Regional Differences and Driving Factors of Coupled Coordinated Development of Digital Economy and Rural Revitalization

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Abstract. Based on the panel data of 11 provinces (municipalities) in the Yangtze River Economic Belt from 2011 to 2021, the coupled coordination degree of digital economy and rural revitalization was measured by entropy method and coupled coordination degree model. The difference of regional coupling coordination was studied by Dagum Gini coefficient decomposition, and the driving factors of the development of the two coupling coordination were studied by grey relational degree model. It is found that as time goes by, the stage of coupled and coordinated development of the Yangtze River Economic Belt continues to improve. In 2011, most areas are still in the stage of serious imbalance, and by 2021, there will be no areas in the stage of imbalance. The gap between the river basins is the main reason for the uncoordinated coupling development of the Yangtze River Economic Belt. The influence of each driving factor on the coupling coordination degree is spatially different, and the correlation degree of each driving factor is government regulation, industrial structure, innovation drive, economic drive and human capital in order from large to small.

Keywords: Yangtze River Economic Belt; Digital economy; Rural revitalization; Coupling coordination

1 Introduction

China's rural areas have developed in tandem with other national undertakings and achieved historic achievements, especially after the 18th National Congress, the agricultural harvest has been achieved every year, the rural society has become more harmonious and stable, and the income of rural residents has continued to increase[1]. After China achieves comprehensive poverty alleviation in 2020, promoting the rural revitalization strategy has become a major task at present. The Yangtze River Economic Belt（YEB）is one of the "three strategies" implemented by the central government. Based on this, the paper firstly explains the coupled and coordinated development of digital economy and rural revitalization in theory; secondly, it takes 11 provinces (municipalities) of the YEB as the research object, constructs the coupled coordination degree model of digital economy and rural revitalization, and quantitatively analyzes the dynamic evolution process, regional differences and driving factors of the coupled and coordinated development.

Literature reviews related to the topics are divided into three categories: First, the connotation of the integration of digital economy and rural revitalization. Rural revitalization emphasizes

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the comprehensive improvement of rural economy, society and environment, and the digital economy plays a significant supporting role. The integration of digital economy with rural revitalization not only involves precision agriculture and the digital upgrading of rural industries, but also includes the application of digital technology in rural governance, ecological protection and cultural inheritance. Second, opportunities. Scholars consider that the digital economy has brought great opportunities for rural revitalization. First of all, the application of digital technology in agriculture, such as precision agriculture and intelligent farming, has improved agricultural efficiency and output, and helped rural industrial upgrading. Secondly, digitalization expands the development space of rural economy, such as rural e-commerce, rural finance and other emerging business forms, creating more employment and income opportunities for farmers. In addition, digital technology can also promote the convenience of rural social services. Thirdly, there are some challenges. The imbalance of digital infrastructure may lead to digital divide, and some remote villages may not be able to fully enjoy the benefits of the digital economy. Additionally, the issues of data security and privacy protection brought about by digitalization need to be effectively solved.

2 Index system construction and measurement method

2.1 Index system construction

Based on the scientific, complete and accessible aspects, and referring to relevant studies by Hu Honda et al.[2]. Paper constructs a digital economy index system including infrastructure, digital industrialization, industrial digitalization and external conditions. When constructing the index system of rural revitalization, referring to Lu Fengying et al.[3], rural revitalization is divided into five secondary indicators, namely, industrial prosperity, ecological livability, rural style civilization, effective governance and prosperity. As shown in Table 1. The data in this paper are mainly from China various Statistical Yearbook. Among them, the Peking University Digital Financial Inclusion Index comes from the Peking University Digital Finance Research Center. For the missing data of some years, interpolation method is used instead.

