

# Research on Coupling and Synergy Analysis Based on Regional Digital Finance, Regional Economic Development, and Regional Financial Risk

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## Abstract

**Objectives** With the increasing degree of influence of digital finance, financial risk, and financial development, exploring the relationship between the three based on a regional perspective is beneficial to regional governments in formulating relevant policies, which in turn will strengthen the degree of digital finance and regional amount development in the region and reduce the corresponding risks, and has positive significance for the comprehensive development of the regional economy. **Methods** Based on the rooting theory, this paper constructs a digital finance indicator system with four indicators, a regional risk indicator system with eight indicators, and a regional financial development system with six indicators, respectively. On this basis, the indicators are weighted by using the CRITIC model and AHM model. Based on the principle of synergy, the theory of synergy between the three subsystems is quantitatively analyzed with the principle of operation in line with the synergistic system. Finally, taking Beijing, China, as an example, by selecting the annual data from 2011 to 2019, the example deduction analysis and policy recommendation formulation are carried out. **Results** The results show that the synergistic analysis of digital finance, financial risk, and regional finance in Beijing, China, as an example, are reasonable. During the period from 2011 to 2019, Beijing's digital finance, regional economy, and regional financial risk showed an M-shaped development trend with alternating increases and decreases, and the phases compounded can be divided into the following five stages: the overall region from 2011 to 2012 conforming to the overall upward trend of the system, the region from 2012 to 2014 conforming to the overall decline of the system, the regional economic weakness from 2014~2017 with regional risk stability, regional economic rise with the weak digital amount in 2017~2018, and regional conformity system rise in 2018~2019. Finally, certain recommendations are put forward. **Conclusions.** Compared with the traditional single-weight synergy theory, the synergy analysis model under the coupled weighting approach based on CRITIC and AHM has reasonable analysis results under the perspective of fixed weighting and synergy analysis, and the quantified synergy process is more universal.

## Keywords

Digital Finance, Regional Financial Risk, Coupling Synergy Analysis.

## 1. Introduction

In recent years, the development of digital finance in China has achieved great results. the Alipay account system was launched in 2004, to the online money market fund Yu Ebao in 2013, China's digital finance has become a leading global flag in just a decade. With the development of digital finance, its spatial agglomeration and regional convergence gradually appear [1]. Therefore, studying the synergistic effect of digital finance, regional economic development and regional financial risks and finding the interactive relationship among them are of great guiding significance to promote the sound development of digital finance, the coordinated development of regional economy and the reduction of regional financial risks.

At present, a large number of scholars have pointed out and studied the relationship among digital finance, regional economic development and regional financial risks. In terms of digital finance and regional economic development, Huang Yiping [2] studied the impact of digital finance on the economy from qualitative analysis. Zhang Heng [3] used a comprehensive evaluation and coupling coordination degree model to measure the spatial-temporal coupling coordination of digital inclusive finance and regional economic development. Jiang Changliu [4] explored the internal mechanism of digital inclusive finance in empowering high-quality economic development from innovation-driven. In addition, many domestic and foreign scholars have studied the indirect positive effects of digital finance on economic growth: enhancing regional innovation capability [5], narrowing the income gap between urban and rural areas [6], encouraging entrepreneurship, promoting regional employment [7], promoting agricultural economic development [8], and promoting household consumption [9]. In terms of digital finance and regional financial risks, Huang Yiping [10] pointed out that the research on the relationship between digital finance and financial risks is of great significance to the development of digital finance. Many studies focused on the impact of Internet finance on the risk-taking of commercial banks through empirical tests [11-13]. In terms of regional economic development and regional financial risks, Geng Delin [14] studied the spatial spillover effect of financial risks on regional economic development, Liu Haiyong [15] discussed the strategy of commercial bank financial risk control to help regional economic development, Ding Zhiguo [16] used empirical analysis to show that economic development in rural areas was strongly affected by financial risks.

