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Research on Coupling and Coordination between Agricultural and Rural Modernization and High-quality Development of County Economy

-- A Case Study of Hebei Province, China

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Abstract

The modernization of agriculture and rural areas is related to the progress and quality of the overall goal of modernization construction. At present, as the hub of urban and rural areas in China, the potential of counties to achieve modernization of agriculture and rural areas still needs to be further explored. This article selects 12 districts and counties with ethnic characteristics in Hebei Province as the research object, aiming to deeply explore the coupling and coordination between modernization of the rural areas and high-quality development of county economy in the selected areas. Firstly, this article constructs an innovative coupling coordination model based on entropy weight coupling coordination method and TOPSIS coupling coordination method, explores and analyzes the inherent relationship between agricultural and rural modernization and county economic development, and provides a new methodological framework for evaluating the interaction between these two key subsystems. The findings reveal the following: (1)The districts and counties involved are mainly in the primary coordination stage of the coupling relationship between agricultural and rural modernization and county-level economic development, and have shown a positive growth trend in the past five years.(2) In the coupling and coordination index system of agricultural and rural modernization and county economy, industrial development has the most significant impact on agricultural and rural modernization. At the same time, the production index is also the factor with the biggest impact on the high-quality development of county economy. Therefore, improving the productivity level of counties and rural areas will continue to empower urban and rural development.Overall, the coupling and coordination level between agricultural and rural modernization and high-quality development of county-level economy is relatively high and showing a growing trend, with a relatively small degree of differentiation between the two levels.In China, rural areas and county economies promote each other, achieve integrated development, and have a strong economic correlation between each other.

Keywords

Agricultural and Rural Modernization; High-quality Development of County Economy; Coupling Coordination; Entropy Weight Method; TOPSIS.

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1. Introduction

Since the reform and opening up, China's agriculture and rural areas have undergone profound changes. Before 1978, Chinese agriculture was mainly based on collective agriculture, with low productivity. At the beginning of the reform and opening-up period, implementing the household contract responsibility system greatly stimulated the production enthusiasm of farmers [1]. It promoted the rapid growth of agricultural production. After entering the 21st century, with China's rapid economic and social development, the modernization of agriculture and rural areas has been put on the agenda, and the government has introduced a series of policies and measures aimed at promoting the transformation of agriculture into a technology-intensive and efficiency-prioritized type and improving the competitiveness of agriculture [2]. In the modernization process, the Chinese government has taken several key measures.

Firstly, the government has invested in the construction of agricultural infrastructure, including irrigation systems, transportation and road networks, and information technology, which are the basis for improving the efficiency of agricultural production and quality [3]. Secondly, it has promoted agricultural science and technology innovation, strengthened agricultural research institutes and higher agricultural colleges, and developed smart agriculture, applying modern information technology and biotechnology to improve planting and breeding methods [4]. Once again, reforms to the rural land system should be implemented; farmers should be allowed to transfer land by transferring, leasing, or acquiring shares, optimize the structure of land use, and promote large-scale operations.

Agricultural and rural modernization still faces a series of challenges. These include the aging of the rural labor force, the outflow of young laborers, and the sustainable use of agricultural resources [5]. The agricultural industry chain is long and extensive, and modernization requires enormous investment and time. In addition, fierce competition in agricultural markets, high price volatility, and unstable growth in farmers' incomes have put considerable pressure on agricultural modernization [6].

"County governance, the world is safe." As the hubs of China's urban and rural areas, counties play a pivotal role in promoting the stable and positive development of the agricultural and rural economy [7]. The development of China's county economy can be traced back to the early stage of reform and opening up. Since 1978, China has gradually implemented market-oriented reforms, and local governments have played a decisive role in promoting local economic development. During this period, many counties achieved initial economic growth through developing township and village enterprises and optimizing agricultural structures [8].

Entering the 21st century, as the economic development model shifted from high-speed growth to high-quality development, county economies needed transformation and upgrading, which required more attention to innovation-driven, green development, industrial upgrading, and regionally coordinated development. 2022 In May 2012, the state promulgated the Opinions on Promoting the Construction of Townships and Urbanization by Using Counties and Townships as an Important Vehicle, which more explicitly pointed out that counties and townships are essential for rural revitalization [9]. The county economy has strong independence and initiative, and different regions have distinct natural and economic characteristics. Small counties have big strategies; usually, one end of a county connects cities and rural areas, making it an essential carrier for urbanization. In most provinces, counties are the service side of urban and rural areas, and the development status of counties will significantly influence the development effect of urban and rural areas, thus realizing the high-quality development of the county economy. It is conducive to promoting the overall development of the economy in the direction of stabilization and improvement and has a more decisive impetus for economic development [10].

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Hebei Province is located in North China, south of the Zhanghe River, surrounding the capital Beijing. In 2020, the total population of Hebei Province ranks sixth in China, and the total GDP ranks 13th in China. There are 167 county-level divisions in Hebei Province, ranking second in the country, with 47,000 villages. However, such a large number of economic units cannot create better economic benefits, and the county economy and agricultural and rural economies are facing the status quo of being large but not strong and many but not excellent [11]. In order to change this situation, Hebei Province has gradually strengthened its development in the process of realizing agricultural and rural modernization and the high quality of the county economy. In the face of agricultural and rural modernization, Hebei Province pays attention to the construction of its facilities and parks, pays attention to the industrial integration and urban-rural integration process, protects the ecological environment, and develops the digital industry to empower its overall construction [12]. At the same time, the county economy occupies the leading position in the province's economic development. Hebei Province enhances the innovation ability of county enterprises, cultivates leading enterprises to enhance county economic strength, and pays attention to the construction of county enterprise projects. To sum up, this paper will focus on Hebei Province's agricultural and rural modernization construction and county economic high-quality development statistical measurement research.

This article conducts statistical measurements on the economic development level and agricultural and rural modernization construction of each county in Hebei Province, taking into account the country's strong emphasis on promoting agricultural and rural modernization. This study enhances and expands the TOPSIS model by utilizing the entropy weight model to improve and extend the model, through the construction of the linked coordinated scheduling model. To demonstrate the impact of index factors on the development of county economy and the modernization of agriculture and rural areas, as well as the interconnection between the high-quality development of county economy and the modernization of agriculture and rural areas, it is crucial for China to achieve the modernization of agriculture and rural areas. This will enable the county economy to effectively drive the development of agriculture and rural areas, providing a foundation and recommendations for advancing our modernization efforts. This research holds significant practical importance.

2. Literature Review

2.1. Research on the Strategic Position and High-quality Economic Development of County Areas

County economies play a crucial role in China's economic framework and serve as significant contributors to the gross domestic product (GDP) and industrial value added. The level of growth of county economies directly affects regional economic balance and social stability, as these areas serve as vital economic zones that integrate urban and rural areas [13]. With China's economic development transitioning to a new phase, the focus is now on achieving high-quality growth rather than simply rapid expansion. This shift necessitates a change in the county's economy from fast-paced growth to a more refined and superior kind of growth. An in-depth analysis of the interrelationship between the county economy and agricultural and rural development can provide valuable insights into the challenges faced in county rural development. This analysis can also help identify the factors that influence this development, leading to the continuous improvement of strategies, enhanced efficiency, and the promotion of modernization and sustainable development [14]. According to Zhang et al [15], the county economy plays a crucial role in urbanization. They argue that developing the county economy helps address the divide between urban and rural areas, and serves as a fundamental level of governance to support grassroots development.