Table 1 Rural revitalization and digital economy coupling coordination index system

Primary index	Secondary index	Level 3 indicators/units
Rural revitalization	Prosperous industry	Total power of agricultural machinery per capita/(kW/person)
		Labor productivity/(Yuan/person)
		Land productivity/(Yuan/mu)
	Ecological habitability	Green coverage rate /%
		Fertilizer application per hectare of cultivated land/(tons/hectare)
		Average number of health technicians per 1000 people/(persons / 1000)
	Rural culture	Full-time primary school teachers with bachelor degree or above /%
		Per capita cultural and entertainment consumption expenditure/(Yuan/person)

		Number of cultural activity places in towns and villages per 10,000 people/(per 10,000)
	Effective governance	Number of residents receiving minimum living allowance /%
		Rural and urban income ratio/(rural =1) /%
		Number of village committees per 10,000 inhabitants/(number / 10,000)
	Be well off	Resident Engel coefficient /%
		Per capita residential floor area/(square meters)
		Per capita consumption expenditure/yuan
	infrastructure	Cell phone base station density /%
		Optical cable density /%
Digital economy	Digital industrialization	Telecom business volume per capita/(100 million yuan / 10,000 people)
		Employment in information industry /%
	Industrial digitization	E-commerce sales / 100 million yuan
		BeiJing University Digital Financial Inclusion Index
	External environment	R&D investment intensity /%

2.2 Measurement method

Before calculating the coupling coordination degree of digital economy and rural revitalization, it is necessary to determine the weight of each index. The entropy method is a relatively objective method, and can effectively eliminate the deviation caused by some subjective factors. Therefore, referring to the research method of Yang Yujing[4], this paper selects the entropy method of adding time variables to calculate the weights of indicators, and then calculates the comprehensive development indexes, and builds the coupling coordination degree model.

$$C = \sqrt{\frac{U_1 U_2}{\left(\frac{U_1 + U_2}{2}\right)^2}} \tag{1}$$

$$T = \lambda_1 U_1 + \lambda_2 U_2, D = \sqrt{CT} \tag{2}$$

Where, U_1 and U_2 are the digital economy and rural revitalization development indexes respectively, C is the coupling degree, T is the comprehensive development index of the two subsystems, and D is the coupling coordination degree. In both subsystems, λ_1 and λ_2 are usually equal to 0.5.

3 Empirical analysis

The Dagum Gini coefficient decomposition, introduced by Dagum in 1997, is employed to analyze the differences in coordinated development both within and among basins[5]. This study employs the Dagum Gini coefficient and its decomposition to assess regional disparities

in the coupling coordination between the digital economy and rural revitalization, analyzing the sources of these differences. The specific formula for the Dagum Gini coefficient is:

$$G = \frac{\sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{n_j}\sum_{r=1}^{n_h}\left|Y_{ji} - Y_{hr}\right|}{2n^2\overline{Y}} \tag{3}$$

$$G_{jj} = \frac{\frac{1}{2\overline{Y}_j}\sum_{i=1}^{n_j}\sum_{r=1}^{n_h}\left|Y_{ji} - Y_{hr}\right|}{n_j^{\,2}} \tag{4}$$

$$G_w = \sum_{j=1}^{k} G_{jj} p_j s_j ; G_{jh} = \frac{\sum_{i=1}^{n_j}\sum_{r=1}^{n_h}\left|Y_{ji} - Y_{hr}\right|}{n_j n_h\left(\overline{Y}_j + \overline{Y}_h\right)} ; G_{nb} = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}\left(p_j s_h + p_h s_j\right) D_{jh} \tag{5}$$

Where, G is the overall Gini coefficient, the Gini coefficient of the region j within G_{jj} and G_w subgroups, and the contribution degree of the Gini coefficient within subgroups. G_{jh} and G_{nb} represent the contribution of the Gini coefficient between region j and region h and the net difference between subgroups to the overall Gini coefficient. $p_j = n_j / n$ 、$s_j = n_j \overline{y}_j / n\overline{y}$, D_{jh} represents the relative impact of the coupling coordination of digital economy and rural revitalization between regions j and h . k represents the number of regions divided, n represents the number of all provinces, $Y_{ji}\left(Y_{hr}\right)$ represents the index level of $i(r)$ provinces in $j(h)$ region, $n_j\left(n_h\right)$ represents the number of provinces in $j(h)$ region, and $\overline{Y}$ represents the average of the coupling coordination degree of digital economy and rural revitalization in all provinces.

