A study on the measurement of coupled and coordinated development: Based on the rural digital economy and rural revitalization of Sichuan Province

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Abstract: The development of rural digital economy is an inevitable choice in promoting rural revitalization, as it complements and promotes each other. This article is based on the data of rural digital economy and rural revitalization in Sichuan Province from 2012 to 2021. It establishes an evaluation index system for the coordinated development of rural digital economy and rural revitalization, and conducts measurement research on their coupling coordination. In addition, the obstacle degree model is used to identify key obstacles. The research results show that the level of rural digital economy and rural revitalization in Sichuan Province has been continuously improving, with stable coupling degree. The coordination degree and coupling coordination degree have shown a steady growth trend. However, there are still some key obstacles, such as insufficient sharing of open data, lagging information network infrastructure, low digital literacy of rural residents, and inadequate application of new generation information technologies. Based on the above research results, this article proposes several policy recommendations. In the future, it is necessary to pay full attention to the construction of smart villages, cultivate and strengthen the team of rural digital talents, efficiently promote the prosperity of industries, and expand the application scenarios of digital villages. Additionally, it is important to break down data silos and system barriers, and accelerate the modernization of agriculture and rural areas. This article provides important empirical evidence and decision support for promoting the coordinated development of rural digital economy and rural revitalization in Sichuan Province.

1. Introduction

The role of the digital economy in rural revitalization has garnered significant attention. Since the 19th National Congress of the Communist Party of China introduced the strategy of rural revitalization emphasizing "prosperous industries, pleasant ecology, civilized rural areas, effective governance, and improved living standards", the government has implemented a series of policies to

promote digital economic development[1]. Starting from the issuance of the Central No. 1 Document in 2018, which outlined digital rural development, to the launch of the "Digital Agriculture and Rural Development Plan (2019-2025)", the digital economy has emerged as a crucial force bolstering rural revitalization. Its comprehensive coverage and convenience have positioned it as an engine and driving force for rural development[2]. Concurrently, rural revitalization has provided avenues for digital economic growth, such as rural digital governance, industrial digitization, and the development of digital infrastructure[3].

With the proliferation of technologies like blockchain and artificial intelligence, the role of the digital economy in fostering steady national economic growth and activating rural revitalization has become a focal point of interest. Research indicates the affirmative impact of rural digital economy on revitalization. Firstly, it has increased residents' income, stimulated household consumption, and enhanced efficiency in poverty alleviation efforts and entrepreneurial vitality[1]. Secondly, the application of digital technology in modern agriculture has facilitated precise data collection, resulting in refined agricultural production management and heightened efficiency[4]. Additionally, the rural digital economy has empowered farmers in the industrial chain, elevating their decision-making participation[5]. Lastly, the digital economy has widened avenues for students to access knowledge and fostered balance in urban-rural education and healthcare resources, providing convenient services for poverty alleviation and public services, thereby promoting balanced urban-rural development[6].

Based on extensive research on relevant literature, it is evident that the development of rural digital economies is an imperative requirement for constructing Digital China, revitalizing rural areas, and implementing sustainable development strategies. Data relevant to this paper is sourced from publications including the 'China Statistical Yearbook', 'Sichuan Statistical Yearbook', 'China Rural Statistical Yearbook', 'Sichuan Agricultural Statistical Yearbook', 'National Broadcasting and Television Industry Statistical Bulletin', as well as statistics from the Ministry of Industry and Information Technology, among others. In instances of missing data, linear interpolation methods were utilized for supplementation. The study will base its analysis on data spanning from 2013 to 2022, establishing a comprehensive evaluation indicator system for rural digital economy and rural revitalization based on data from 2012 to 2021. The study will establish models for comprehensive evaluation, coupling coordination, and obstacle assessment to measure the coupled and coordinated development of rural digital economy and rural revitalization in Sichuan Province. Modeling and solving will be conducted using the R software, followed by in-depth analysis of the conclusions drawn, and ultimately, the formulation of policy recommendations.