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According to Li et al. [16], the county is considered the crucial unit and starting point for implementing the rural rejuvenation strategy in the new era. Fan & Fang [17] asserts that the county economy plays a crucial role in promoting China's internal circular growth. This, in turn, leads to the enhancement and optimization of China's economic development model, as well as continuous improvements in development patterns and structural optimization, hence creating additional opportunities and resources. Osei-Kyei et al. [18] argues that leveraging the industry is crucial for enhancing the county's economic prowess. It is imperative to actively foster distinctive industries, nurture key sectors, and enhance the county's economic resilience.

2.2. Research on the Measurement of Agricultural and Rural Modernization

Agricultural and rural modernization involves various aspects, including the implementation of technology and the enhancement of agricultural productivity, as well as the development of rural infrastructure and improvement of socio-economic conditions [19]. The term "modernization" denotes a transition from conventional methods and ways of life to more contemporary, frequently technologically sophisticated, approaches. Researchers such as Xia et al. [20] frequently associate these shifts with the broader concept of diffusion of innovations, which investigates the mechanisms, reasons, and speed at which new ideas and technology move across different cultures.

Rural areas frequently undergo a blend of technological, economic, and social transformation as part of the modernization process. The models presented by Sachs et al. [21] not only emphasize scientific advancements in agriculture but also consider the societal transformations required for achieving sustainable growth. These frameworks frequently discuss whether modernization should give priority to advanced and intensive agricultural techniques, or if efforts should be focused on preserving ecological balance and social equality.

The modernization of agriculture in rural areas is a crucial subject in the agricultural growth of both China and the world. It is not only important for ensuring food security and stability in rural areas, but also has significant consequences for environmental sustainability [22]. Academics have recently performed thorough research on measuring agricultural and rural modernization, aiming to build a scientific and complete evaluation system. The assessment of agricultural and rural modernization is conducted through a multifaceted evaluation indicator system in research. These indicators typically encompass agricultural production capability, agricultural scientific and technology advancement, rural economic structure, rural social security, ecological environmental preservation, and other related issues. Researchers have attempted to measure these indicators at both the macro and micro scales in order to assess the overall degree of agricultural and rural modernization, as well as regional variations [23].

In theory, the assessment of agricultural and rural modernization frequently depends on modernization theory and agricultural economic development theory. The modernization theory prioritizes the concurrent advancement of economic, technological, social, and cultural dimensions. In contrast, the agricultural economic development theory places greater emphasis on enhancing agricultural production efficiency and optimizing agricultural structure. By integrating these two theories, scholars have put forward a range of comprehensive assessment models, including the DEA model, the TOPSIS method, and the AHP method, among others [24]. These models are capable of taking into account multiple factors in order to evaluate the efficiency and effectiveness of agricultural and rural modernization in a comprehensive manner.

2.3. Research on the Internal Relationship between County Economic Development and Agricultural and Rural Modernization.

Liu et al. [25] proposed a method for constructing an index to achieve rural rejuvenation at the county level. They also studied the key variables for achieving rural revitalization from many

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perspectives. Li et al. [26] constructed an assessment system to evaluate indicators in the context of rural revitalization. The study focused on the development patterns and categorization of county villages in Anhui province. The county villages were classified into four types: industry-led, ecologically sustainable, economically self-sufficient, and balanced development. Yiting [27] examined the interconnection and harmonization between the revitalization of rural areas and the high-quality development of the county's economy. Feng & Zhang [28] constructed an evaluation index system to measure the coupling and coordination between rural revitalization and the county's economy. Additionally, they developed a model to illustrate the mechanism by which rural revitalization contributes to the high-quality development of the county's economy. Finally, they conducted an analysis of the sub-system using the established indices. The tight relationship between the county economy and rural rehabilitation is emphasized. Yin et al. [29] conducted a study on the interconnected progress of rural regeneration and new urbanization at the county level in Gansu Province. The study involved creating a comprehensive evaluation index system to assess the growth of rural revitalization and new urbanization. Xing et al. [30] developed a comprehensive model to assess the elements influencing the degree of coupling coordination. The model was applied to evaluate data from six main provinces in China over the past decade, revealing the evolving pattern of the coupling coordination link between counties and rural areas in different provinces.

Ma et al. [31] primarily investigates the approach to urban-rural integration and the promotion of high-quality regional economic and social development in China's central region. This is achieved through the construction of a coupled and coordinated evaluation index system for new urbanization and agricultural and rural modernization in China, using the global principal component analysis and coupled coordination model. Gómez-Carmona et al. [32] has the belief that fostering the growth of the digital economy in rural regions is beneficial for facilitating the exchange of information between urban and rural areas. Additionally, Ding Keke deems it imperative to augment entrepreneurial endeavors in county areas. Lynn et al. [33] performed a thorough assessment and spatial analysis of the level of urban-rural integration in 26 counties located in the hilly regions of Zhejiang Province. The investigation included evaluating the coordination and degree of obstacles in the integration process. Zhu & Luo [34] argues that enhancing the comprehensive urban-rural development, service provision, and governance system at the county level is crucial. This may be achieved by fostering the integrated growth of primary, secondary, and tertiary industries, as well as optimizing the urban and rural development arrangement. Zhang et al. [35] conducted an analysis of the interdependence between county economy and agricultural modernization, asserting that the two mutually reinforced each other. In order to invigorate the county's economy, it is necessary to promote agricultural modernization. Furthermore, the advancement of agricultural modernization is also dependent on the promotion of county economic development.

Through a comprehensive analysis of current literature, experts have progressively focused their attention and conducted research on the interconnectedness between county economy and the modernization of agriculture and rural areas. The current focus is on achieving efficient and high-quality county and agricultural rural construction in the new era. Existing research mostly focuses on the development of county economies and the modernization of agriculture and rural areas in various regions and provinces. Currently, many researchers primarily focus on analyzing the accomplishments in construction and the future potential of both subjects, without thoroughly exploring their interconnectedness. The relationship between the high-quality growth of the county economy and the modernization of agricultural and rural areas is a topic of interest. This paper focuses on twelve counties in Hebei Province that possess distinct national characteristics. The study aims to measure the economic development of these counties and the level of agricultural and rural modernization. To achieve this, a comprehensive

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indicator system is constructed and used to analyze the relationship between high-quality county economy development and the attainment of agricultural and rural modernization. The study also conducts a thorough analysis and evaluation of the influencing factors and the degree of internal relationship among the indicators.

3. Study design

3.1. Research object

This study focuses on 12 counties and districts in Hebei Province that have state-level distinctive towns as research subjects. These distinctive communities serve as innovative hubs for talented individuals, specialized industries, and the influx of high-quality resources in urban, suburban, and rural areas. Baixiang County, Kuancheng Manchu Autonomous County, Gaoyang County, Feixiang District, Zaoqiang County, Longyao County, Lulong County, Qinghe County, Quyang County, Luquan District, Wuqiang County, and Xushui District in Hebei Province are districts and counties that depend on state-level characteristic towns. These areas serve as representatives for Hebei Province and the entire country in advancing agricultural and rural modernization, as well as promoting high-quality development of the county economy.