$$G_t = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}\left(p_j s_h + p_h s_j\right)\left(1 - D_{jh}\right) \tag{6}$$

$$D_{jh} = \frac{d_{jh} - p_{jh}}{d_{jh} + p_{jh}} \tag{7}$$

$$d_{jh} = \int_0^{\infty} dF_j(y)\int_0^{\infty}(y - x)\,dF_h(y) \tag{8}$$

$$p_{jh} = \int_0^{\infty} dF_h(y)\int_0^{\infty}(y - x)\,dF_j(y) \tag{9}$$

$$G = G_w + G_{nb} + G_t \tag{10}$$

Where, G_t is the supervariable density contribution, $1 - D_{jh}$ is the supervariable density, and $F_j\left(F_h\right)$ represents the distribution function of $j(h)$ in the region.

3.1 Coupling coordination development difference

Table 2 displays the Dagum Gini coefficients for the YEB between 2011 and 2021.

Although the downstream area's Gini coefficient shows a decreasing trend, it remains high, highlighting a significant developmental gap. In contrast, Anhui lags behind regions like Jiangsu, Zhejiang, and Shanghai, where more advanced rural infrastructure and greater integration of the digital economy with rural revitalization contribute to higher levels of coupled development. Meanwhile, the developmental disparity in the middle reaches is smaller, with the Gini coefficient falling to 0.011 in 2021. The upstream region experienced the most substantial reduction, with its Gini coefficient decreasing from 0.128 to 0.022, the largest decline among all basins.

In general, with the passage of time, the coordinated development gap between different regions has an obvious decreasing trend, and the level of coupled coordinated development is gradually moving closer to the high-level regions, but due to the different geographical locations and resource advantages, the differences in some regions are still obvious.

Table 2 Gini coefficient values of the YEB during 2011-2020

year	upstream	Middle reaches	downstream	YEB
2011	0.128	0.067	0.106	0.172
2012	0.100	0.029	0.093	0.141
2013	0.082	0.028	0.088	0.122
2014	0.069	0.026	0.087	0.113
2015	0.059	0.025	0.084	0.103
2016	0.061	0.026	0.081	0.103
2017	0.049	0.020	0.075	0.090
2018	0.038	0.017	0.069	0.080
2019	0.027	0.015	0.065	0.071
2020	0.022	0.011	0.058	0.063
2021	0.030	0.011	0.058	0.065

3.2 The source of regional disparity in coupled and coordinated development

Table 3 presents the contribution values and rates of disparities within and among basins from 2011 to 2021, indicating a general downward trend in disparities across the YEB. The internal basin disparity peaked at 0.036 in 2011, dropping to 0.013 by 2021, with a temporary rise only in that year. Inter-basin differences also decreased, from a high of 0.123 in 2011 to a low of 0.048 in 2020. Over time, the gaps in coupled and coordinated development both within and between basins have consistently narrowed.

The contribution rate between basins has slightly fluctuated, from 20.812% in 2011 to 20.224% in 2021, consistently around 20%. Meanwhile, contribution rates within basins consistently exceed 70%, representing the majority of the total difference. Thus, minimizing disparities between river basins is crucial for enhancing the coupled and coordinated development of the digital economy and rural revitalization in the YEB.

Table 3 Decomposition of contribution rate of the coordinated development level gap in the YEB from 2011 to 2021

year	Total variance	Within the basin		interbasin	
		Contribution value	Contribution rate /%	Contribution value	Contribution rate /%
2011	0.172	0.036	20.812	0.123	71.448
2012	0.141	0.028	19.807	0.108	75.996
2013	0.122	0.025	20.571	0.090	74.018
2014	0.113	0.023	20.794	0.084	74.875
2015	0.103	0.022	20.960	0.076	73.485
2016	0.103	0.021	20.771	0.076	73.772
2017	0.090	0.019	20.752	0.066	73.404
2018	0.080	0.016	20.344	0.058	73.270
2019	0.071	0.014	19.939	0.052	74.337
2020	0.063	0.012	19.328	0.048	76.618
2021	0.065	0.013	20.224	0.049	75.558

3.3 Dynamic factor analysis

Given that multiple factors may influence the coupled and coordinated development of the digital economy and rural revitalization, in order to explore the impact of each driving factor, this paper uses the grey correlation degree model to explore the driving factors of coupled and coordinated development. Compared with regression analysis, grey correlation analysis can ignore the number of sample sizes and is also applicable when the sample size is small, while avoiding abnormal results. See Reference[6] for specific calculation steps of grey correlation analysis.

