

## Article

# The Digital Economy Promotes Rural Revitalization: An Empirical Analysis of Xinjiang in China

Lin Zhu, Xuehui Mei \*  and Zhengqing Xiao

College of Mathematics and System Science, Xinjiang University, Urumqi 830046, China

\* Correspondence: meixuehui163@163.com

**Abstract:** The digital economy now plays a pivotal role in reshaping the global economic structure and optimizing the allocation of resources. With the popularization of digital technology in rural areas, the impact of the digital economy on rural development is also increasing. In order to explore the impact of the digital economy on rural revitalization in Xinjiang of China, this study constructed an indicator system based on the data from 14 prefectures or cities (of the same administrative level as the prefectures) in Xinjiang from 2013 to 2019. The entropy weight method and coupling coordination degree (CCD) model were used to analyze the digital economy level (DEL) and rural revitalization level (RRL) in Xinjiang, and the relationship between the digital economy and rural revitalization was emphasized. Finally, the obstacle degree model was used to reveal the factors that hinder the coupled and coordinated development between the digital economy and rural revitalization. The research shows that: (1) Xinjiang's DEL generally increased steadily, and digital economy development in 14 prefectures or cities had strong spatial heterogeneity. At the same time, Xinjiang's RRL showed similar characteristics. (2) The CCD between the two systems was increasing, and the regional distribution features of high-level CCD were in northern Xinjiang and low-level CCD in southern Xinjiang. The coupling coordination was in its infancy, but the interaction between the two systems was increasing, and the development prospect was broad. (3) Overall, the main obstacle affecting the CCD between the digital economy and rural revitalization was the digital infrastructure among four factors, including digital investment, thriving businesses, social etiquette and civility, and effective governance. The degree of this obstacle varied in different phases of coupling coordination development.

**Keywords:** digital economy; rural revitalization; regional heterogeneity; coupling coordination degree model; obstacle model



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## 1. Introduction

With a new round of in-depth scientific and technological development, the digital transformation has become the trend of economic development and is advancing constantly on a global scale. The transformation and upgrading of traditional industries into smarter, greener, and more integrated ones are being accelerated. The new industries and new models are flourishing, and production and lifestyles are changing profoundly [1]. Since the 18th National Congress of the CPC, China has made it a national strategy to improve the digital economy level (DEL), issued some major policies, and promoted the building of digital China as a whole. By 2021, China's DEL had reached CNY 45.5 trillion, for a nominal growth rate of 16.2% over the previous year. It accounted for 39.8% of GDP [2]. In addition, as a new form of economic and social development, the digital economy is a key driver of endogenous development dynamics in rural areas, exploring green development potential, promoting the transformation and modernization of rural industries, and improving agricultural and rural modernization [3,4]. In 2021, the Central No.1 Document of China clearly called for comprehensive rural revitalization to implement digital countryside construction projects, and to accelerate agricultural and rural modernization. The 2022 "Digital Rural

Development Action Plan (2022–2025)” pointed out the strategic importance of the digital economy in promoting urban–rural integration, helping the overall revitalization of rural areas, promoting common prosperity, and solving problems of uneven development [5]. These policies and documents reflect the potential and importance of the digital economy to promote rural revitalization, and also show that the research of this paper has theoretical and practical significance. As we all know, developments in digital technology have fostered the interaction between DEL and rural revitalization level (RRL) and promoted a flourishing economy [6]. After the COVID-19 pandemic, when facing the challenge of economic recovery, it was important to explore the evolution of the coupling coordination degree (CCD) between DEL and RRL, and this has become an academic focus.

The digital economy has been a hot topic in academia [7]. Tapscott was the first to conceptualize the digital economy in the 1990s, which he characterized but did not clearly define [8]. In 2016, the G20 Digital Economy Development and Cooperation Initiative clearly pointed out that it is a series of economic activities in which digital knowledge and information are taken as inputs, supported by information networks, and the effective use of ICTs is taken as the driving force for improving efficiency and optimizing economic structure [9]. Presently, the research hotspots in the field of the digital economy are centered on the three phrases of “cloud computing, big data, and artificial intelligence”, which involve employment [10,11], the environment [12–14], productivity [15], economic development [16,17] and other fields [18,19]. The research perspective is complex and broad in scope. The CCD model is an analytical tool used to evaluate and analyze the interrelationships between different elements. Fu et al. [20] used it to analyze the evolutionary characteristics of DEL and ecological environmental level (EEL) in time and space in China. They found that development of the CCD between DEL and EEL was good, and the level was improved. Guo et al. [21] used the composite synergy model to evaluate the degree of coordination between DEL and the logistics industry. Through analysis, it was found that their coordination level has improved. However, synergies need to be further enhanced. Wang et al. [22] discussed how the DEL relates to transforming the low-carbon urban economy and found a U-shaped relationship between them. Zhang et al. [23] examined the implications of DEL for the green economy using the SBM-GML model.

In recent years, the academic community has been widely concerned with rural development, and some scholars have taken a qualitative approach to exploring how the DEL relates to RRL [24,25]. For example, Katara [26] argued that the integration of information and communications technology (ICT) into smart village construction could raise the living standards of farmers and promote the use of mobile technology to make e-government services more accessible to residents in the countryside. Sutherland [27] believed that internet carrier innovation has changed rural consumption patterns, while Young [28] thought that the digital economy empowers agricultural production, rural circulation, social governance, lifestyles, cultural concepts, and other application scenarios by building a virtual space of the “physical world” and “digital world” to achieve comprehensive rural development. Mossberger [29] argued that the increasing popularity of digital technology in economically backward countries created educational and economic opportunities, and that information technology could break down socio-economic activity barriers and reduce poverty. Zhu et al. [30] believed that information technology could promote the total factor productivity of agriculture, and that digital technology could change the mode of agricultural development. Zhao and Ding [31] found that digitization can improve agrarian quality and competitiveness, optimize rural production, living, and ecological space, and improve the urban–rural integration development system and policy system. Feng and Xu [32] noted that the DEL could promote rural infrastructure construction, empower digital agriculture and new rural formats, promote effective governance, and provide further impetus for industrial upgrading.

Through the above scholars’ qualitative research on the DEL and RRL, it can be found that the integration of the digital economy into the countryside can effectively improve the level of rural development. Additionally, Yang theoretically stressed that the digital

economy provides a driving force for rural development and rural areas provide enabling space for the digital economy, and the two can promote each other and integrate each other. However, at present, the research on the coordinated development relationship between the two is still relatively weak, and quantitative regional research is still practically nonexistent. The current quantitative analysis is mainly reflected in the construction of the index system. Based on systematically sorting out the evolution of the internet economy, information economy and digital economy, Xu and Zhang [33] researched China's DEL from 2007 to 2017 by refining the connotations and defining elements of the digital economy. To study China's DEL from 2010 to 2018, Li and Han [34] built an indicator system in terms of digital industrialization and industrial digitization. Regarding measuring RRL, some scholars have conducted preliminary econometric studies using relevant data based on the theory of rural revitalization strategies. Han et al. [35] constructed a rural development indicator system from the perspectives of economy, society, life, ecology, and urban–rural relations, studied the national and regional rural development process from 2011 to 2016, and found that the rural construction of the country, provinces and regions was advancing steadily. Yan and Wu [36] constructed a dynamic indicator system for rural development, assigned weights to each index through principal component analysis and an expert scoring method, and measured the RRL of each province in China. Lu et al. [37] constructed an indicator system focusing on the connotation of the rural revitalization strategy and measured the RRL in each province of China from 2013 to 2019. In addition, Gini coefficients were used to examine regional disparities in RRL in China.

To sum up, the existing literature has reference value for exploring CCD development between DEL and RRL, but there are still some limitations:

- (1) Empirical research on them is still lacking, and their two-way relationship needs to be revealed.
- (2) The two index systems involve many factors and complex data sources. Therefore, it is a complicated problem to formulate an accurate evaluation index system.
- (3) There has been widespread use of CCD models, but few studies in the literature have analyzed possible obstacles to the process of coupling coordination.
- (4) Existing empirical studies focus on a national perspective, ignoring the differences between different regions. As a result, they fail to provide a thorough understanding of the development situation in remote and poor areas from a micro perspective.

In order to make up for these deficiencies, we constructed a comprehensive, measurable and evaluable indicator system based on existing scholarly research with the spatial scale of 14 prefectures or cities in Xinjiang from 2013 to 2019. The entropy weight method and CCD model were adopted to objectively and scientifically reflect the development of DEL and RRL, the CCD, and the trend in spatial and temporal evolution. At the same time, the obstacle degree model was used to analyze the obstacle factors in the process of coupling coordination. It is hoped that this study can enrich the research in the field of the digital economy and fill the gap between DEL and RRL in regional research.

## 2. Research Methods and Data Sources

### 2.1. Research Methods

#### 2.1.1. Entropy Weight Method

Before exploring the CCD, the respective levels of development need to be measured. To ensure that the results are objective and accurate, the entropy weight method is used in this paper. This method determines the weight based on the degree of variation in the values of each indicator. This is an objective method of weighting that avoids the influence of human factors. The specific steps are as follows:

- (1) Data standardization

Data standardization is very important in research, and it can avoid numerical problems and balance the contribution of various characteristics.

For metrics with positive impact:

$$r_{ij} = \frac{a_{ij} - \min(a_{ij})}{\max(a_{ij}) - \min(a_{ij})} \quad (1)$$

For metrics with negative impact:

$$r_{ij} = \frac{\max(a_{ij}) - a_{ij}}{\max(a_{ij}) - \min(a_{ij})} \quad (2)$$

where  $r_{ij}$  represents the data after standardized processing;  $a_{ij}$  is the original value of item  $j$  in year  $i$ . Since the normalized value may be zero, the following conversion is required:

$$x_{ij} = r_{ij} + 0.01 \quad (3)$$

(2) Entropy calculation:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} \quad (4)$$

where  $p_{ij}$  indicates the proportion of item  $j$ 's indicator in year  $i$ ;  $x_{ij}$  is the converted data in Equation (3).

$$H_j = \frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln p_{ij} \quad (5)$$

where  $H_j$  indicates the entropy value of the  $j$ -th indicator.