Hebei Province is ranked 11th in the national comprehensive strength rating, indicating that its economic strength has a significant position among the middle and upper provinces. Using 2021 statistics as an illustration, the province's aggregate Gross Domestic Product (GDP) amounted to $626.3 billion, exhibiting a yearly growth rate of 19.34%. In the same year, the average disposable income of people living in urban areas was 39,791 yuan, marking a 6.7 percent growth. On the other hand, the average disposable income of people living in rural areas was 17,547 yuan. In the first quarter of 2023, Hebei's gross domestic product (GDP) reached 1004.14 billion yuan, experiencing a real growth rate of 5.1%. During this time frame, the earnings of individuals living in Hebei province continued to expand, with the average amount of money that each person had available for spending reaching 8,257 yuan. This represents a 5.0 percent growth compared to the previous year. The urban residents' per capita disposable income, when divided into permanent residence, had a 3.9% growth to reach 10,932 yuan. Similarly, the rural residents' per capita disposable income increased by 5.8% to reach 5,384 yuan. The data demonstrate the ongoing upward trajectory of income for both urban and rural populations in Hebei Province, serving as a good indication of economic progress.

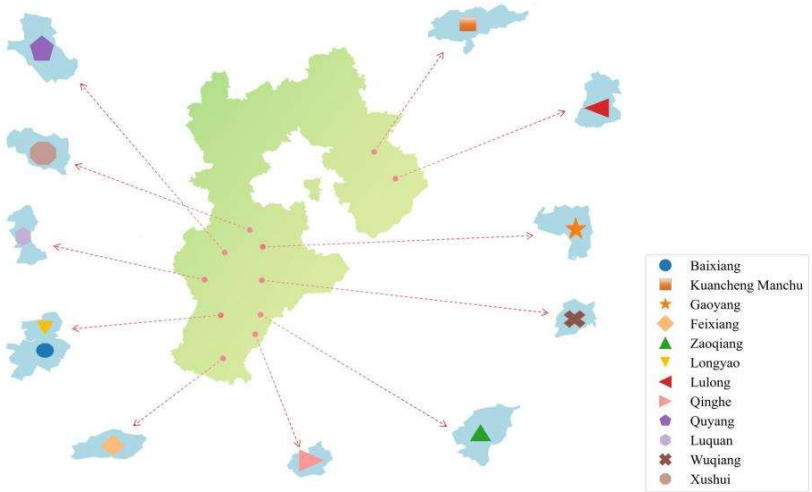

Figure 1. Geographical distribution diagram of 12 districts and counties in Hebei Province, the object of this paper

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3.2. Construction of Evaluation Index System

Table 1. Coupling coordination index system of agricultural and rural modernization and high-quality development of county economy

Subsystems	Criterion layer	Index level	Indicator specification	Weight
Agriculture and rural modernization X	Thriving businesses X_1	Proportion of total output value of agriculture, forestry, animal husbandry and fishery X_{11}	Gross output value of agriculture, forestry, animal husbandry and fishery/Gross regional product (ten thousand yuan /%)	0.159
		Level of agricultural mechanization X_{12}	Total power of agricultural machinery/cultivated land area (kW/km2)	0.097
	Pleasant living environment X_2	Number of hospital beds per 10,000 people X_{21}	Total number of people in the county/Total number of hospital beds in the county	0.100
		Traffic highway mileage X_{22}	Domestic highway mileage (km) Unit: km	0.091
	Effective governance X_3	General public budget Expenditure X_{31}	Revenue units with tax as the main body: (ten thousand yuan)	0.092
		Endowment insurance coverage rate X_{32}	Number of participants in basic endowment Insurance for Urban and rural residents/Township population (%)	0.090
	Social etiquette and civility X_4	Education expenditure X_{41}	Educational expenses (100 million yuan)	0.088
		Sports and cultural infrastructure X_{42}	Number of stadiums and theatres and cinemas (number)	0.095
	on easy street X_5	Income level of urban residents Y_{51}	Per capita Disposable income of urban residents (Yuan)	0.093
		Residents' consumption level X_{52}	Total retail sales of consumer goods (RMB 100 million)	0.090
County economic high-quality development Y	Production Y_1	Substitute and alternative industries Y_{11}	Gross tertiary industry Product/Gross regional Product	0.151
		The industrial structure is advanced Y_{12}	Gross Product of Tertiary Industry/Gross Product of Secondary Industry (%)	0.142
		Scientific and technological innovation level Y_{13}	Number of patent applications granted (item)	0.170
		Agricultural industrialization management rate Y_{14}	Industrial agricultural output value (%)	0.121
	Live Y_2	Medical insurance Y_{21}	Unit: Yuan	0.139
		Living standards of urban residents Y_{22}	Per capita Disposable income of urban residents (Yuan)	0.129
	Ecotope Y_3	Applying quantity of chemical fertilizer Y_{31}	Agricultural fertilizer application amount (tons) / Land area (sq. km)	0.145

Bu et al. [36] developed an evaluation index system to quantitatively assess the level of coordination between rural rejuvenation and county-level economy. This system takes into consideration the principles of scientificity, representativeness, and data availability, and

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focuses on promoting the coordinated development of these two areas. The system comprises a total of 17 evaluation indicators. The sub-system of rural revitalization encompasses industrial development, ecological environment, local culture, effective government, and rich living. These indicators align perfectly with the concise 20-word policy of the rural revitalization plan. Additionally, establish 10 subsidiary indicators that provide a detailed representation of the major substance of the five primary indicators. The county-level economic subsystem prioritizes productivity, quality of life, and ecological protection as primary indicators, which demonstrate the notion of spatial coordinated development known as the "integration of three kinds of life". Additionally, establish seven secondary indicators to measure the specific impact of these three primary indicators on the advancement of the county-level economy towards high-quality growth.

3.3. Data Sources

This study primarily examines the interconnection and harmonization between the advancement of agriculture and rural areas and the high-quality growth of the county economy in Hebei Province during the period of 2016 to 2020. The data utilized in this paper have been sourced from the 2017-2021 China Statistical Yearbook to guarantee the veracity and dependability of the data.

3.4. Research Technique

3.4.1. Entropy Weight Method

The information entropy method is an objective approach to allocating weights, which accurately and comprehensively represents the information contained in the index data. The information entropy approach is more trustworthy and accurate compared to the subjective weight allocation method. To assure the scientific and objective nature of the comprehensive assessment outcomes, this research use the information entropy method to quantify the importance of each indicator. This approach establishes a dependable foundation for the comprehensive evaluation. This study utilizes the entropy approach to ascertain the weights of the two evaluation indicators for agricultural and rural modernization and county economy sub-systems. This strategy is applied based on the pertinent study findings of Wang Jun and other experts. The entropy technique correctly quantifies the relative relevance of each assessment indicator in the evaluation system, ensuring the objectivity and correctness of the research outcomes. This research can enhance the evaluation of the combined performance of the two subsystems by adopting this approach.

(1) Standardized treatment:

$$Z'_{ij} = \frac{Z_{ij} - \min(Z_{ij})}{\max(Z_{ij}) - \min(Z_{ij})} (+) \tag{1}$$

$$Z'_{ij} = \frac{\max(Z_{ij}) - Z_{ij}}{\max(Z_{ij}) - \min(Z_{ij})} (-) \tag{2}$$

In formula (1), Z_{ij} is the value of the j th index in year i, Z'_{ij} is the result after standardization, max(Z_{ij}) is the maximum value of the index, and min(Z_{ij}) is the minimum value of the index.