2. The evaluation index system of rural digital economy and rural revitalization system

2.1. The interactive mechanism of rural digital economy and rural revitalization

Rural Digital Economy and Rural Revitalization collectively serve the vulnerable populations in rural areas, achieving poverty alleviation, prosperity, and increased income. The goals of both are highly aligned, naturally forming a mutual relationship[4]. Currently, the new generation of digital technologies is rapidly penetrating the agricultural and rural sectors, providing a golden opportunity for digitally enhancing rural revitalization. The deep integration of digital technology into rural areas propels scientific production, transparent governance, intelligent living, and convenient services, thereby aiding prosperous industries, ecological livability, cultural refinement, effective governance, and affluence in rural life. Simultaneously, rural revitalization offers a developmental stage for the infrastructure of rural digital economy, governance level, industrial digitization, and digital industrialization. The interactive and synergistic development paths and mechanisms of rural digital economy and rural revitalization are illustrated in Figure 1.
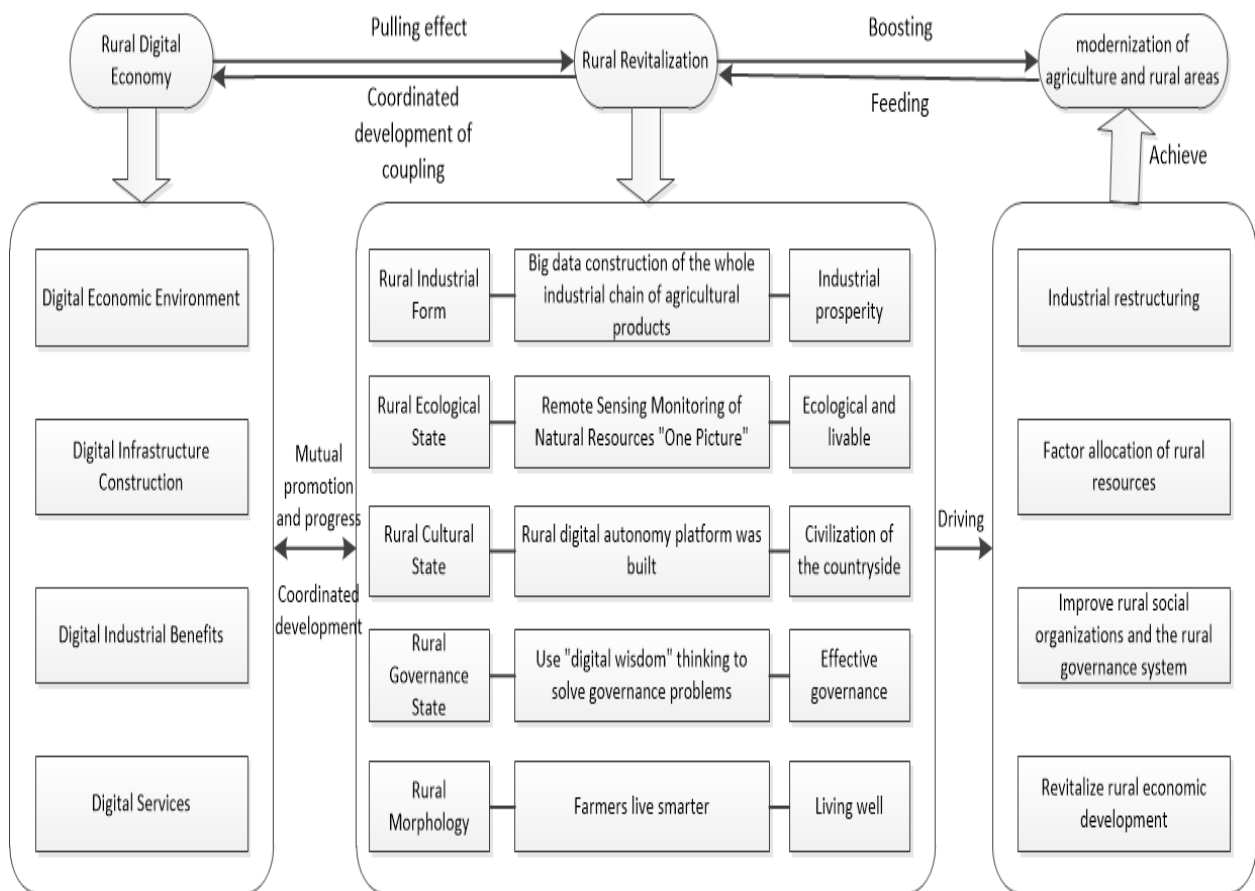
Figure 1: Coupling relationship between Rural Digital Economy and Rural Revitalization