(3) Weight calculation

$$d_j = 1 - H_j$$

$$w_j = \frac{d_j}{\sum_{j=1}^n d_j} \quad (6)$$

where  $d_j$  represents the different coefficient of the  $j$ -th indicator;  $w_j$  represents the weight of the  $j$ -th indicator.

(4) Evaluation index calculation:

$$U_1 = \sum_{k=1}^n S_k R_k \quad (7)$$

$$U_2 = \sum_{l=1}^m S_l R_l \quad (8)$$

where  $U_1, U_2$  represent the comprehensive assessment indices of the DEL and RRL;  $S_k$  is the weight of the digital economy index  $k$ , and  $R_k$  is the standardized value;  $S_l$  denotes the weight value of the rural revitalization index  $l$ ;  $R_l$  is the standardized value of rural revitalization indicators;  $n$  and  $m$  are the numbers of indicators for DEL and RRL, respectively.

### 2.1.2. Improved CCD Model

Coupling was first applied in physics and later widely adopted in the social sciences. It denotes the degree to which two or more systems interact. It was later developed into the "CCD model" for assessing the evolution of inter-system CCD. Based on the research

methods proposed by Li [38] and Cong [39], this model was utilized to evaluate the CCD between DEL and RRL. The specific formulas are given as follows:

$$C = \sqrt{\frac{U_1 \cdot U_2}{\left(\frac{U_1 + U_2}{2}\right)^2}} = \frac{2\sqrt{U_1 \cdot U_2}}{U_1 + U_2} \quad (9)$$

$$T = \lambda U_1 + \mu U_2 \quad (10)$$

$$D = \sqrt{C \times T} \quad (11)$$

where  $C$  is the coupling degree of DEL and RRL,  $U_1$  represents DEL, and  $U_2$  represents RRL, and  $C \in [0, 1]$  reflects the intensity of the interaction between the two;  $T$  is the comprehensive coordination index of DEL and RRL, reflecting the overall synergy effect.  $\lambda$  and  $\mu$  represent the weights of the DEL and RRL, respectively, and  $\lambda + \mu = 1$ ;  $D$  is the CCD, and  $D \in [0, 1]$ .

Note: In the traditional CCD model,  $\lambda$  and  $\mu$  were generally determined by subjective factors and were set as  $\lambda : \mu = 1 : 1$  to indicate that both systems are equally important. Indeed, the digital economy is not static. Both it and rural revitalization are dynamic processes of continuous development. And at different times, due to different policies, the requirements for them are also different. Therefore, we make the following improvements by setting the parameter  $\lambda$  according to the incremental ratio of the DEL and RRL as shown in Equation (12).

$$\lambda = \frac{\Delta U_1}{\Delta U_1 + \Delta U_2} \quad (12)$$

where  $\Delta U_1$  represents the increment of Xinjiang's digital economy, and  $\Delta U_2$  indicates the increment of Xinjiang's rural revitalization.

So

$$\mu = 1 - \lambda \quad (13)$$

### 2.1.3. Obstacle Degree Model

Analyzing the factors that hinder CCD development can provide certain recommendations for formulating and adapting relevant development policies. Therefore, this paper introduces the obstacle degree model to determine the main obstacles affecting the CCD between Xinjiang's DEL and RRL. The calculation of obstacle degree involves three indicators: factor contribution, index deviation, and obstacle [40]. Factor contribution level represents the contribution value of a factor to the total, which is represented by the weight  $w_j$  of a single factor; index deviation degree is the difference between the actual value and the optimal value of each index, which is usually expressed as  $I_{ij} = 1 - x_{ij}$ ; obstacle degree  $Z_{ij}$  represents the degree to which factors of each index or criterion layer affect the CCD. The calculation formula is:

$$Z_{ij} = \frac{I_{ij}w_j}{\sum_{j=1}^n I_{ij}w_j} \quad (14)$$

## 2.2. Index Selection and Data Source

### 2.2.1. Construction of the Index System

As both the DEL and RRL are influenced by multiple factors, their index systems have been built, respectively.

Combined with the definition of the digital economy, it can be found that the index system includes not only infrastructure such as the computer network and information communication equipment but also the service scenarios such as telecommunications business and digital finance. This article draws on the index selection methods of Liu et al. [41] and Pan et al. [42] and takes 14 prefectures (or cities) in Xinjiang as the study objects. Based on data availability and content similarity, the DEL index system containing

six secondary indicators was constructed under three first-tier indexes, namely digital infrastructure, digital investment, and digital convergence development (see Table 1). As far as the indexes of RRL are concerned, rural revitalization is a long-term historical issue, and its development is an ongoing dynamic process that should involve various aspects of social and economic life. Thus, we have constructed a rural revitalization indicator system by integrating the research conducted by Fang et al. [43] and Mao et al. [44]. This indicator system considers the unique development characteristics of Xinjiang and takes into account the availability and representativeness of data. Ultimately, we identified 13 specific indicators for measuring rural revitalization in Xinjiang (Table 2).

**Table 1.** Index system for evaluating the digital economy.

| Main Index                        | First-Tier Indexes                    | Second-Tier Indexes                                | Weight |
|-----------------------------------|---------------------------------------|----------------------------------------------------|--------|
| Digital Economy Development Index | Digital Infrastructure $x_1$          | Mobile phone penetration rate (% , +)              | 0.166  |
|                                   |                                       | Internet penetration rate (set, +)                 | 0.207  |
|                                   |                                       | Telecommunications services per capita (10,000, +) | 0.216  |
|                                   | Digital Investment $x_2$              | Education expenditure per capita (CNY, +)          | 0.201  |
|                                   |                                       | Percentage of persons employed in ICT (% , +)      | 0.110  |
|                                   | Digital Convergence Development $x_3$ | Digital inclusive finance index (% , +)            | 0.100  |

**Table 2.** Index system for evaluating rural revitalization.

| Main Index                 | First-Tier Indexes                  | Second-Tier Indexes                                                                         | Weight |
|----------------------------|-------------------------------------|---------------------------------------------------------------------------------------------|--------|
| Rural Revitalization Index | Thriving Businesses $x_4$           | Per capita output value of primary industry (CNY, +)                                        | 0.049  |
|                            |                                     | Total machinery power per capita (kW/10,000 people, +)                                      | 0.056  |
|                            |                                     | Domestic tourism revenue (CNY million, +)                                                   | 0.154  |
|                            | Pleasant Living Environment $x_5$   | Afforestation area per capita (hectares/10,000 people, +)                                   | 0.052  |
|                            |                                     | Number of hospital beds per 10,000 population (piece, +)                                    | 0.032  |
|                            |                                     | Harmless disposal rate of garbage (% , +)                                                   | 0.050  |
|                            | Social Etiquette and Civility $x_6$ | Number of television villages per 10,000 people (piece, +)                                  | 0.069  |
|                            |                                     | Education fixed asset input (CNY 10,000, +)                                                 | 0.108  |
|                            |                                     | Investment in fixed assets for culture and sports (CNY 10,000, +)                           | 0.100  |
|                            | Effective Governance $x_7$          | General public budget expenditures (CNY 10,000, +)                                          | 0.058  |
|                            |                                     | Number of urban and rural residents participating in social endowment insurance (10,000, +) | 0.163  |
|                            | Prosperity $x_8$                    | Per capita electricity consumption of rural residents (kWh, +)                              | 0.104  |
|                            |                                     | Rural disposable income (CNY, +)                                                            | 0.050  |

## 2.2.2. Data Sources

Considering data availability as well as authenticity, panel data from 14 prefectures (or cities) in Xinjiang from 2013 to 2019 were selected for research in this paper. The Digital Inclusive Finance Index comes from the Digital Finance Research Center of Peking University. Other data come from the Xinjiang Statistical Yearbook, Economy Prediction System, China Rural Statistical Yearbook, and statistical bulletins of 14 prefectures (or cities) in Xinjiang. For some missing data, the trend extrapolation prediction method was used for defining their values.

### 3. Empirical Analysis

Applying the research methods from Section 2, this section first measures the DEL and RRL in the 14 prefectures (or cities) in Xinjiang. Then, the spatiotemporal evolution characteristics of their CCD development are investigated. Finally, the obstacle factors affecting CCD are studied, and feasible policy suggestions are put forward.

#### 3.1. Analysis of DEL and RRL

In order to examine how DEL and RRL have developed in Xinjiang, it was necessary to first measure their comprehensive evaluation indicators. Based on the existing index research system, each index's weight was calculated using the entropy weight method Formulas (1)–(6). As shown in Table 1, digital infrastructure accounts for 58.9% of the total weight, digital investment accounts for 31.1%, and digital convergence development, 10%. Digital infrastructure occupies a primary position in the digital economic system, which confirms the statement that the modern information network is an important carrier of the digital economy and that the effective use of ICT is the driving force to improve the DEL. In Table 2, the index weights of the five factors of thriving businesses, pleasant living environment, social etiquette and civility, effective governance, and prosperity are 25.9%, 8.9%, 27.7%, 22.1% and 15.4%, respectively. The three fields of thriving businesses, social etiquette and civility, and effective governance have a greater impact on RRL.

##### (1) Measurement of Xinjiang's DEL

According to the index weight, Equations (7) and (8) were used to calculate Xinjiang's DEL from 2013 to 2019 (Table 3). Considering the geographical locations and economic development levels of the 14 prefectures (or cities), we grouped the 14 prefectures (or cities) into Northern Xinjiang, Southern Xinjiang, and Eastern Xinjiang to conduct the analysis.