(2) Calculate the proportion of the JTH index in year i:

$$d_{ij} = \frac{Z'_{ij}}{\sum_{i=1}^{m} Z'_{ij}} \tag{3}$$

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(3) Calculate the information entropy of the JTH index:

$$e_j = \frac{-1}{\ln(m)\Sigma_{i=1}^{m}\{d_{ij}\ln(d_{ij})\}} \tag{4}$$

(4) Calculate the weight of the JTH indicator:

$$\varphi_j = \frac{-(1-e_j)}{\sum_{j=1}^{n}(1-e_j)} \quad \varphi_j \epsilon [0,1];\ \Sigma_{j=1}^{n}\psi_j = 1 \tag{5}$$

(5) Calculate the development index of each subsystem in the first year:

$$f(x)\ or\ g(y)\Sigma_{j=1}^{n}\varphi_j * d_{ij} \tag{6}$$

In the above formula, m is the number of years, n is the number of indicators, f(x) and g(y) are the development indexes of rural revitalization and county economic subsystems, respectively.

3.4.2. Coupling Coordination Degree Model

This study establishes a linkage system between rural regeneration and county economics, drawing inspiration from past research findings. The objective is to assess the degree of coordinated development between these two factors. The coupling degree is a metric used to gauge the level of interaction and mutual constraint between rural revival and the county economy. By assessing the level of benign coupling, we may gauge the extent of coordination between rural rejuvenation and the county economy. The coupling system exhibits an intricate nonlinear coupling connection that necessitates analysis using a coupling coordination degree model. Hence, the model that represents the degree of coordination between agricultural and rural modernization and county economy can be formulated as follows:

$$\text{There into: } D = \sqrt{C * T} \tag{7}$$

$$C = \left\{\frac{f(x) * g(y)}{[f(x)+g(y)/2]^2}\right\}^{\frac{1}{2}} \tag{8}$$

$$T = \alpha f(x) + \beta g(y) \tag{9}$$

In formula (6), D is the coupling coordination degree, C is the coupling degree, and is the comprehensive evaluation value of the two subsystems. α and β are undetermined coefficients, which usually take a value of 0.5 for the two subsystems. The value range of coupling coordination degree is 0 to 1. This paper draws on Chen et al. [37] ,s grade evaluation and standard division of coordination degree, as shown in Table 2.

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Table 2. Classification standard of coupling coordination degree between rural revitalization and county economy

Coordination level	Coupling coordination degree D value interval	Degree of coupling coordination
1	D∈[0.0,0.1]	hyperdysregulation
2	D∈(0.1,0.2]	Severe disorder
3	D∈(0.2,0.3]	Moderate dysregulation
4	D∈(0.3,0.4]	Mild disorder
5	D∈(0.4,0.5]	Borderline disorder
6	D∈(0.5,0.6]	Forced coordination
7	D∈(0.6,0.7]	Primary coordination
8	D∈(0.7,0.8]	Intermediate coordination
9	D∈(0.8,0.9]	Good coordination
10	D∈(0.9,1.0]	Quality coordination

3.4.3. An Improved TOPSIS Method based on Entropy Weight Method

The entropy weight method is a technique used to objectively evaluate the weight of an assessment index based on its information quantity. The fundamental concept of this strategy is the disparity in the quantity of information. As the entropy of the index decreases, the information validity increases, resulting in a higher weight. The TOPSIS approach is a decision-making technique that relies on perfect solutions. The relative approximation of each scheme is calculated by calculating the distance between each scheme and the positive ideal solution as well as the negative ideal solution. The best scheme is then picked based on the ranking. The primary benefit of this approach is its ability to fully leverage the information contained in the original data, enabling precise identification of small distinctions between evaluation methods. In this work, we employed the entropy weight method and TOPSIS method to do a comprehensive evaluation [32] in order to guarantee the objectivity and precision of the assessment. Figure 2 illustrates the precise stages and methods used in the investigation.

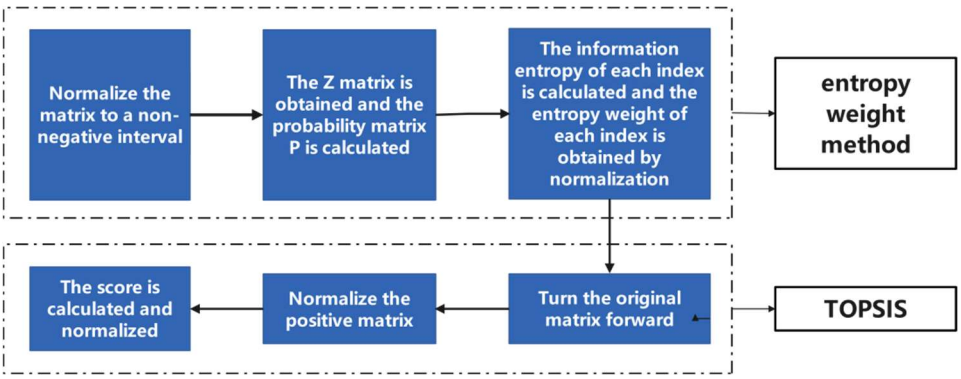

Figure 2. Comprehensive evaluation step diagram of entropy weight method and TOPSIS method

Since TOPSIS method defaults that the weights of each indicator are the same, but in the actual evaluation, the indicators have their own weights, so the formula should be improved with weights. Combined with the weights of each indicator obtained in the first step, combined with the improved formula is as follows (ω stands for weights).

$$D_i^+ = \sqrt{\sum_{j=1}^{m} \omega_j \left(Z_j^+ - z_{ij}\right)^2}, D_i^- = \sqrt{\sum_{j=1}^{m} \omega_j \left(Z_j^+ - z_{ij}\right)^2} \quad (10)$$

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Aiming at the rural revitalization strategy, this study comprehensively selected 10 key indicators in the five fields of industrial prosperity, ecological livability, effective governance, rural culture and prosperity for evaluation, and then constructed a function f(x) for quantitative evaluation. At the same time, for the high-quality development of county economy, we subdivide it into three dimensions of production, life and ecology, select seven important indicators for in-depth analysis, and obtain the function g(x). By using the coupling coordination degree model and TOPSIS method based on entropy weight method, this study established the coupling coordination degree evaluation model of rural revitalization and high-quality county economic development in Hebei Province, aiming at comprehensively measuring the interaction and coordination between the two.

4. Agricultural and Rural Modernization and County Economy Subsystem Index and Comprehensive Evaluation Analysis

4.1. Agricultural and Rural Modernization and Sub-system Index Analysis of County Economy

The development indices of 12 counties and districts in Hebei Province, where state-level typical towns are located, were estimated separately for the township development and county economic subsystems throughout the period of 2016-2020, using formula (6). These calculations are presented in Figure 3. Overall, indices such as rural rejuvenation and county economy have experienced a recovery in 12 counties and districts in Hebei. By the year 2020, the average index for rural revitalization and development and the average index for county economy would increase by 1.57 times and 2.05 times, respectively, compared to the values in 2016. The projected values for these indices in 2020 are 0.3324 and 0.3719. The primary characteristic of the county economic index is that its growth momentum is considerably swifter than that of the rural revitalization and development index. Over time, the gap between the county economic index and the rural revitalization and development index has been closing, albeit the former is still smaller than the latter. Since 2013, there has been a situation where individual counties have outperformed the economic indicators of rural revitalization development. In comparison to rural revitalization, the growth rate of county economies is higher.