2.2. The evaluation index system of rural digital economy and rural revitalization system

Constructing a rational and scientific evaluation indicator system serves as the foundation for analyzing the relationship between rural digital economy and rural revitalization. The comprehensive promotion of rural revitalization is the current strategic task for the 'Three Rural' work, essentially reflecting the dynamic equilibrium between rural productivity and production relations[7]. The mission of rural digital economy lies in fully utilizing digital technology to achieve digitization of governance, services, and applications, thereby enhancing the intrinsic dynamics of 'Three Rural' development. Building upon the interaction between rural digital economy and rural revitalization and referring to previous research outcomes[7], guided by principles of scientific rigor, systematicity, and operability, this paper establishes an evaluation indicator system for rural digital economy and rural revitalization. The evaluation dimensions for digital rural areas include 'Digital Economic Environment', 'Digital Infrastructure Construction', 'Digital Industrial Benefits', and 'Digital Services'; while those for rural revitalization encompass 'Rural Industrial Form', 'Rural Ecological State', 'Rural Cultural State', 'Rural Governance State', and 'Rural Morphology' (refer to Table 1).

The selection of specific indicators draws upon relevant indicators in documents such as the 'National Rural Revitalization Strategy Plan (2018-2022)', 'Digital Agriculture and Rural Development Plan (2019-2025)', and 'China Digital Rural Development Report (2020)[8]. Using a comprehensive measurement approach that combines ratio indicators, aggregate indicators, average indicators, and structural indicators, a comprehensive assessment of the level of digital rural areas and rural revitalization is conducted.

Table 1: Evaluation index system of rural digital economy and rural revitalization system

Subsystems	Primary indicators	Secondary indicators (Positive or Negative)	Measure Units	Weights
Rural digital economy	Digital Economic environment	Rural postal rates(+)	%	0.027
		Farmers' digital literacy(+)	year	0.075
		Electricity consumption per capita in rural areas(+)	kwh / person	0.054
		Investment in digital construction(+)	100 million yuan	0.067
		Digital talent ownership(+)	10,000 persons	0.024
	Digital Infrastructure Construction	Internet penetration rate(+)	%	0.064
		Proportion of rural fixed telephone users(+)	%	0.068
		Mobile phone penetration rate(+)	%	0.045
		Number of agrometeorological observation stations(+)	unit	0.020
	Digital Industrial Benefits	Rural digitalization scale(+)	100 million yuan	0.067
		Investment in agricultural production(+)	100 million yuan	0.060
		Total Agricultural Machinery Power(+)	10,000 kw	0.034
	Digital Services	Farmers' digital service consumption level(+)	yuan / person	0.046
		Rural network payment level(+)		0.039
		Development level of rural logistics(+)	10,000 units	0.071
		Level of rural e-commerce development(+)	100 million yuan	0.063
		Level of online education in rural areas(+)	10,000 yuan	0.174
Rural revitalization	Industrial prosperity	Grain yield per mu(+)	t/hm^2	0.045
		Fertilizer application rate per unit cultivated land area(-)	t/hm^2	0.179
		Total value of agriculture, forestry, animal husbandry and fishery per capita(+)	yuan / person	0.080
		Proportion of rural employees(-)	%	0.055
	Ecological and livable	Number of beds in health centers per 10,000 people(+)	unit	0.066
		Per capita residential area owned in rural areas(+)	m^2 /person	0.032
		Forest resource coverage rate(+)	%	0.084
	Civilization of the countryside	Proportion of rural residents' expenditure on education, culture and entertainment(+)	%	0.055
		Number of township cultural stations per 10,000 people(+)	unit	0.050
	Effective governance	Number of units per 10,000 villagers' neighborhood committees(+)	unit	0.044
		Spending on social security and employment as a share of GDP(+)	%	0.040
		Public security spending as a share of GDP(+)	%	0.037
	Living well	Rural per capita disposable income(+)	yuan	0.061
		Rural per capita consumption expenditure(+)	yuan	0.058
		Engel's coefficient for rural residents(-)	%	0.034
		Per capita highway mileage(+)	m	0.080

Note: The indicators are referenced from the '14th Five-Year National Plan for Agricultural and Rural Informatization Development', 'Digital Agriculture and Rural Development Plan 2019-2025', and the 'National Quality-Driven Agriculture Revitalization Strategy Plan (2018-2022)'.