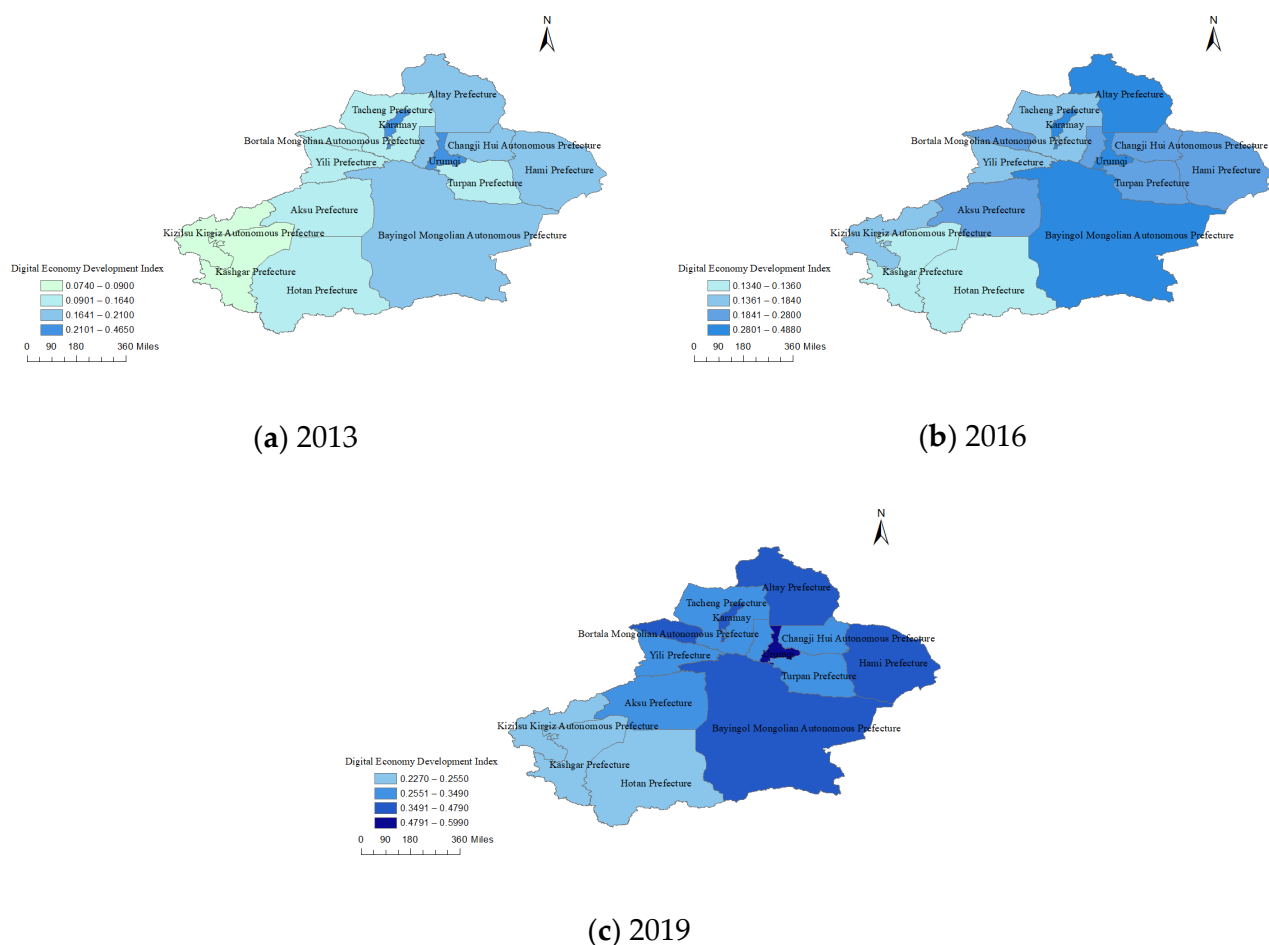
**Table 3.** Xinjiang's DEL.

| Group                    | Prefecture or City                                | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  |
|--------------------------|---------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| Northern Xinjiang        | Urumqi                                            | 0.354 | 0.380 | 0.379 | 0.488 | 0.569 | 0.630 | 0.599 |
|                          | Karamay                                           | 0.465 | 0.364 | 0.437 | 0.471 | 0.561 | 0.585 | 0.479 |
|                          | Changji Hui Autonomous Prefecture (Changji)       | 0.191 | 0.228 | 0.221 | 0.280 | 0.425 | 0.349 | 0.330 |
|                          | Yili                                              | 0.116 | 0.148 | 0.173 | 0.184 | 0.227 | 0.265 | 0.349 |
|                          | Tacheng                                           | 0.136 | 0.136 | 0.130 | 0.178 | 0.218 | 0.268 | 0.323 |
|                          | Altay                                             | 0.210 | 0.232 | 0.302 | 0.378 | 0.332 | 0.376 | 0.392 |
|                          | Bortala Mongolian Autonomous Prefecture (Bozhou)  | 0.164 | 0.177 | 0.221 | 0.236 | 0.342 | 0.411 | 0.396 |
| Eastern Xinjiang         | Turpan                                            | 0.124 | 0.152 | 0.169 | 0.230 | 0.286 | 0.250 | 0.303 |
|                          | Hami                                              | 0.198 | 0.199 | 0.224 | 0.273 | 0.291 | 0.360 | 0.443 |
| Southern Xinjiang        | Bayingol Mongolian Autonomous Prefecture (Bazhou) | 0.208 | 0.231 | 0.294 | 0.375 | 0.428 | 0.583 | 0.403 |
|                          | Aksu                                              | 0.157 | 0.175 | 0.191 | 0.238 | 0.334 | 0.243 | 0.306 |
|                          | Kizilsu Kirgiz Autonomous Prefecture (Keshou)     | 0.090 | 0.113 | 0.136 | 0.180 | 0.174 | 0.254 | 0.242 |
|                          | Kashgar                                           | 0.074 | 0.048 | 0.108 | 0.134 | 0.230 | 0.223 | 0.255 |
|                          | Hotan                                             | 0.141 | 0.137 | 0.115 | 0.136 | 0.278 | 0.163 | 0.227 |
| Xinjiang's average level |                                                   | 0.188 | 0.194 | 0.221 | 0.270 | 0.335 | 0.354 | 0.361 |

As shown in Table 3, Xinjiang's DEL from 2013 to 2019 followed a slowly rising trend. The overall DEL in Xinjiang increased from 0.188 to 0.361. This shows the growing importance that Xinjiang attaches to the digital economy. In recent years, China, as well as its province of Xinjiang, has formulated many implementation plans to upgrade the DEL, such as expanding and upgrading information consumption, developing industrial internet, and implementing a three-year action plan to encourage Xinjiang enterprises to use cloud technology. All of these helped Xinjiang's digital economy to flourish. Nevertheless, due to the vast territory and high dispersity of the cities in Xinjiang, a "digitization gap" existed

between the cities, and the digital economy developed at a relatively slower pace in the less digitized areas.

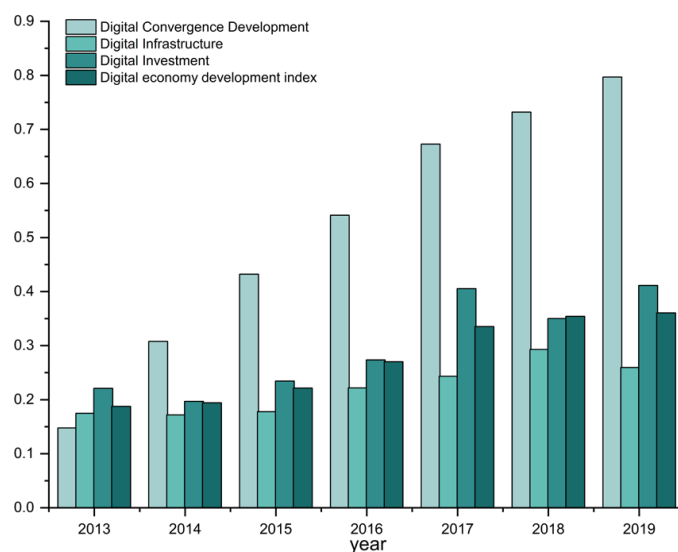
In terms of regions, DEL development has shown a clear heterogeneity in time and space. The DEL in Southern Xinjiang, Northern Xinjiang, and Eastern Xinjiang was unbalanced, which was manifested by having Urumqi as the center of the highest level and a gradually decreasing level from Northern Xinjiang to Eastern Xinjiang and Southern Xinjiang. To help understand the heterogeneity, we focused on the results in 2013, 2016, and 2019 and used the ArcGIS platform to visualize the DELs of 14 prefectures (or cities), as shown in Figure 1. From the spatial distribution perspective, Figure 1 indicates that Northern Xinjiang's DEL was generally higher, while Southern Xinjiang's DEL was generally lower. In 2013, the DELs of Urumqi, Karamay, Changji, and Altay in Northern Xinjiang exceeded the average level, and the development momentum was good. Eastern Xinjiang had balanced development, with little difference in DEL between Turpan and Hami. The DELs of the four prefectures in Southern Xinjiang (Aksu, Kezhou, Kashgar, and Hotan) were all lower than the average level of Xinjiang as a whole. The DELs of Kezhou and Kashgar were less than 0.1, seriously lagging behind in the development trend. In 2016, the DELs of Urumqi and Karamay of Northern Xinjiang far exceeded the provincial average level. The digital economy index of Turpan of Eastern Xinjiang increased by 85% compared with 2013 and developed more rapidly. Southern Xinjiang's DEL was also improved. Bazhou's digital economy development index was twice the value of the index in Kezhou, showing a significant regional difference. In 2019, the DELs of Altay and the cities around the Tianshan Mountains in northern Xinjiang were higher, and the regional agglomeration with Urumqi as the center was more obvious. The digital economy index in southern Xinjiang increased, which indicated the improvement in the DEL in this area.



**Figure 1.** Spatial distribution of Xinjiang's DEL in 2013 (a), 2016 (b) and 2019 (c).

From the spatial evolution of the DEL, we can find that the DELs in Karamay and Urumqi have always been ahead of those in other prefectures. Karamay is the core base of Xinjiang's "Tianshan Cloud" program. The construction of the Cloud Computing Industrial Park has strongly promoted digital industry development, placing its DEL at the forefront. Urumqi, as the provincial capital, connects the north and the south and has a convenient transportation network that has facilitated the digital economy transformation. Urumqi High-tech Zone is the most concentrated area of the high-tech and information industry in Xinjiang. In recent years, based on advantageous resources, the Urumqi High-tech Zone has cultivated many software enterprises and built the foundation for digital industries like cloud computing. As a result, the digital technology level in Urumqi is significantly advanced. During the evolution of DEL, regional integration was promoted by radiating to surrounding cities. From 2013 to 2019, Altay in northern Xinjiang and Bazhou in southern Xinjiang, with their resources and geographical advantages, accelerated infrastructure development with 5G and the internet as the core. They also promoted the development of industrial digital integration with smart tourism and ensured that the digital economy remains at the forefront. On the contrary, due to the large population, low overall cultural quality, relatively backward regional economic development, and weak internet infrastructure, the digital economy lags in the four southern regions of Xinjiang.