This development tendency is favorable for the advancement of interconnected systems to a more advanced stage. Most counties and districts in Hebei province are situated in the central region, benefiting from a strong economic and social foundation, notable competitive advantages in specific industries, efficient urban and rural governance, innovative operational models, and suitable ecological protection measures. These elements have stimulated the rejuvenation of rural communities. The economic indicators of each county in the county are generally high, but the development of the rural economy is hindered by two closely related sub-system development indicators. These indicators, namely Xushui, Qinghe, Zaoqiang, and Feixiang, are generally below the average value due to the relatively weak development foundation of these regions.

4.2. Analysis of the Comprehensive Evaluation Value of Agricultural and Rural Modernization and County Economy Subsystem

For the two subsystems of rural revitalization comprehensive assessment T and county economic comprehensive assessment T of 12 counties in Hebei Province, we can calculate according to formula (9), and the results are shown in Figure 3.

The data show that the comprehensive assessed value of the two subsystems of rural revitalization and county economy in 2016-2020 shows an overall upward trend, with the average value rising from 0.1805 in 2016 to 0.3371 in 2020, an increase of 1.87 times.

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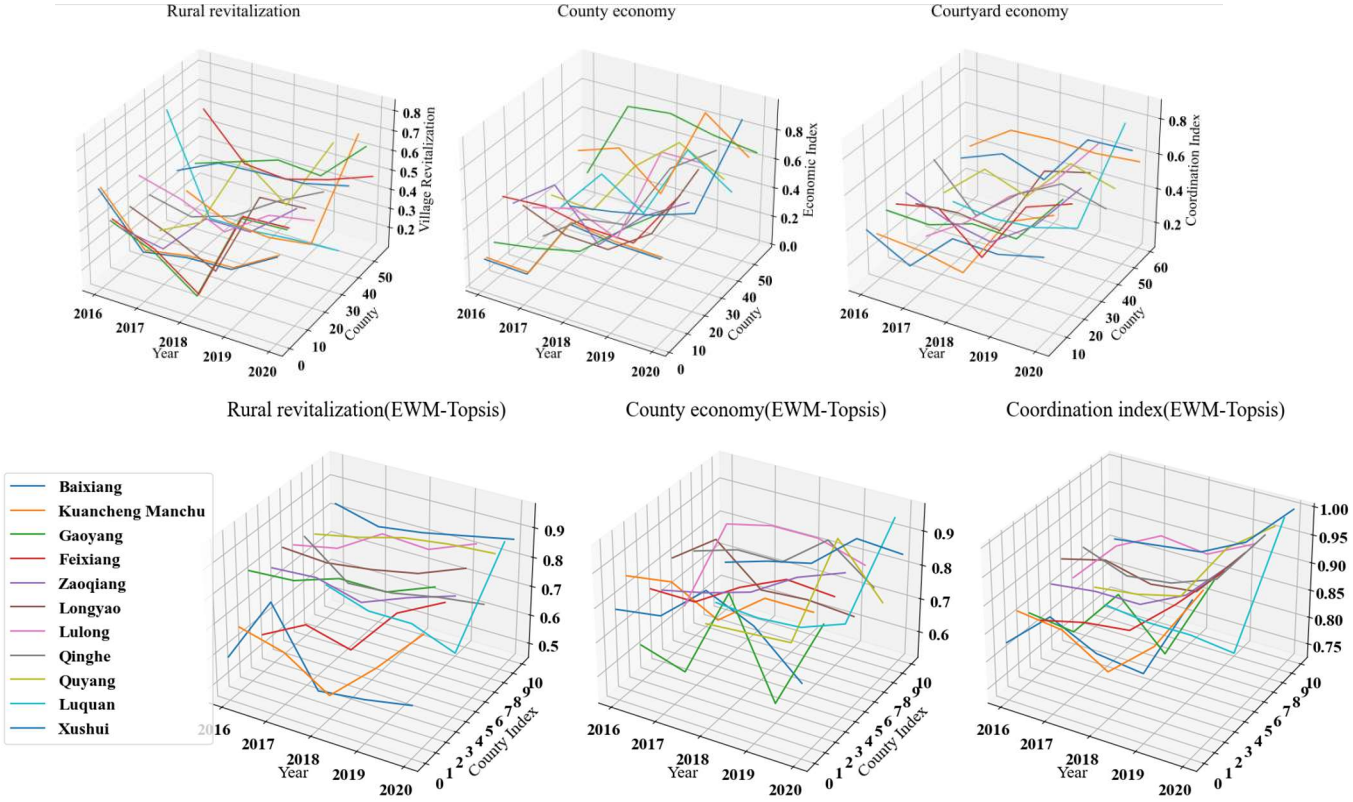

Figure 3. The entropy weight method and the entropy weight-TOPSIS agricultural and rural modernization and county economic high-quality development index of 12 counties in Hebei Province

Among them, Baixiang, Longyao and Zaoqiang ranked the top three in the comprehensive evaluation growth rate of each county, while Luquan and Quyang ranked the bottom. The comprehensive assessment value added of the county economic subsystem of Lulong County is far higher than that of other counties, with an increase of 4.19 times, which is the most comprehensive assessment value added of the rural revitalization subsystem.

5. Spatio-temporal Analysis of Coupling Coordination between Rural Revitalization and County Economy

5.1. Spatiotemporal Analysis of Coupling Degree

According to formula (8), the coupling degree of rural revitalization and county economy in 12 counties of Hebei Province from 2016 to 2020 can be obtained. The results of TOPSIS based on entropy weight method show that the coupling degree of 12 counties in Hebei Province presents a trend of wave-like increase, and the overall level is high. The mean increased from 0.9513 in 2016 to 0.9461 in 2020, with an average of 0.9565, at a high coupling level. Since 2016, except for Lulong County's coupling degree of 0.8899 in 2016, Qinghe County's coupling degree of 0.9194, and Luquan District's coupling degree of 0.9362, the coupling degree of rural revitalization and county economy in other counties and districts has been above 0.43. Among them, Gaoyang County ranked first (0.989659), Feixiang District ranked second (0.989605), and Kuancheng Manchu Autonomous County ranked third (0.9734). This shows that there is a close interdependence between the two subsystems of rural revitalization and county economy in Hebei Province, and there is a strong correlation between rural revitalization and county economy. Therefore, the study of coordinated interaction can be carried out.