2.3. Research methodology

2.3.1. Comprehensive evaluation model of rural digital economy and rural revitalization

$$f(x) = \sum_{j=1}^{n} w_j x'_{ij}, \quad g(y) = \sum_{j=1}^{n} w_j y'_{ij}$$

(1)

In equation (1), $f(x)$ and $g(y)$ represent the comprehensive evaluation functions of rural digital economy and rural revitalization respectively, where w_j stands for the weight of each indicator in the category system, and x'_{ij} and y'_{ij} denote the normalized values of respective indicators. The indicator weights are determined using the entropy method, based on the magnitude of information entropy to ascertain the weights within the system.

2.3.2. Coupling coordination degree model

$$C = \frac{\sqrt{4f(x)g(y)}}{f(x) + g(y)}$$

(2)

In equation (2), C represents the coupling degree, where a value closer to 0 indicates a weaker coupling between the two systems. Based on equation (2) and existing research, this paper establishes the following model to illustrate the coordinated development of rural areas in different periods in Sichuan Province.

$$T = \lambda f(x) + \mu g(y)$$

(3)

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

(4)

In equations (3) and (4), T represents the comprehensive coordination index of rural digital economy and rural revitalization, which reflects the degree of coordination between the two. D denotes the coupling coordination. λ and μ are undetermined coefficients, where $\lambda + \mu = 1$. Considering the equal importance of rural digital economy and rural revitalization, this paper sets $\lambda = \mu = 0.5$. As there is currently no consensus on the classification criteria for coupling degree and coupling coordination in the academic community, this paper, based on relevant literature and considering the actual situation of rural development, divides the coupling coordination of rural digital economy and rural revitalization into five stages (refer to Table 2).

Table 2: Classification of coupling and coordinated development types

Classification standard	Stages
$D \in [0, 0.4]$	Severe misalignment recession
$D \in [0.4, 0.5]$	Mildly disordered recession
$D \in [0.5, 0.6]$	Barely coordinated development
$D \in [0.6, 0.8]$	Sound and coordinated development
$D \in (0.8, 1]$	Highly coordinated development

2.3.3. Obstacle degree model

Based on the coupling coordination of rural digital economy and rural revitalization, this paper

introduces the Barrier Degree Model to perform a pathological diagnosis of the main obstacles to the coordinated development of the two systems. The Barrier Degree Model is a mathematical model used to statistically calculate obstacles to the development of things[8]. By calculating the contribution and deviation of each indicator factor in the evaluation indicator system, the model identifies the barrier degree of unidirectional indicators to the overall evaluation goal[2]. This provides theoretical guidance for adopting targeted measures based on local conditions in various regions.

$$d_{ij} = 1 - x'_{ij} \tag{5}$$

$$O_{ij} = \frac{d_{ij} w_j}{\sum_{j=1}^{n} d_{ij} w_j}, S_i = \sum_{j=1}^{n} O_{ij} \tag{6}$$

In equations (5) and (6), d_{ij} represents the indicator deviation of the j th indicator in the i th year, while O_{ij} signifies the barrier degree of the j th indicator in the i th year. A higher value of O_{ij} indicates a stronger constraint of that indicator factor on the coordinated development of rural digital economy and rural revitalization in Sichuan Province. A larger O_{ij} value further establishes the relative significance of the corresponding obstacle factors. S_i represents the barrier degree at the subsystem level.

3. Result and analysis

3.1. Analysis on the development level of rural digital economy and rural revitalization in Sichuan Province

Based on the previously constructed evaluation index system and calculation formulas, we have obtained data on the development levels of rural digital economy and rural revitalization in Sichuan Province from 2012 to 2021 (Figures 2 and Figures 3). From the evolution of the time series, various aspects of Sichuan Province's rural digital economy, including its digital economic environment, digital infrastructure construction, digital industrial benefits, and digital services, show a trend of fluctuating growth, with similar directions of change. The level of rural digital economy has demonstrated a rapid upward trend under the comprehensive influence of various systems. This upward trend indicates that the construction of digital rural areas in Sichuan Province is continually expanding as the application of networking, informatization, and digitization in rural economic and social development continues to grow, with increasing depth and breadth.