The digital economy is inseparable from digital infrastructure, digital investment, and digital convergence development. To further understand Xinjiang's DEL, we measured the three level 1 indicators using the entropy weight method. They reflect the changes in digital economic development from three dimensions, as shown in Figure 2. Viewed from a time series evolution, the digital economic development index, digital infrastructure, and digital investment all show a fluctuating upward trend, and the changes are converging. From 2013 to 2019, the digital infrastructure level increased from 0.175 to 0.260, and the digital investment level developed from 0.221 to 0.411, highlighting steady increases in both. In contrast, the digital convergence development level was more variable. Its level was measured through the digital inclusive financial index, including payments, funds, credit, investment, and other businesses. The index grew from 0.148 in 2013 to 0.797 in 2019, with a 36% yearly growth rate on average. Such rapid development has benefited from the popularity of internet finance and the rise in electronic payments. A steady stream of users and funds have poured into the market to promote financial growth. In terms of changing trends, all fields are showing positive upward development, and the combined effect has made Xinjiang's digital economy better and better.



**Figure 2.** Changes in Xinjiang's digital economy.

## (2) Measurement of Xinjiang's RRL

According to the index system constructed in Table 2, Equation (8) was used to calculate the rural revitalization index for Xinjiang from 2013 to 2019. Xinjiang's RRL is shown in Table 4.

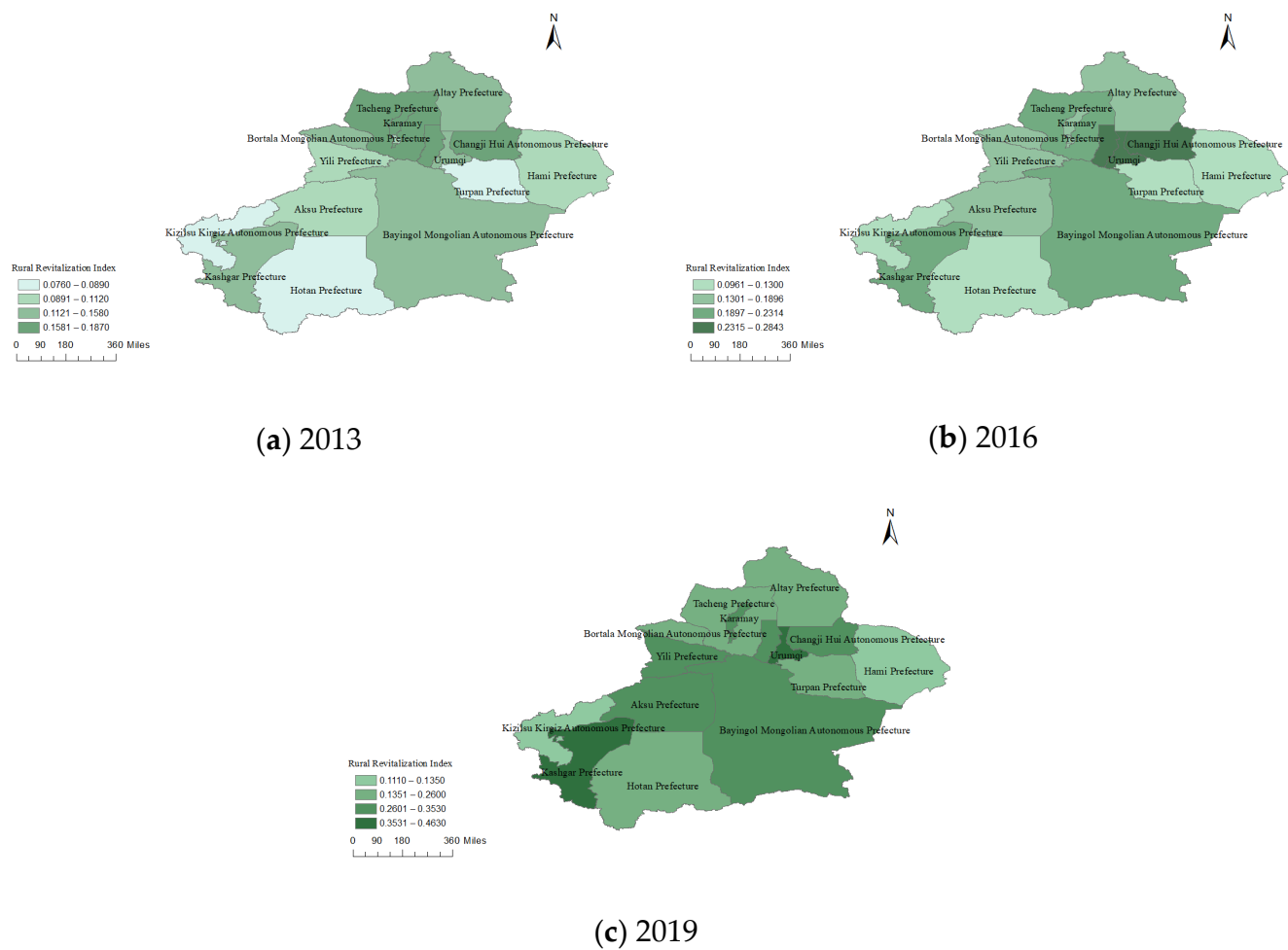
**Table 4.** Xinjiang's RRL.

| Group                    | Prefecture or City | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  |
|--------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|
| Northern Xinjiang        | Urumqi             | 0.158 | 0.199 | 0.198 | 0.271 | 0.277 | 0.315 | 0.463 |
|                          | Karamay            | 0.172 | 0.159 | 0.181 | 0.172 | 0.178 | 0.296 | 0.280 |
|                          | Changji            | 0.183 | 0.207 | 0.266 | 0.284 | 0.400 | 0.318 | 0.342 |
|                          | Yili               | 0.108 | 0.115 | 0.172 | 0.180 | 0.221 | 0.255 | 0.353 |
|                          | Tacheng            | 0.187 | 0.178 | 0.223 | 0.228 | 0.251 | 0.250 | 0.260 |
|                          | Altay              | 0.156 | 0.157 | 0.196 | 0.190 | 0.173 | 0.207 | 0.233 |
|                          | Bozhou             | 0.139 | 0.142 | 0.183 | 0.168 | 0.180 | 0.183 | 0.198 |
| Eastern Xinjiang         | Turpan             | 0.089 | 0.096 | 0.121 | 0.130 | 0.163 | 0.168 | 0.175 |
|                          | Hami               | 0.098 | 0.096 | 0.110 | 0.127 | 0.145 | 0.137 | 0.135 |
| Southern Xinjiang        | Bazhou             | 0.154 | 0.170 | 0.207 | 0.231 | 0.257 | 0.245 | 0.273 |
|                          | Aksu               | 0.112 | 0.120 | 0.150 | 0.170 | 0.280 | 0.269 | 0.303 |
|                          | Kezhou             | 0.076 | 0.078 | 0.096 | 0.096 | 0.097 | 0.113 | 0.111 |
|                          | Kashgar            | 0.134 | 0.140 | 0.276 | 0.217 | 0.370 | 0.391 | 0.410 |
|                          | Hotan              | 0.087 | 0.087 | 0.156 | 0.109 | 0.218 | 0.222 | 0.241 |
| Xinjiang's average level |                    | 0.132 | 0.139 | 0.181 | 0.184 | 0.229 | 0.241 | 0.270 |

As indicated in Table 4, from 2013 to 2019, Xinjiang's RRL continuously improved, rising from 0.132 to 0.270. From 2017 to 2019, Xinjiang's RRL development increased significantly. This is because during this period, China consistently implemented a series of rural revitalization initiatives that created a strong foundation for building a beautiful and livable modern countryside, while also providing historic opportunities for rural economic development. Concrete projects were conducted on this front based on the development strategies, and the results were seen in rural construction.

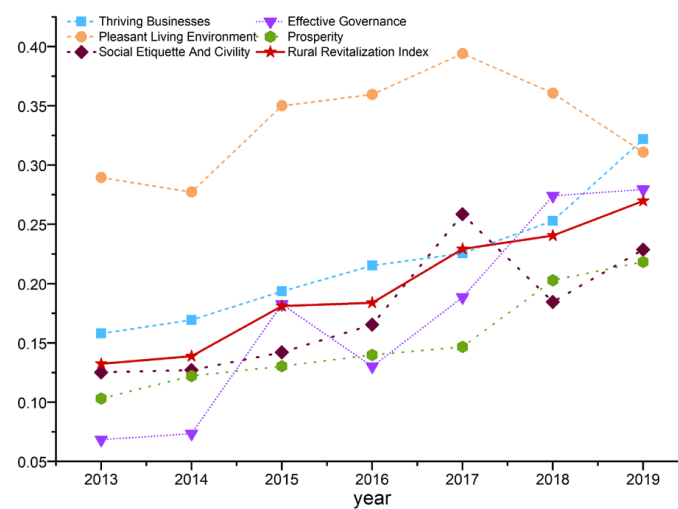
From a regional perspective, Xinjiang's RRL was relatively unbalanced, showing a pattern of decline in northern Xinjiang, eastern Xinjiang and southern Xinjiang. In order to more intuitively reflect its spatial distribution differences, ArcGIS 10.8 software was used to visualize the RRL development over the years, and the results are shown in Figure 3. The rural revitalization development levels led by Karamay and Changji in northern Xinjiang were higher than that in southern Xinjiang. In 2016, rural revitalization in various regions increased, and northern Xinjiang's RRL was relatively balanced; there were obvious regional differences in southern Xinjiang. Bazhou and Kashgar had higher levels, while Hotan and Kezhou had lower levels. The rural revitalization index for Turpan and Hami in eastern Xinjiang was less than 0.13, lagging behind other regions. In 2019, thanks to the great progress made in southern Xinjiang, Xinjiang's rural revitalization was greatly improved. In addition, the overall level in northern Xinjiang was improving, showing a fan-out effect from Urumqi as the center; Kashgar region in southern Xinjiang successfully leapfrogged into the first echelon in rural revitalization, with a development index greater than 0.35; the development of rural revitalization in Hami and Kezhou was relatively slow and needs to be improved.