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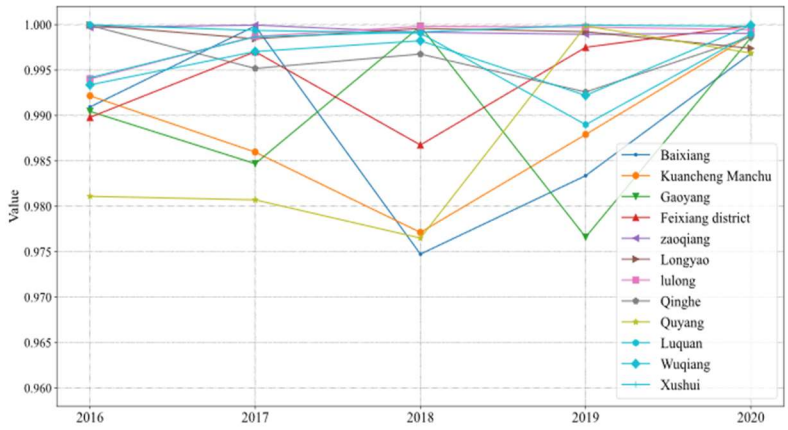

Figure 4. Coupling degree between agricultural and rural modernization and county economic system in 12 counties of Hebei Province

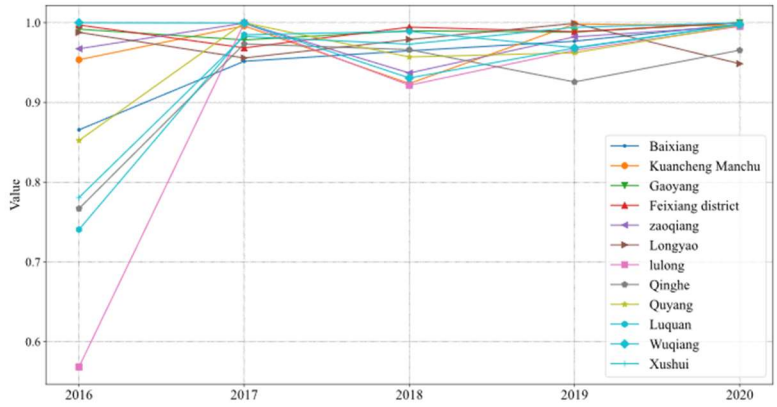

Figure 5. Coupling degree of TOPSIS agricultural and rural modernization and county economic system based on entropy weight method in 12 counties of Hebei Province

5.2. Timing analysis of Coupling Coordination Degree

According to the entropy weight method + coupled coordination degree model and entropy weight TOPSIS+ coupled coordination degree model, as a whole, the rural revitalization and county economic system of 12 counties and districts in Hebei Province from 2016 to 2020 show an obvious upward trend on the two models, which reflects the positive impact of relevant policies.

Figure 6 Average parameters of coupling coordination degree of entropy weight method in 12 counties of Hebei Province. The mean value of coupling coordination degree increased from 0.8452 to 0.9986 in this period, showing a change trend from good coordination to good coordination. Especially since 2018, with the introduction of the rural revitalization strategy and the active promotion of high-quality development of county economy by governments at all levels, most counties and districts have barely reached the coordination level in the entropy weight + coupling scheduling model. Figure 7-8 shows that from 2016 to 2020, the coupling coordination degree between agricultural and rural modernization and county economic system in 12 districts and counties of Hebei Province shows an upward trend.

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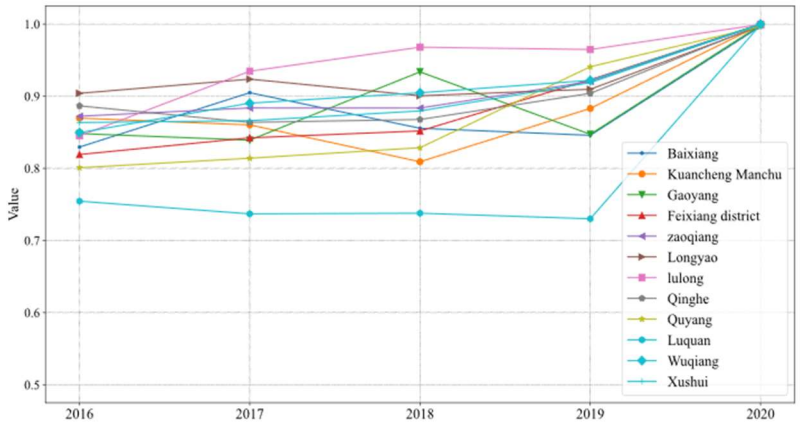

Figure 6. Degree of coupling coordination between agricultural and rural modernization and county economic system in 12 counties of Hebei Province

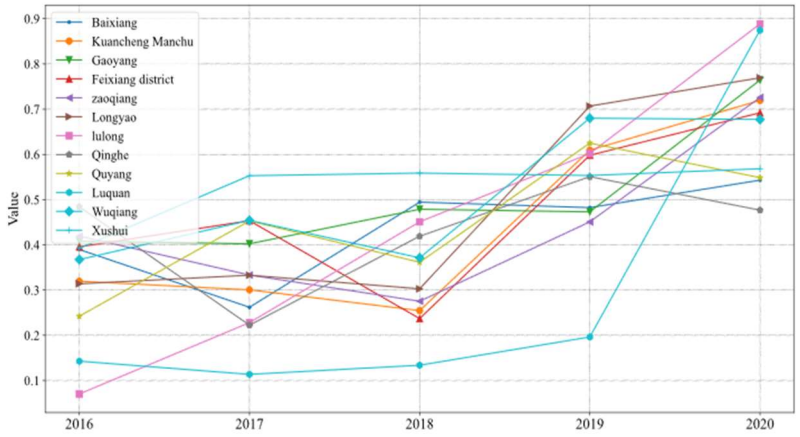

Figure 7. Coupling coordination degree between agricultural and rural modernization and county economic system based on entropy weight method TOPSIS in 12 counties of Hebei Province

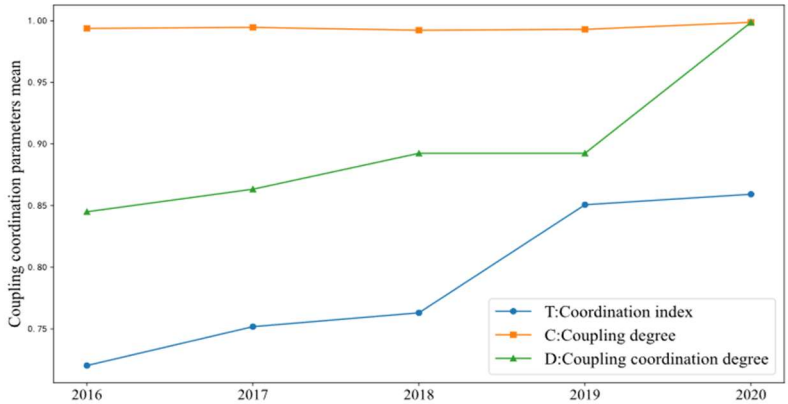

Figure 8. Average parameters of coupling coordination degree of entropy weight method in 12 counties of Hebei Province

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Combined with Figure 8, the analysis results of entropy weight method and TOPSIS method can more accurately show the trend of coupling coordination degree between agricultural and rural modernization and county economy in 12 districts and counties of Hebei Province in the past four years.

5.3. Spatiotemporal Analysis of Coupling Coordination Degree

According to the research results of entropy weight method + coupling coordination degree model and entropy weight TOPSIS+ coupling coordination degree model, the coupling coordination degree of rural revitalization and county economic system in 12 counties of Hebei Province shows a steady rising trend from 2016 to 2020. In summary, the coupling coordination degree of 12 counties in Hebei Province has reached the coordination level through the development and policy support in recent years, and most of them have reached the intermediate coordination level.