Simultaneously, benefiting from the active implementation of the rural revitalization strategy, the implementation of a series of policies aimed at benefiting and enriching rural areas, and the continuous intensification of poverty alleviation efforts, the overall level of rural revitalization has shown a sustained upward trend. Various aspects of rural development, including the revitalization of industries, rural forms, cultural characteristics, ecological preservation, and effective governance, have experienced diversified integration.
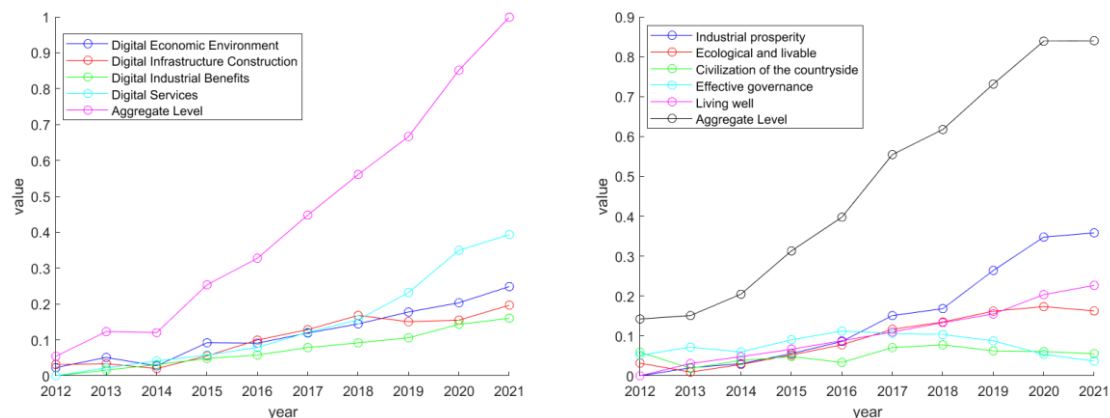
Figure 2: Development level of rural digital economy in Sichuan Province from 2012 to 2021 (Left)
Figure 3: Development level of rural revitalization in Sichuan Province from 2012 to 2021 (Right)

3.2. Characteristics of coupling and coordinated development of rural digital economy and rural revitalization in Sichuan Province

Using the coupling coordination model, we have revealed the state of coordinated development between rural digital economy and rural revitalization in Sichuan Province (Figure 4). During the period from 2012 to 2021, these two systems exhibited a high degree of coupling, yet their coordination has been steadily improving. This indicates a continuous exploration of their coupling degree and ongoing efforts to infuse vitality into rural areas through digitization, benefiting rural communities.
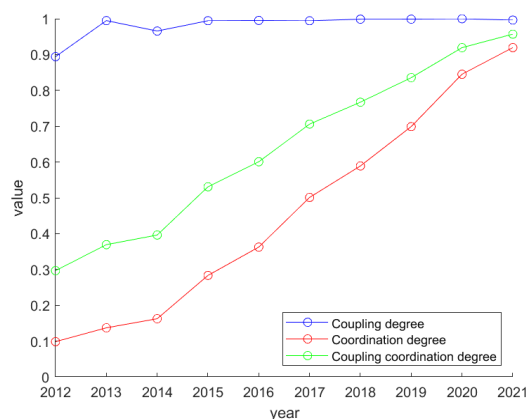

Figure 4: Coupling and coordinated development characteristics of rural digital economy and rural revitalization in Sichuan Province from 2012 to 2021

3.3. Analysis of the influence mechanism of coupled and coordinated development

For achieving high-quality coordinated coupling between the rural digital economy and rural revitalization in Sichuan Province, it is not only necessary to have strategic planning and top-level design from the national and provincial governments, but also to identify the obstacles that arise during the coupling process between the two systems. This identification is crucial for providing targeted solutions. To address this, the article utilizes the barrier degree model to diagnose and rank the obstacles in the coordinated development of rural digital economy and rural revitalization in Sichuan Province.