Figure 3 also indicates that RRL development in northern Xinjiang was always at the forefront from 2013 to 2019, mainly due to its superior geographical location with good rural infrastructure and a convenient transportation system. The oases in southern Xinjiang were scattered in the region. The natural conditions for agricultural development are very fragile. Overall rural development in the region was much lower. The rural revitalization index has improved. This is mainly due to the implementation of poverty alleviation policies in southern Xinjiang, which has laid an excellent institutional and material foundation for rural development.



**Figure 3.** Spatial distribution pattern of Xinjiang's RRL in 2013 (a), 2016 (b) and 2019 (c).

Rural revitalization is a multi-factor and multi-dimension dynamic development process. Based on the index weight of Equation (6), the scores of the five dimensions of the rural revitalization system were calculated, reflecting the changes taking place at different levels in the countryside, as can be seen in Figure 4. Viewed from a time perspective, the levels across all five first-level indices were all on the rise, and the trend of change was similar. Among them, industrial prosperity and effective governance had the largest increases, while pleasant living environment and prosperity had relatively small increases. The RRL showed a good growth trend, rising from 0.132 to 0.270. Since the publication of the Central No.1 Document in 2014, which proposed to deepen rural reform and promote agricultural modernization, the Xinjiang Government has invested significantly in financial and human resources, as well as material resources to support rural development, which greatly improved the rural governance level. In 2018, the country issued a package of policies (the Rural Revitalization Strategy) and set out a road map for rural revitalization, and rural development entered a new phase. Poverty has long plagued parts of Xinjiang and hindered rural development due to inconvenient transportation and weak industrial development. To achieve rural revitalization, we must first eliminate poverty. By 2018, Xinjiang had implemented targeted poverty alleviation policies, lifted 537,000 people out of poverty, improved the lagging rural development in Xinjiang and effectively advanced local governance. In the past few years, the country has placed greater emphasis on ecological civilization, which has promoted the ecological development of Xinjiang with blue sky and green water.



**Figure 4.** Changes in Xinjiang's rural revitalization.

### 3.2. Analysis of the CCD between DEL and RRL

#### 3.2.1. Measurement of the CCD

Through the measurement of DEL and RRL, it was found that they were on the rise during the study period. On this basis, an improved CCD model was used to explore the CCD between DEL and RRL in Xinjiang. According to their overall evaluation index, the change increment was obtained (see Table 5) and brought into Formulas (12) and (13) to obtain the system weights  $\lambda$  and  $\mu$ .

**Table 5.** The extent of change in the DEL and RRL.

| Year                                   | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | Mean  |
|----------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Digital Economy Development Index      | 0.188 | 0.194 | 0.221 | 0.270 | 0.335 | 0.354 | 0.361 | 0.275 |
| Increment $\Delta U_1$                 |       | 0.006 | 0.027 | 0.048 | 0.065 | 0.019 | 0.007 | 0.029 |
| Rural Revitalization Development Index | 0.132 | 0.139 | 0.181 | 0.184 | 0.229 | 0.241 | 0.270 | 0.197 |
| Increment $\Delta U_2$                 |       | 0.007 | 0.042 | 0.003 | 0.045 | 0.012 | 0.029 | 0.023 |

As shown in Table 5, Xinjiang's CCD development is broadly divided into two stages: stage 1 from 2013 to 2016 with a focus on improving the RRL, and stage 2 from 2017 to 2019, when the development of rural revitalization was the focus.

In the first stage, China proposed a "National Big Data Strategy", the digital transformation was deepened, and a number of concrete projects were implemented. Xinjiang's digital economy entered a boom period. During this period, rural revitalization was still sprouting. Therefore, the system weights for DEL and RRL should also be different when measuring CCD. Based on this, according to Equations (12) and (13), the weight ratio was set as  $\lambda:\mu = 0.6:0.4$ .

In the second stage, Xinjiang's digital economy continued developing at a stable pace. During this period, China made a decision to deploy a "rural revitalization strategy". A large amount of funding was allocated, many policies were implemented, and rural construction entered a booming stage. From Equations (12) and (13), we concluded that  $\lambda:\mu = 0.38:0.62$ .

The values of  $\lambda$  and  $\mu$  were used in Equations (10) and (11) to obtain the CCDs for the 14 prefectures (or cities) in Xinjiang from 2013 to 2019. As there is no consensus in the academic community on the division of the D value, in this paper, we refer to the study by

Miao et al. [45], which studied and divided the CCD with reference to the actual situation of rural development in Xinjiang (see Table 6).

**Table 6.** Classification criteria for the CCD.

| CCD Interval | Coordination Level | Coordination Degree       |
|--------------|--------------------|---------------------------|
| (0.0~0.1)    | 1                  | Extreme disorder          |
| [0.1~0.2)    | 2                  | Serious disorder          |
| [0.2~0.3)    | 3                  | Moderate disorder         |
| [0.3~0.4)    | 4                  | Mild disorder             |
| [0.4~0.5)    | 5                  | On the verge of disorder  |
| [0.5~0.6)    | 6                  | Barely coordinated        |
| [0.6~0.7)    | 7                  | Mild coordination         |
| [0.7~0.8)    | 8                  | Moderate coordination     |
| [0.8~0.9)    | 9                  | Good coordination         |
| [0.9~1.0)    | 10                 | High-quality coordination |

#### (1) Time evolution of CCD

The CCD of each prefecture or city is shown in Table 7, based on the above classification standards. Considering the effective length of the article, only the levels in 2013, 2016 and 2019, as well as the average CCD of the 14 prefectures (or cities) are presented here.

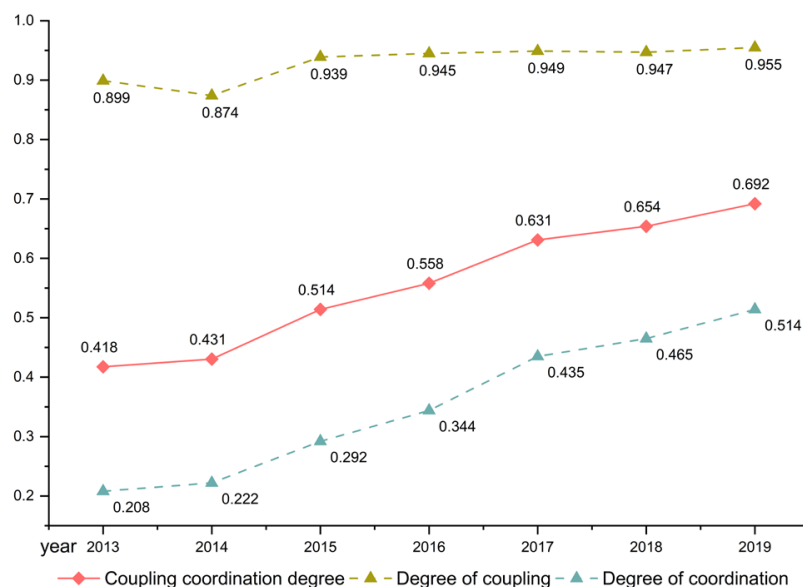
**Table 7.** Coupling coordination level of Xinjiang from 2013 to 2019.

| Group                    | Prefecture or City | 2013  | 2016  | 2019  | Average | Coordination Degree      |
|--------------------------|--------------------|-------|-------|-------|---------|--------------------------|
| Northern Xinjiang        | Urumqi             | 0.605 | 0.800 | 0.985 | 0.770   | Moderate coordination    |
|                          | Karamay            | 0.682 | 0.685 | 0.773 | 0.701   | Moderate coordination    |
|                          | Changji            | 0.512 | 0.671 | 0.774 | 0.680   | Mild coordination        |
|                          | Yili               | 0.331 | 0.502 | 0.793 | 0.534   | Barely coordinated       |
|                          | Tacheng            | 0.449 | 0.534 | 0.689 | 0.550   | Barely coordinated       |
|                          | Altay              | 0.502 | 0.661 | 0.685 | 0.600   | Mild coordination        |
|                          | Bozhou             | 0.436 | 0.538 | 0.636 | 0.544   | Barely coordinated       |
| Eastern Xinjiang         | Turpan             | 0.292 | 0.481 | 0.564 | 0.451   | On the verge of disorder |
|                          | Hami               | 0.384 | 0.505 | 0.529 | 0.463   | On the verge of disorder |
| Southern Xinjiang        | Bazhou             | 0.498 | 0.700 | 0.738 | 0.655   | Mild coordination        |
|                          | Aksu               | 0.386 | 0.542 | 0.726 | 0.560   | Barely coordinated       |
|                          | Kezhou             | 0.181 | 0.364 | 0.398 | 0.317   | Mild disorder            |
|                          | Kashgar            | 0.288 | 0.468 | 0.780 | 0.522   | Barely coordinated       |
|                          | Hotan              | 0.299 | 0.358 | 0.615 | 0.446   | On the verge of disorder |
| Xinjiang's average level |                    | 0.417 | 0.558 | 0.692 | 0.557   | Barely coordinated       |

The calculation results show that the CCD improved across the board from 2013 to 2019, and there were great differences between cities.

The changes in CCD in Xinjiang were analyzed from the perspective of time evolution (Figure 5). During the study period, the coupling remained relatively stable at a high level, and the coupling degree increased from 0.899 to 0.955, indicating that the interaction between DEL and RRL was strengthened. The coordination degree T was increased from 0.208 to 0.514, and the synergistic effect of the two systems was strengthened. Their CCDs fluctuated slightly, but showed a steady growth trend as a whole. The D value was increased from 0.418 to 0.692, realizing the leap from imbalance to mild coordination. This shows that as digital technologies were further developed in the new countryside, the interaction between DEL and RRL became gradually harmonized. From the results, the D value reached its peak in 2019, but it was still in the stage of primary coordination, showing that they were still far from quality coordination. In other words, although the interaction

between DEL and RRL strengthened, it still needed to be further optimized, and there was room for development. In 2018, China formally proposed the rural revitalization strategy to push coordinated development. In 2019, China issued the “Digital Rural Development Strategy Schema”, which clearly defined the digital village as the strategic direction of rural revitalization, accelerated the development of informatization, and promoted agricultural and rural modernization. These policies have provided institutional guarantees for improving Xinjiang’s DEL and RRL. They have created a new situation of coordinated development of DEL and RRL.