Table 3. Means of coupling coordination degree in 12 counties of Hebei Province

County territory	Average of the comprehensive index of rural revitalization	County economic composite index mean	Concordant index mean	Coupling coordination degree
lulong county	0.67755	0.65116	0.76696	Intermediate coordination
Xushui District	0.63129	0.68882	0.80259	Good coordination
Kuancheng Manchu Nationality Autonomous County	0.54016	0.66833	0.76290	Intermediate coordination
Quyang county	0.65945	0.53335	0.76022	Intermediate coordination
Baixiang county	0.55132	0.61861	0.76228	Intermediate coordination
Wuqiang County	0.65566	0.67427	0.80644	Good coordination
Qinghe County	0.53254	0.67640	0.75850	Intermediate coordination
Luquan District	0.43315	0.48385	0.63519	Primary coordination
zaoqiang county	0.63482	0.61982	0.77782	Intermediate coordination
Feixiang district	0.56616	0.68200	0.78028	Intermediate coordination
Longyao county	0.64958	0.66870	0.80040	Good coordination
Gaoyang county	0.66680	0.62780	0.79674	Intermediate coordination

Separately, in the entropy weight method + coupling coordination degree model, most of the innovative counties are promoted from the stage of good coordination to the stage of high-quality coordination, among which Luquan has the largest increase, and the coordination degree in 2020 is 1.3244 times that in 2016. In the entropy weight TOPSIS+ coupling coordination degree model, the coupling coordination degree of most counties in Hebei province is improved from the dissonance stage to the coordination stage. Among them, Lulong County and Luquan District had great changes, increasing by 18.3 and 180.81 percentage points

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respectively. The coupling coordination degree of Lulong County increased from extreme disorder to good coordination stage, and the increase rate of Qinghe County was small, only 0.076 percentage points, and the grade did not change. During 2016-2020, there is a spatial difference in the coupling coordination degree of rural revitalization and county economic system in 12 counties and districts of Hebei Province. As shown in Figure 7, the characteristics of Central Hebei Province > Southwest Hebei Province > North Hebei Province > East Hebei Province are divided into four echelon in this paper. The first echelon includes Gaoyang District, Wuqiang County and Longyao County, and the coordination degree of the three counties has reached the level of coordination and even entered the stage of good coordination. The first-tier counties and districts have great development advantages, including location advantages, convenient transportation, higher development level of characteristic industries, and better integration of primary, secondary and tertiary industries. The second echelon includes Xushui District, Zaoqiang County and Fexiang County. The districts and counties in this echelon can make the coupling coordination level present a higher level through digital rural construction, characteristic planting and promoting digital benefit agriculture and other measures. The third echelon includes Kuancheng Manchu Autonomous County, Lulong County, Quyang County and Baixiang County, which are in the intermediate coordination stage. Some counties in this echelon can keep their coordination degree relatively stable by developing characteristic tourism industry and industrial assistance measures. Although the coupling coordination degree of these counties is maintained at a high level on the whole, but considering the results of Model 2 alone, there is still a large room for improvement in the coordination degree of some counties. These counties should absorb the development advantages of the first echelon of counties, vigorously develop their characteristic industries, take industry as the core competitiveness, and achieve rural revitalization and high-quality development of county economy.

Table 4. Coupling coordination levels obtained by entropy weight method and entropy weight-TOPSIS in 12 districts and counties of Hebei Province

Counties	Entropy weight method - coupling coordination level	Entropy weight -TOPSIS- coupling coordination level
Baixiang county	Good coordination	Forced coordination
Kuancheng Manchu Nationality Autonomous County	Good coordination	Primary coordination
Gaoyang county	Good coordination	Primary coordination
Feixiang district	Good coordination	Primary coordination
zaoqiang county	Quality coordination	Primary coordination
Longyao county	Quality coordination	Primary coordination
lulong county	Quality coordination	Primary coordination
Qinghe County	Quality coordination	Borderline disorder
Quyang county	Quality coordination	Primary coordination
Luquan District	Quality coordination	Primary coordination
Wuqiang County	Quality coordination	Primary coordination
Xushui District	Quality coordination	Intermediate coordination

In 2016, Hebei Province launched a major project called "thousand village demonstration and ten thousand village renovation". The goal of the project is to promote rural revitalization through a variety of measures to improve rural infrastructure, improve environmental health

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and strengthen rural safety, and gradually improve the level of coordinated development of the 12 counties. In general, these measures have helped the development of county economy and rural revitalization, and improved the level of coupling coordination. The most prominent one is that Xushui District has accelerated the construction of beautiful villages in the new era according to the overall requirements of rural revitalization. The agricultural and rural economy has achieved rapid development, and the county economy has also been growing, and its coordination degree has reached the highest level in the study sample.

In summary, there are spatial differences between the coupling coordination degree of rural revitalization and county economic system in 12 counties of Hebei Province, and the overall trend is gradually improving. These data and analysis results can provide reference for further promoting rural revitalization and county economic development.

6. Conclusion and Suggestion

6.1. Conclusion

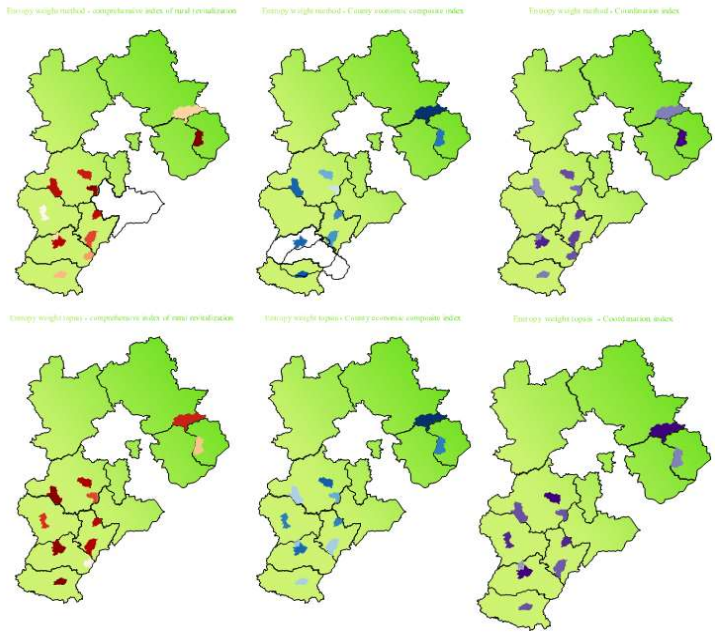

Figure 9. Spatio-temporal analysis of coupling coordination in 12 counties of Hebei Province

This study does a comprehensive examination of the interconnection and synchronization between the modernization of agriculture and rural areas, as well as the high-quality development of the county economy. A coupling and coordination model of agricultural and rural modernization and high-quality development of the county economy is established by selecting indicators related to agricultural and rural modernization and high-quality development of the county economy. The model is constructed using data from 12 regions in Hebei Province between 2016 and 2021. The coupling coordination degree of agricultural and rural modernization and county economic growth in each region is analyzed using the entropy weight method and TOPSIS method. Additionally, the study investigates the significant elements that influence the development of both aspects. Ultimately, the coupling coordination degree of 12 regions is thoroughly assessed and examined, and the counties are categorized based on varying levels of coordination. This study uncovers the intrinsic connection and influential elements between the modernization of agriculture and rural areas, and the high-quality development of the county economy in Hebei Province. The primary findings can be summarized as follows.