From a temporal perspective, the ranking of obstacle degrees for primary indicators from highest to lowest during the period 2012-2022 is as follows: digital services, industrial prosperity, digital economic environment, affluent living, effective governance, rural cultural development, digital infrastructure construction, livable ecology, and digital industry benefits. The average obstacle degrees are: 20.94%, 16.45%, 11.24%, 10.99%, 9.59%, 8.11%, 7.98%, 7.51%, and 7.18%, respectively. This result shows relatively small differences among different years within the observation period.

4. Conclusions and policy recommendations

4.1. Conclusions

This study constructed an evaluation index system for assessing the coupling coordination of rural digital economy and rural revitalization. By employing the coupling coordination model and the obstacle degree model, we analyzed the development status and key influencing factors between the years 2012 and 2021 in Sichuan Province regarding the rural digital economy and rural revitalization. The research findings indicate that the levels of rural digital economy and rural revitalization in Sichuan Province have continuously improved, and the coupling coordination index has shown a steady growth trend over time. However, the development of the digital economy still faces obstacles such as inadequate data openness and sharing, lagging information network infrastructure, low digital literacy among rural residents, and insufficient popularization of new-generation information technology applications. Factors such as online education levels in rural areas, the proportion of rural public safety expenditures in GDP, Engel coefficient for rural residents, and per capita rural road mileage play a significant role in promoting the development of coupling coordination.

In the face of a new stage and starting point, considering the provincial conditions and regional characteristics of Sichuan Province, it is important to follow the evolution of digital information technology and the development trends of the digital economy. This will help inject vitality into the rural revitalization strategy by promoting rural digital economy, addressing digital governance weaknesses, and leveraging new technologies, new scenarios, and new rural individuals to support and serve rural revitalization. It's necessary to establish a comprehensive and interconnected rural digital governance system covering the entire region, promoting the comprehensive revitalization of rural industries, forms, culture, ecology, and governance. In light of this, we propose four policy recommendations to enhance the coordinated development of rural digital economy and rural revitalization.

4.2. Policy recommendations

Firstly, we should persist in the construction of smart rural areas and advance the digitization of infrastructure. A comprehensive plan should be formulated to enhance the development level of rural digital economy. In key areas, policy adjustments should be made to optimize fiscal investment in rural digital economy, with special attention to the construction of digital infrastructure in Sichuan Province. On one hand, governments should promote the digital upgrade of traditional infrastructure. On the other hand, they should actively promote the development of new types of infrastructure such as the internet and mobile communications.

Secondly, based on the actual conditions of rural areas, implement regionally coordinated integrated development. Considering the complex topography and diverse climate in Sichuan Province, practical exploration is needed for issues such as comprehensive governance of human habitats, rural planning and construction, rural governance, and rural industrial layout. For instance,

customized digital training programs can be formulated to address varying levels of digital literacy in different rural areas. Through cultural stations in rural areas, mobile learning platforms, and other means, targeted digital education can be provided to rural residents to enhance their digital skills. Moreover, customized rural digital innovation demonstration zones can be established based on the regional characteristics of Sichuan Province to play a leading role.

Thirdly, promote industrial prosperity efficiently and achieve the systematization of agricultural industry operation. In the process of comprehensively promoting rural revitalization, it is essential to focus on key areas and solve the coordination challenges between rural digital economy and rural revitalization, with particular attention to industrial prosperity. Through innovation driven by the digital economy and technological empowerment, the government should promote high-quality development of rural industries. It should apply digital technology to agricultural production, support the cultivation of deep-processed agricultural products, and introduce influential agricultural processing enterprises. Additionally, the government should facilitate the transformation of digital technology into agricultural productivity, stimulate endogenous driving forces in agricultural production, optimize the agricultural industry structure, and achieve reasonable allocation of production factors in rural areas through the digital economy. This will establish close connections between industries and drive the systematization of agricultural industry operation.

Lastly, emphasize the cultivation of digital talents. Local governments should develop specialized talent support plans focusing on digital technology. They should establish relevant courses and majors related to artificial intelligence, the Internet of Things, big data services, and e-commerce in local universities and vocational colleges. Furthermore, they should encourage cooperation between research institutions, training institutions, e-commerce companies, and others to explore joint training models and conduct qualifications certification for related talents.

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