), and the Research Program for Humanities and Social Science Granted by Chinese Ministry of Education (grant number 21YJC790139).

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We thank three anonymous reviewers for their helpful comments of this paper.

Conflicts of Interest: The authors declare no conflict of interest.

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