When selecting driving factor variables, five driving factor variables were selected with reference to the research results of He Leihua et al.[7]. They are: economic drive, human capital, industrial structure, government regulation and innovation drive.

Table 4 shows the correlation degree of economic drive, human capital, industrial structure, government regulation, innovation drive and coupled coordinated development. From the perspective of correlation value, the order from the largest to the smallest is government regulation > industrial structure > innovation-driven > economic driven > human capital.

Table 4 displays the correlation degrees between economic drive, human capital, industrial structure, government regulation, innovation drive, and coupled coordinated development, ranking from highest to lowest as government regulation, industrial structure, innovation drive, economic drive, and human capital. Government regulation is crucial for optimizing the utilization of social resources and driving the integrated development of the digital economy and rural revitalization. Numerically, its impact is greatest in the downstream areas, followed by the middle reaches and least in the upstream, possibly due to the lower economic and social development levels of the upstream compared to the downstream coastal regions.

Upgrading the industrial structure, guided by agriculture and high-tech industries, accelerates the modernization of rural industries, enhances the integration of the digital economy with rural revitalization, and promotes their coupled development. The results indicate that

industrial structure is a strong driver, second only to government regulation, in influencing the level of coupled and coordinated development. However, its impact is least effective in the upstream region, with a coordination degree of 0.683, likely due to its relatively underdeveloped industrial base and less diverse industry types compared to the middle and lower reaches.

Table 4 Correlation degree of coupling coordination driving factors

district	Industrial structure	Economic drive	Human capital	Government regulation	innovation-driven
Shanghai	0.637	0.590	0.536	0.664	0.598
Jiangsu	0.843	0.581	0.566	0.582	0.603
Zhejiang	0.863	0.549	0.548	0.715	0.625
Anhui	0.827	0.605	0.646	0.598	0.664
Jiangxi	0.639	0.519	0.580	0.561	0.549
Hubei	0.814	0.590	0.589	0.627	0.618
Hunan	0.841	0.582	0.658	0.619	0.620
Chongqing	0.830	0.638	0.757	0.585	0.668
Sichuan	0.726	0.576	0.693	0.586	0.614
Guizhou	0.561	0.614	0.711	0.560	0.607
Yunnan	0.615	0.587	0.670	0.572	0.590
upstream	0.683	0.604	0.708	0.576	0.620
Middle reaches	0.765	0.564	0.609	0.602	0.596
downstream	0.792	0.581	0.574	0.640	0.623
YEB	0.637	0.590	0.536	0.664	0.598

Innovation ranks third as a driver. Essential for the advancement of both, innovation provides a continuous boost and accelerates digital transformation. It significantly enhances the rural ecological environment by reducing industrial waste emissions and boosts rural incomes through improved labor and production efficiency. Furthermore, innovation is critical for integrating and advancing the coupled development of both. However, the impact of economic and human capital drivers is relatively weak, especially in the downstream and midstream areas where a significant developmental gap exists compared to urban regions, and where rural areas suffer from a lack of high-level talent, diminishing the effectiveness of these drivers.

4 Conclusion

Analyzing 11 provinces along the YEB from 2011 to 2021, this study constructs a model to assess the coupling coordination degree. It explores regional differences using Gini coefficient decomposition and identifies driving factors through a grey relational degree model. The main conclusions are as follows:

Firstly, over time, the coupled and coordinated development of both in the YEB has continuously improved, notably accelerating since 2017 and entering a new phase. Secondly, the contribution rate of inter-basin differences consistently exceeds 70%, with these gaps being the primary source of uncoordination across the region. Thirdly, in analyzing the drivers

of this development, government regulation emerges as the most significant, followed by industrial structure and innovation, while the influence of human capital and economic drive remains limited.

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