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Firstly, from 2016 to 2020, the level of coordination between agricultural modernization and county economic development in most of the 12 districts and counties in Hebei Province, where state-level characteristic towns are located, was primarily coordinated. There were also instances of intermediate coordination, reluctant coordination, and near imbalance.

There were also instances of intermediate coordination, reluctant coordination and near imbalance, but they also gradually develop towards a higher level of coupling and coordination.In a word, the rural areas and county areas of Hebei Province of China have a strong economic correlation, and they also play a role of promoting and supporting each other's economic development, which is conducive to accelerating urban-rural integration, and promoting the joint realization of modernization and high-quality economic development among regions.

Secondly, in the coupling coordination index system used to measure the progress of agricultural and rural modernization and the high-quality development of the county economy in this study, the calculation of index weights reveals that industrial prosperity is the most significant factor among the various influencing factors and indicators. The enhancement of productivity and production efficiency is beneficial for advancing agricultural and rural modernization. Within the county's advanced economic development system, the production index carries the most significance. This highlights the crucial role played by production factors in both systems. Enhancing productivity and production efficiency is beneficial for advancing the modernization of agriculture and rural areas, as well as fostering high-quality development within the county's economy.

6.2. Suggestion

In view of the above conclusions, in order to promote the modernization of agriculture and rural areas and the high-quality development of county economy, we put forward the following suggestions.

6.2.1. Suggestions for Agricultural and Rural Modernization

Improve the level of agricultural mechanization and increase the total output value of agriculture.

The majority of the rural areas examined in this study rely on agriculture as their primary industry. Therefore, the degree of agricultural development has a significant impact on the level of agricultural and rural modernization to some extent. The degree of agricultural mechanization is a significant indicator for assessing the success of agricultural and rural modernization sectors in China. It has a significant influence on the overall output value of rural agriculture, forestry, animal husbandry, and fishery. In regions characterized by low agricultural productivity, the local government should enhance the promotion and utilization of appropriate agricultural machinery, equipment, and mechanization technology. This should be done in accordance with the specific conditions of the area, taking into consideration the unique characteristics of crops and the ecological environment of farmland. Furthermore, the government should promote agricultural machinery companies to provide training on the use of agricultural machinery equipment and mechanization technology to farmers in specific regions. Additionally, they should offer regular feedback and maintenance services to enhance the efficiency of agricultural machinery and equipment in farming activities and elevate the level of agricultural mechanization.

Promote the construction of digital countryside and bridge the digital divide between urban and rural areas.

The findings of this study demonstrate that the digital rural development in Xushui District, Zaoqiang District, and Feixiang County, which are at the second level of coupling coordination, have achieved a higher level of development and have made a substantial contribution to

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overall coupling coordination. Furthermore, the degree of digital development has a significant influence on industrial development, ecological life, and rural governance within the index system of agricultural and rural modernization. Despite China's issuance of numerous policies, the occurrence of levitation is prevalent during the process of digital village construction. This refers to the inability of digital products to effectively align with the unique characteristics of rural development and the usage habits of residents, as well as the inconsistency between policy design and the local development reality. Hence, it is imperative to enhance the assessment of the current state of the supply region for rural digital products, enhance the diversity and flexibility of digital products, and offer more precise and tailored digital products.

6.2.2. Suggestions for High-quality Development of County Economy

Enhance industrial productivity in county areas and build industrial clusters.

The industrialization of rural areas has an impact on both the countryside and urban areas. The economic growth rate of rural areas is determined by the outcomes of industrialization, while the proportion of industrial output value in the overall output value indicates the quality of the local industrial structure. Hence, the advancement of the county's economy relies heavily on enhancing industrial productivity. The implementation of significant projects presents a valuable opportunity for the county's industrial economic expansion, and it also enhances the overall output value of the county while optimizing its economic structure. Simultaneously, fostering industrial clusters and emphasizing economies of scale by closely integrating different production departments can gradually enhance industrial productivity through the elimination of low efficiency and excess production capacity in market competition.

Improve the talent mechanism and strengthen the core driving force for economic development.

In North China, the economic progress in rural areas is typically lagging behind, and the opportunities for development are significantly fewer compared to major cities of higher tiers. As a result, highly educated and skilled individuals rarely choose to settle in rural areas, leading to a weak scientific and technological innovation capacity in these regions. Consequently, the industrial transformation and economic development in rural counties are hindered. Thus, while striving for high-quality development of the county economy, the market encounters the challenge of a talent bottleneck. Given this, the county government should enhance the talent recruitment strategy by providing suitable subsidies for housing, children's education, and other elements of life. Simultaneously, ensuring the retention of indigenous populations is crucial for overcoming the talent shortage in rural areas. Their extensive knowledge of local customs, living habits, and economic development enables them to effectively promote varied work and design products and projects that align with the local context. To attract and keep talented individuals, the county government should enhance its incentives and training programs, organize skills competitions, and provide talent development activities for this group.

6.2.3. For the Coordinated Development of Agricultural and Rural Modernization and County Economy

(1) Create characteristic industries and promote production capacity

According to the research results, Gaoyang County, Wuqiang County and Longyao County, as the counties with the highest degree of coupling and coordination in this survey, have their development advantages in the following aspects: the development level of characteristic industries is higher, the integration of primary, secondary and tertiary industries is better, and industrial development and production capacity improvement are one of the most important indicators in the most indicator system of county economy and agricultural and rural development. Therefore, each county area can create a differentiated and diversified industry by means of business entity innovation, stimulating the potential of scientific and technological innovation, and coordinating the existing development achievements. County areas can

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incubate and catalyze a number of new industries and occupations on the basis of their local characteristic agricultural development achievements, combine characteristic advantages, integrate science and technology, finance, talents, data and other factors, realize the optimization and upgrading of characteristic products, promote differentiated competition, build scientific and reasonable agricultural modernization industry, and drive the coordinated development of county areas and modern agriculture.

(2) Play the role of characteristic town gathering and innovate the platform carrier

This research focuses on studying the 12 districts and counties in Hebei Province where the national distinctive towns are situated. Upon examining the standard table of coupling coordination degree, it is evident that the majority of these regions are in the primary coordination state. However, there is still a need for further improvement in the coupling coordination level between agricultural and rural modernization and the high-quality development of the county economy. In order to achieve this goal, counties and districts can fully utilize the potential of characteristic towns as catalysts for agricultural and rural modernization and the high-quality development of the county economy.

They can attract valuable resources to flow into rural and county areas, entice exceptional talents to contribute to agricultural and rural modernization and the economic growth of the county, promote scientific and technological innovation and the establishment of emerging industries, and align these efforts with the unique characteristics of the region where the towns are situated. In order to enhance productivity, regions that are imbalanced or on the brink of imbalance should take inspiration from regions that have achieved a high level of coupling and coordination. They should deviate from their current development trajectory and expedite the establishment of a core industry in their towns. Additionally, they should facilitate the creation of high-tech industrial clusters within the county and fully utilize the county's potential as a pivotal point. We will expedite the advancement of county economy and hasten the modernization of agricultural and rural areas to reach a higher level.

Author Contributions

Conceptualization, F.Y. and S.Z.; methodology, Z.S.; software, W.L.; validation, F.Y. and S.Z.; formal analysis, S.Z..; investigation, F.Y. and Z.S.; resources, F.Y. and Z.S.; data curation, F.Y. and S.Z.; writing-original draft preparation, F.Y.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data will be made available on request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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