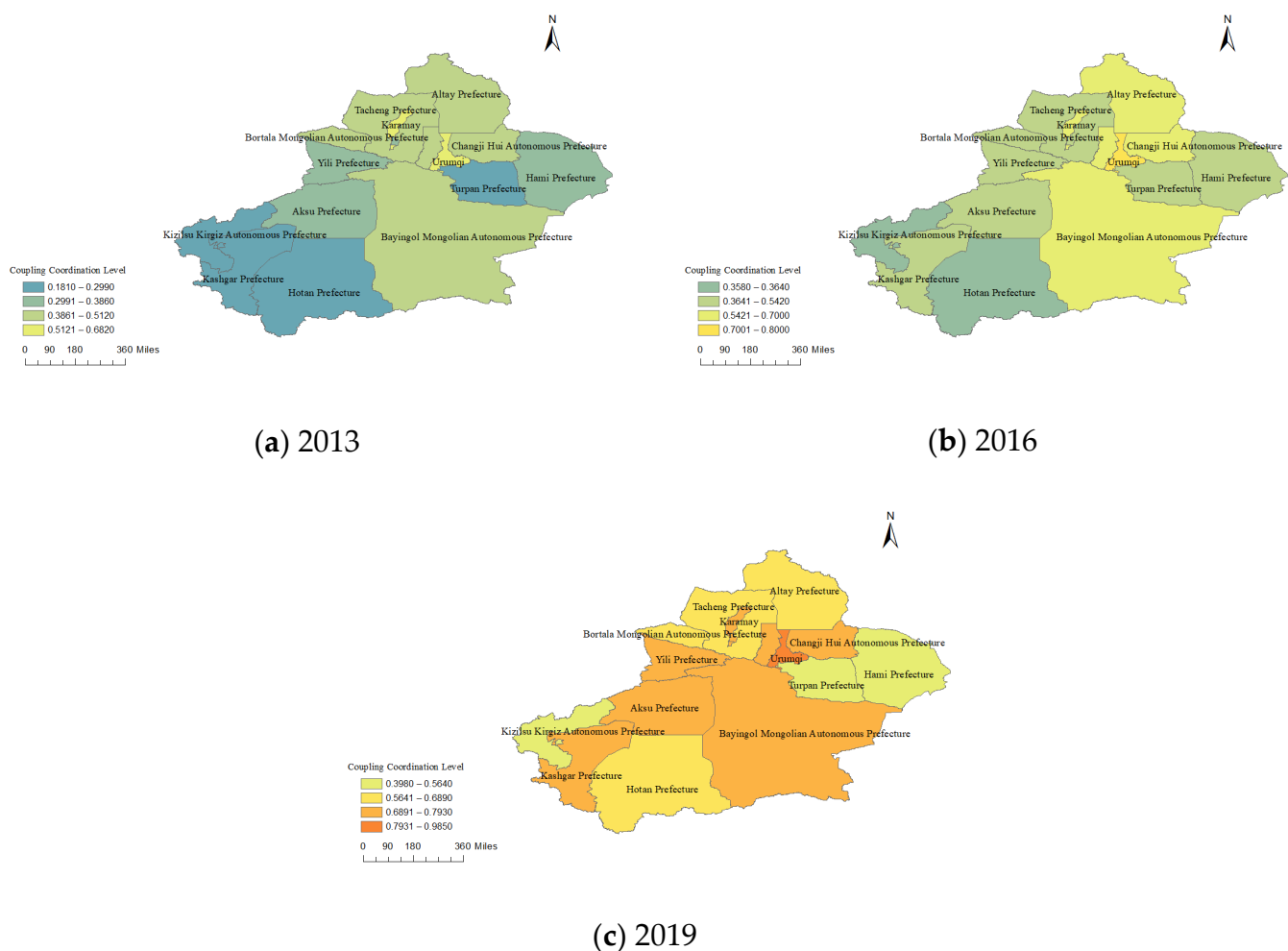
**Figure 5.** Variation in CCD.

## (2) Spatial evolution of CCD

Studying the CCD among different cities is necessary for achieving high-quality coupling development in Xinjiang. This study selected the values of the CCD in three years, namely 2013, 2016 and 2019, and ArcGIS 10.8 software was used to study the spatial evolution of the CCD in 14 prefectures (or cities) (see Figure 6).

As can be seen from Figure 6, the CCD was unevenly distributed in space, showing a stepwise decreasing pattern from north to south, which was basically manifested as “higher levels in northern Xinjiang and lower levels in southern Xinjiang”. At the beginning of the study period, most of the development of northern Xinjiang was in a stage of mild imbalance. CCDs were better for Urumqi and Karamay, which were at the stage of mild coordination. There were many prefectures in the stages of serious imbalance and moderate imbalance in southern Xinjiang. The difference between the two prefectures in eastern Xinjiang was small, and their CCDs were in a stage of mild imbalance. In 2016, the CCDs of Altay, Karamay and Changji in northern Xinjiang were further improved and entered the stage of coordinated development. The differences among the prefectures in southern Xinjiang were obvious. Kezhou and Hotan were in the stage of mild imbalance, and Bazhou was in the stage of coordination. In 2019, the CCDs among prefectures increased, but Kezhou, Turpan, and Hami were still in the stage of imbalance. Urumqi in northern Xinjiang took the lead in achieving high-quality coordination of DEL and RRL, and Yili Prefecture, Karamay, and Changji achieved moderate coordination. The two prefectures in eastern Xinjiang were on the verge of imbalance. The regional differences in CCD in southern Xinjiang weakened, and Kashgar, Aksu, and Bazhou moved toward intermediate coordination. As indicated by the color in Figure 6, the southern Xinjiang region moved from low coupling coordination to high coupling coordination at a rapid pace in the second phase of CCD development (2017–2019) because, during this period, local

governments in southern Xinjiang relied on national industrial policies and aid to upgrade industrial development and continuously improve the transportation and logistics systems. In addition, the fan-out effect of the Urumqi metropolitan area gradually covered the southern region, promoting the development of “southern Xinjiang urban agglomeration”, forming a virtuous circle and making southern Xinjiang a strong “magnetic field” to attract investment and improve the DEL and RRL. Despite this, the situation of high-quality coupling and coordination across Xinjiang had not yet emerged in general, and there were still significant differences among different prefectures. However, as digital technology started gaining ground in its rural areas, Xinjiang was expected to achieve high-quality coordination across the board in the future.



**Figure 6.** Spatial distribution pattern of CCD in 2013 (a), 2016 (b) and 2019 (c).

### 3.2.2. Diagnostic Analysis of Obstacle Factors

To improve the DEL and RRL in Xinjiang and realize their high-quality coordination, we should not only view national strategic planning as the top-level design but also identify the obstacles in the development process. Through the obstacle degree model, we calculated the obstacle degree of digital infrastructure ( $x_1$ ), digital investment ( $x_2$ ), digital convergence development ( $x_3$ ), thriving businesses ( $x_4$ ), pleasant living environment ( $x_5$ ), social etiquette and civility ( $x_6$ ), effective governance ( $x_7$ ) and prosperity ( $x_8$ ) in different years using Formula (14). The specific results are shown in Table 8.

**Table 8.** Obstacle degree of the factors in coupling coordination development.

| Year | $x_1$  | $x_2$  | $x_3$ | $x_4$  | $x_5$ | $x_6$  | $x_7$  | $x_8$  |
|------|--------|--------|-------|--------|-------|--------|--------|--------|
| 2013 | 33.37% | 17.29% | 6.84% | 10.43% | 3.81% | 10.07% | 12.13% | 6.06%  |
| 2014 | 34.37% | 19.29% | 5.02% | 9.66%  | 3.84% | 10.23% | 11.92% | 5.67%  |
| 2015 | 36.97% | 18.99% | 3.79% | 9.45%  | 3.52% | 10.43% | 10.92% | 5.94%  |
| 2016 | 34.18% | 19.56% | 2.48% | 9.50%  | 4.02% | 10.38% | 13.25% | 6.63%  |
| 2017 | 21.96% | 8.65%  | 3.55% | 16.60% | 3.89% | 16.41% | 16.74% | 12.20% |
| 2018 | 18.84% | 10.65% | 2.97% | 15.96% | 4.60% | 19.99% | 15.53% | 11.46% |
| 2019 | 23.00% | 9.02%  | 2.34% | 16.13% | 5.77% | 18.23% | 16.25% | 12.26% |

Considering the barriers posed by each factor, digital infrastructure, rural civilization, digital investment, and effective governance had a more significant impact on the CCD between DEL and RRL. In the first phase of CCD development (2013–2016), the top three factors of obstacle degree were digital infrastructure, digital investment, and effective governance, with an average annual obstacle degree of 34.72%, 18.78%, and 12.06%, respectively. The digital infrastructure and digital investment subsystem were expanding, and the impact on CCD development was strengthened. The subsystems of the pleasant living environment, thriving businesses, and prosperity fluctuated less, which had a relatively stable impact on CCD development. The decline in the digital convergence development subsystem was obvious, indicating that its influence on coordinated development was gradually weakened. In the second phase (from 2017 to 2019), the main factors were digital infrastructure, thriving businesses, and social etiquette and civility, with an average annual obstacle degree of 21.27%, 16.23%, and 16.17%, respectively. As a result of the rural revitalization strategy, the obstacles of each subsystem of rural revitalization have been strengthened, and the impact on CCD development has deepened.

It was found that the obstacle degree of the digital infrastructure subsystem was always the highest, and the obstacle degrees of digital integration development and the pleasant living environment subsystem were always the weakest. This indirectly proves that digital infrastructure is the cornerstone of the digital economy, covering the three fields of the internet, communication and transportation, and has a greater impact on the DEL. Furthermore, in the process of rural development, digital infrastructure development can use information and communications technology to integrate traditional industries, drive the flow of technology, material, capital and talent in the entire rural area, break down the barriers of the urban–rural dual structure, and improve the rural economic level. Local finance promotes the development of rural network infrastructure, improves the digital management mechanism of rural roads, and makes up for the shortcomings of rural digital infrastructure. However, insufficient investment by local finance in digitally inclusive finance and the development of an ecologically sustainable society makes the development process relatively slow, and its impact on CCD is weakened.

In the first phase of CCD development (from 2013 to 2016), the obstacle degree of the digital input subsystem reached 19.56%, and that of the effective governance subsystem reached 13.25%, which greatly affected the CCD. This is because digital investment covers two aspects of education and information transmission services, while providing talent input for rural development, software and information technology are also integrated into the three major rural industries, directly affecting the DEL and RRL. There are two aspects to effective governance: public budget expenditure to ensure and improve people’s livelihoods, and pension insurance for urban and rural residents. The former reflects the local government’s efforts in its public services to improve people’s livelihood and the equalization of financial resources. The latter can narrow the urban–rural gap to a certain extent, ease social contradictions, and “escort” rural revitalization. The macro control of these governments has integrated digital technology into rural governance and grassroots organization development, improved the efficiency of the rural governance system, and laid a foundation for the accurate implementation of organizational decision-making. At

the same time, the implementation of professional decision-making can also react to the digital economy and help realize high-quality development.

In the second phase (from 2017 to 2019), the average obstacle degrees of thriving businesses and social etiquette and civility increased significantly. This shows that the influence of thriving businesses, social etiquette and civility on coupling coordination development was strengthened at this stage. Thriving businesses involve three aspects: agricultural production, mechanization level, and tourism industry. Rural areas have been dominated by agricultural production for a long time. The lack of labor in the countryside, the low level of agricultural mechanization, and the relatively unreasonable agricultural industrial structure have led to the lagging development of secondary and tertiary industries, which has affected the process of rural development. Tourism is a strategic pillar industry in Xinjiang. The driving force of integrated development brought by “tourism+” has stimulated the integrated development of tourism in Xinjiang with agriculture, animal husbandry, forestry, ecology, and health care, helping adjust Xinjiang’s economic structure, facilitating the employment of local residents, and gradually improving their quality of life. Building rural civilization is an important part of the rural revitalization strategy, and it is also the practice of the “Let Culture Nourish Xinjiang” project. On the one hand, it can cultivate good rural customs, family customs, and folkways, stimulate rural cultural creativity, and lay a foundation for creating unique rural tourism. On the other hand, through investment in culture and education, we can improve the cultural quality of farmers, strengthen the popularization of information and communications technology in the countryside, alleviate the situation when the development of ICT in the countryside was lagging behind the times, and promote the establishment of a rural data resource system. In the process of exploring the obstacle factors of coupling coordination, it was found that the obstacle factors have gradually shifted from the early digitization problem to the rural problems, which also confirms that Xinjiang’s digital economy level has been constantly improving. However, the rural revitalization strategy was put forward late, and rural development in some areas is still relatively backward, which had affected the process of developing the CCD of Xinjiang’s DEL and RRL.

#### 4. Discussion

Current research on the digital economy for rural revitalization focuses mainly on theoretical studies that explore the related roles and mechanisms. Some studies have also explored the relationship between the DEL and RRL. However, these studies have not clearly indicated that the coordinated development of the two is an interactive and dynamic process, and there is a lack of in-depth exploration of the mechanisms for their coordinated development. Additionally, the research has mainly centered on the national and city clusters, neglecting the development potential of the digital economy in promoting rural revitalization at the local and regional levels. In this study, we aimed to address this knowledge gap and provide new insights into the coordinated development of the digital economy and rural revitalization. Specifically, we made improvements in the following three aspects:

Firstly, this study made a significant theoretical contribution by quantitatively analyzing the relationship between the DEL and RRL. It addressed the research gap in this field and provided a foundation for future research and policy formulation on rural development and the thriving digital economy in Xinjiang.

Secondly, it explored the heterogeneity of DEL and RRL development by examining various regions in Xinjiang as case studies. This macro-level perspective helped to identify and comprehend the disparities in DEL and RRL across different regions, thereby offering valuable insights into promoting more-balanced development.

Thirdly, the study utilized an improved CCD model to analyze the interaction between the digital economy and rural revitalization system. Additionally, an obstacle degree model was employed to conduct an in-depth analysis of the factors impeding the coordinated development of the DEL and RRL. These methodological approaches enhanced the research

on the relationship between the DEL and RRL and laid a solid theoretical foundation for evidence-based policy recommendations.

In the future, research should explore and expand on the findings to deepen our understanding of the relationship between the digital economy and rural revitalization. For example, future research can consider incorporating more factors such as the policy environment, social culture, and environmental sustainability to comprehensively evaluate the overall effects of the digital economy and rural revitalization. Alternatively, efforts can be made to enhance the quality and feasibility of data by improving their accuracy and reliability, thereby enabling a more precise assessment of the relationship between the digital economy and rural revitalization.

## 5. Conclusions and Suggestions

### 5.1. Conclusions

With the continuous development and wide application of digital technology, the digital economy is gradually spreading into rural areas, promoting the integration of modern industries and traditional industries, improving the rural infrastructure, and having a significant impact on rural development. At present, few scholars in the academic community have studied the relationship between the digital economy and rural revitalization from the perspective of quantitative analysis. Therefore, in this paper, we aimed to empirically investigate the development of rural revitalization promoted by the digital economy in Xinjiang. First, two evaluation index systems were established to reveal the development of Xinjiang's DEL and RRL from a temporal and spatial perspective. The CCD in 14 prefectures was evaluated using an improved CCD model. In addition, the obstacle degree model was used to calculate the obstacle value of the first-level index to the CCD, and the influence of each index in the different stages of coupling coordination was discussed. The conclusions reached in this paper are as follows:

From the comprehensive scores of the two systems, we found that Xinjiang's digital economy and Xinjiang's rural revitalization have made certain progress over the years, and the overall level has shown an increasing trend. Among them, the development of northern Xinjiang was the best, followed by eastern Xinjiang, and southern Xinjiang was relatively backward. In general, Xinjiang's DEL was better than its RRL, and the RRL in the different prefectures of Xinjiang had great room for development. In the second phase (from 2017 to 2019), the development speed of the RRL exceeded the DEL. Based on an analysis from the perspective of economic results, the rural revitalization strategy launched by the state during this period had a positive impact on the rural development of Xinjiang, bringing good social benefits, and the level of rural revitalization in Xinjiang greatly improved.

The results of the CCD model showed that the development of CCD between DEL and RRL can be divided into two stages. In stage 1 (from 2013 to 2016), Xinjiang's DEL development was better than that of rural revitalization, with a weight ratio of 0.6:0.4. In stage 2 (from 2017 to 2019), rural revitalization development was better than that of the digital economy, with a weight ratio of 0.38 to 0.62. The interaction between DEL and RRL was gradually increased. The CCD of the 14 prefectures (or cities) was improved, but there was still significant regional heterogeneity, which was reflected by higher value in northern Xinjiang and lower value in southern Xinjiang.

Through the diagnosis of obstacles, it was found that the CCD of DEL and RRL is influenced by many factors, and the barrier factors are different for each stage. Among them, digital infrastructure had the highest level of obstacles. In the first phase of coupling coordination, the average obstacle degree reached 34.72%; in the second phase of coupling coordination, the average obstacle degree reached 21.27%. In addition, the two factors of thriving businesses and social etiquette and civility had a greater impact on the second phase, and the average obstacle degrees reached 16.23% and 16.17%, respectively. By comparing the obstacle factors of the two phases, we found that the factors affecting development of the CCD between Xinjiang's DEL and RRL had changed from early digitization problems to rural problems. At present, Xinjiang's DEL is relatively high,

while rural revitalization started late and its level is still low, which has greatly affected CCD development.

To sum up, in this paper, we conducted a comprehensive study on the development of the digital economy and rural revitalization in Xinjiang that has enriched research in the field of the digital economy. At the same time, focusing on Xinjiang as the research object filled a current research gap on the digital economy and rural revitalization and development in remote areas. In addition, studying the spatial and temporal differences and bottlenecks in the development of the digital economy and rural revitalization can provide reference for academics to explore the high-quality development of the two, enrich the current theoretical research, and provide feasible suggestions for enhancing regional development.

### 5.2. Proposal

After analysis, we found that development of the CCD of Xinjiang's DEL and RRL has increased yearly, but there is still some distance to go from the perspective of high-quality coordination. What can we do to harness the power of the digital economy to promote comprehensive rural development, enhance the RRL and achieve balanced development? Based on this study, we offer some suggestions in the following paragraphs that can help to promote their coordinated development.

1. Promote the development of rural digital infrastructure. The above study revealed that the current CCD in Xinjiang is not ideal and remains in a primary coordination stage. The 14 prefectures (or cities) have different levels and obvious heterogeneity, which means that rural areas should seize the opportunity for digital development and promote digital infrastructure in their areas. Providing reliable infrastructure to rural areas is the key to upgrading the DEL and RRL. Based on the theory of outcome economics, governments and relevant institutions should invest in infrastructure to promote the spread and use of digital technologies in rural areas. Faced with the problem of brain drain in rural areas, the government can provide entrepreneurship support and funding to encourage young people and rural residents to pursue innovative and entrepreneurial activities in the digital field. In addition, platforms such as business incubators and technology transfer centers have been established to promote the implementation and application of digital technologies in rural areas.
2. Efficiently boost industrial prosperity and enhance the use of digital technologies in rural industries. By strengthening rural digital industry and building the whole industrial chain, we should strengthen the integrated application of modern technologies such as Blockchain, IoT, Big Data, and AI in the five aspects of rural revitalization. For example, digital technology should be fully utilized in the distribution of agricultural products to ensure their quality and safety, increase farmers' incomes and create a high-level and high-quality rural e-commerce industry. In addition, we should grasp the geographical advantages of being located in the Silk Road Economic Belt, promote digital trade exchanges and cooperation among countries and regions, and make use of the power of digital development to bring more unique products from Xinjiang to the international market.
3. Break down data silos and system barriers and attract high-quality resources to rural areas. Breaking the "digital divide" between Xinjiang's regions and states and realizing the circulation of resource elements are important to increase the CCD between the DEL and RRL. Existing research has found that problems such as fragmentation of rural data and information asymmetry limit the interoperability and synergy between the DEL and RRL. Data collection and analysis should be vigorously undertaken in rural areas. The government can establish data collection and analysis mechanisms to monitor economic activities and social indicators in rural areas to provide empirical support and guidance for policy decisions. In addition, the private sector and research institutions are encouraged to participate in data analysis to promote digitization and intelligent development in rural areas.

4. We will adapt to local conditions and implement coordinated integration of regional development. By region, northern Xinjiang has the strongest capacity for coupling coordination, followed by eastern and southern Xinjiang. Therefore, to realize coordinated development across the board in Xinjiang, we will continue to improve the DEL in northern Xinjiang and take the lead in sharing experiences and good practices with eastern and southern Xinjiang. Simultaneously, the eastern and southern Xinjiang regions also need to rely on their rural resources, make use of their unique advantages of local scenery, local culture, and featured agriculture, actively cultivate industries such as sightseeing agriculture and farming experience, and build new forms of the rural digital economy with the help of tourism.

Finally, we hope that this study contributes to academic research and offers practical implications for policymakers striving for sustainable and inclusive rural development in the digital era.

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## References

1. Ren, B.; Dou, Y. The path and policy of promoting China's industrial structure upgrading in the new economy during the 14th Five-Year Plan period. *Econ. Manag. Rev.* **2021**, *37*, 10–22. [\[CrossRef\]](#)
2. Guo, X. The reality and path selection of digital economy cooperation between China and GCC countries. *Arab. World Stud.* **2022**, *202*, 21–41+157–158.
3. Zhang, Y.; Luan, J. Digital Economy Empowers Rural Revitalization: Theoretical Mechanism, Constraints and Promotion Path. *Reform* **2022**, *339*, 79–89.
4. Peng, C.; Ma, B.; Zhang, C. Poverty alleviation through e-commerce: Village involvement and demonstration policies in rural China. *J. Integr. Agr.* **2021**, *20*, 998–1011. [\[CrossRef\]](#)
5. Xie, W.; Song, D.; Bi, Y. Digital Village Construction in China: Internal Mechanism, Connection Mechanism and Practice Path. *J. Soochow Univ. Philos. Soc. Sci.* **2022**, *43*, 93–103. [\[CrossRef\]](#)
6. Ye, Y.; Chen, S.; Li, C. Financial technology as a driver of poverty alleviation in China: Evidence from an innovative regression approach. *J. Innov. Knowl.* **2022**, *7*, 100164. [\[CrossRef\]](#)
7. Ma, Q.; Mentel, G.; Zhao, X.; Salahodjaev, R.; Kuldashaeva, Z. Natural resources tax volatility and economic performance: Evaluating the role of digital economy. *Resour. Policy* **2022**, *75*, 102510. [\[CrossRef\]](#)
8. Tapscott, D. *The Digital Economy: Promise and Peril in the Age of Networked Intelligence*; Mc Graw-Hill: New York, NY, USA, 1996.
9. Sun, J. From Digital Economy to Digital Trade: Connotation, Characteristics, Rules and Implications. *Int. Econ. Trade Explor.* **2020**, *36*, 87–98. [\[CrossRef\]](#)
10. Tian, G.; Zhang, X. Digital economy, non-agricultural employment and social division of labor. *Manag. World* **2022**, *38*, 72–84. [\[CrossRef\]](#)
11. Ye, X.; Du, Y.; He, W. Employment structure effect of digital economy development. *J. Financ. Trade* **2022**, *32*, 1–13. [\[CrossRef\]](#)
12. Xu, W.; Zhao, J.; Liu, C. Spatial effects of digital economy development on urban carbon emissions. *Geogr. Res.* **2022**, *41*, 111–129.

13. Li, Z.; Li, N.; Wen, H. Digital Economy and Environmental Quality: Evidence from 217 Cities in China. *Sustainability* **2021**, *13*, 8058. [\[CrossRef\]](#)
14. Wang, L.; Shao, J. Digital economy, entrepreneurship and energy efficiency. *J. Energy* **2023**, *269*, 126801. [\[CrossRef\]](#)
15. Zhao, C.; Wang, W.; Li, X. How digital transformation affects enterprise total factor productivity. *Financ. Trade Econ.* **2021**, *42*, 114–129. [\[CrossRef\]](#)
16. Zhang, W.; Zhao, S.; Wan, X.; Yao, Y. Study on the effect of digital economy on high-quality economic development in China. *PLoS ONE* **2021**, *16*, e0257365. [\[CrossRef\]](#) [\[PubMed\]](#)
17. Wang, S.; Xue, Z. Has the development of the digital economy improved green total factor productivity in China?—A study based on data at the provincial level in China. *Front. Environ.* **2023**, *11*, 1073997. [\[CrossRef\]](#)
18. Xiao, Y.; Wu, S.; Liu, Z.; Lin, H. Digital economy and green development: Empirical evidence from China's cities. *Front. Environ.* **2023**, *11*, 1124680. [\[CrossRef\]](#)
19. Jing, W.; Sun, B. Digital Economy Promotes High-quality Economic Development: A Theoretical Analysis Framework. *Economist* **2019**, *242*, 66–73. [\[CrossRef\]](#)
20. Fu, L.; Liu, B.; Zhu, Z.; Cao, J.; Sun, C.; Yu, Z. Analysis of the coupling coordinated development and evolutionary trend of digital economy and ecological environment. *Front. Environ.* **2022**, *10*, 1006354. [\[CrossRef\]](#)
21. Guo, Y.; Mao, H.; Ding, H.; Wu, X.; Liu, Y.; Liu, H.; Zhou, S. Data-Driven Coordinated Development of the Digital Economy and Logistics Industry. *Sustainability* **2022**, *14*, 8963. [\[CrossRef\]](#)
22. Wang, Q.; Jiang, H.; Xu, J. The Study of the Effect of the Digital Economy on the Low-Carbon Transformation of Urban Economies under Public Attention. *Sustainability* **2022**, *14*, 16448. [\[CrossRef\]](#)
23. Zhang, W.; Zhang, S.; Bo, L.; Haque, M.; Liu, E. Does China's Regional Digital Economy Promote the Development of a Green Economy? *Sustainability* **2023**, *15*, 1564. [\[CrossRef\]](#)
24. Liu, C.; Han, L. China's rural development process and regional disparities: Current situation, problems and reflections—Based on China's Rural Development Index. *Rural Econ.* **2016**, *410*, 3–8.
25. Huang, X. The road of rejuvenation based on urbanization and rural revitalization: Urban-Rural integrated development. *Rural Econ. Technol.* **2023**, *34*, 6–9.
26. Katara, S.K. Envisioning Smart Villages through Information and Communication Technologies—A Framework for Implementation in India. In *International Conference on Digital Transformation and Global Society*; Springer: Berlin/Heidelberg, Germany, 2016; pp. 463–468.
27. Sutherland, W.; Jarrahi, M.H. The sharing economy and digital platforms: A review and research agenda. *Int. J. Inf. Manag.* **2018**, *43*, 328–341. [\[CrossRef\]](#)
28. Young, J.C. Rural digital geographies and new landscapes of social resilience. *J. Rural Stud.* **2019**, *70*, 66–74. [\[CrossRef\]](#)
29. Mossberger, K.; LaCombe, S.; Tolbert, C.J. A new measure of digital economic activity and its impact on local opportunity. *Telecomm. Policy* **2022**, *46*, 102231. [\[CrossRef\]](#)
30. Zhu, Q.; Bai, J.; Peng, C.; Zhu, C. Has Informatization Improved Agricultural Productivity? *China Rural Econ.* **2019**, *412*, 22–40.
31. Zhao, D.; Ding, Y. Mechanism, path and countermeasures of digitalization to promote rural revitalization. *J. Hunan Univ. Sci. Technol. Soc. Sci. Ed.* **2021**, *24*, 112–120. [\[CrossRef\]](#)
32. Feng, C.; Xu, H. Current practical dilemma and breakthrough path of digital village construction. *J. Yunnan Normal Univ. Philos. Soc. Sci. Edi.* **2021**, *53*, 93–102.
33. Xu, X.; Zhang, M. Research on Measuring the Scale of China's Digital Economy: Based on the Perspective of International Comparison. *China Ind. Econ.* **2020**, *386*, 23–41.
34. Li, Y.; Han, P. Comprehensive evaluation and forecast of China's digital economy development. *Stat. Decis.* **2022**, *38*, 90–94. [\[CrossRef\]](#)
35. Han, L.; Wang, S.; Liu, C. Rural Development Process and Regional Comparison in China: Based on the 2011–2017 China Rural Development Index. *China Rural Econ.* **2019**, *415*, 2–20.
36. Yan, Z.; Wu, F. From binary division to integrated development: A study on the evaluation index system of rural revitalization. *Economist* **2019**, *246*, 90–103. [\[CrossRef\]](#)
37. Lu, F.; Pang, Z.; Deng, G. Measurement and formation mechanism of regional differences in rural revitalization and development in China. *Explor. Econ. Issues* **2022**, *477*, 19–36.
38. Li, Z. Research on Coupling Mechanism and Coordinated Development of Rural Revitalization-Rural Tourism System: A Case Study of Fenghuang County, Hunan Province. *Geogr. Res.* **2019**, *38*, 643–654.
39. Cong, X. The form, properties and misuse of coupling degree models in geography. *Econ. Geogr.* **2019**, *39*, 18–25. [\[CrossRef\]](#)
40. Xu, Y.; Liu, Z.; Hong, J.; Wang, J. Evaluation of comprehensive development level and obstacle analysis of urban parks in China. *Ecol. Econ.* **2021**, *37*, 87–93+123.
41. Liu, J.; Yang, Y.; Zhang, S. Research on the measurement and driving factors of China's digital economy. *Shanghai Econ. Res.* **2020**, *381*, 81–96. [\[CrossRef\]](#)
42. Pan, W.; He, Z.; Pan, H. Spatial-temporal evolution and distribution dynamics of China's digital economy development. *China Soft Sci.* **2021**, *370*, 137–147.

43. Fang, F.; Li, Y. Evaluation of the difficulty of rural revitalization in the western region and identification of key counties. *Econ. Geogr.* **2022**, *42*, 8–18. [[CrossRef](#)]
44. Mao, J.; Wang, L. Construction of Rural Revitalization Evaluation Index System: Based on Empirical Evidence at the Provincial Level. *Stat. Decis.* **2020**, *36*, 181–184. [[CrossRef](#)]
45. Miao, L.; Wen, B.; Wen, Q. Coupling and Coordination Relationship between Local Financial Investment in Education and Economic Development Level in China. *Econ. Geogr.* **2021**, *41*, 149–157. [[CrossRef](#)]

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