In summary, a large number of studies have focused on the relationship among digital finance, regional economic development and regional financial risks. However, there is a lack of research on the coupling coordination of the three as a composite subsystem. Digital finance, regional economic development and regional financial risks are the whole of mutual influence, mutual penetration and close connection. Clarifying the coordinated development of the three is of great significance to the development of digital finance and regional economy. For the study of coupling coordination of three systems, scholars in various fields have applied the method [17-19], which fully illustrates its rationality and significance. Based on this, this paper uses the coupled collaborative research to study the collaborative development of digital finance, regional economic development and regional financial risks as three sub systems. The AHM-CRITIC comprehensive weighting method is used to determine the data weight, and the provincial panel data are used for empirical analysis. Finally, the synergistic relationship between the three is obtained.

## **2. Index System Construction of Digital Finance, Regional Economic Development and Regional Financial Risk Subsystem**

### **2.1. Index System Construction of Digital Finance Subsystem**

In order to study the synergy of regional digital finance, regional economic development and regional financial risks, it is necessary to quantitatively measure the three systems and establish an index system. Following the principles of systematic, operability, objectivity and comprehensiveness, this paper constructs the evaluation index system of digital finance, regional economic development and regional financial risk subsystems through extensive literature review, collection and extraction.

Digital finance refers to a new generation of financial business that combines the Internet and information technology with traditional financial service formats. The starting point of China's digital finance can be traced back to the launch of Alipay's account system in 2004, and the industry usually regards 2013 as the first year of development of China's digital finance [10]. For the evaluation index system of digital finance, many scholars [1] have done comprehensive research and the results are highly scientific and objective. Therefore, this paper refers to the data obtained from the digital inclusive finance index of Peking University, and constructs the evaluation index system of digital finance from four aspects: the total index (U1), the coverage width (U2), the depth of use (U3) and the degree of digitalization (U4).

### **2.2. Regional Economic Development**

#### **2.2.1. Economic Development Structure**

Regional economy is the national economy distributed to various administrative regions, which combines internal factors and external conditions of economic development in a certain region. Regional economic development is a process in which the original economic structure, economic scale and economic benefits change under the mutual influence and interaction of various economic factors within and among regions. The construction of regional economic development index refers to the study of Qiu Shaolang [20], Xie Yanlong [21], Huo Yuan [17] and Zhang Heng [3]. On the basis of summarizing the existing research, combined with the definition of regional economic development and the principle of index selection, this paper selects three primary indexes: economic development structure (V1), economic development scale (V2) and economic development benefit (V3) and nine secondary indexes to measure the development level of regional economy.

Economic development structure reflects the composition and structure of the national economy, determines the basic mode of regional resource allocation, and is one of the important factors affecting regional economic growth. This paper selects the proportion of secondary industry to GDP (V11), the proportion of tertiary industry to GDP (V12), consumption ratio of urban and rural residents (V13) as the evaluation index under this dimension.

#### **2.2.2. Scale of Economic Development**

The scale of economic development is a direct reflection of the strength of regional economic development. Regional GDP, total investment in fixed assets and retail sales of social consumer goods reflect the scale of regional economic development. This paper selects Regional GDP (V21), total investment in fixed assets (V22) and retail sales of social consumer goods (V23) as the evaluation index [20, 21].

#### **2.2.3. Economic Development Benefits**

The Economic development benefits are an important indicator to measure economic development results. Per capita GDP, per capita disposable income of urban residents and regional fiscal revenue can reflect the economic development efficiency of a region. This paper

selects per capita GDP (V31), per capita disposable income of urban residents (V32) and regional fiscal revenue (V33) as the evaluation index under this dimension.

## **2.3. Regional financial risk**

### **2.3.1. Macroeconomic Risk**

Regional financial risk is the financial risk the financial industry faces within the economic region. Regional financial risk is composed of financial risks within the region and regional external risks. Referring to the research results of Wu Shiwei [22], Wang Zujie [23] and Tan Zhongming [24] and combining with the principle of index selection, this paper determines three first-level indicators of macroeconomic risk (W1), regional commercial banks (W2) and regional financial ecology (W3) and ten second-level indicators to measure regional financial risk.

Economy is the basis for the development of the financial industry, and the sound operation of the macroeconomy is an effective guarantee for preventing financial risks. The growth rate of regional GDP is the most effective indicator for measuring macroeconomic development. If the growth rate is too low, it will be very likely to lead to insufficient funding sources of the financial industry and increase financial risks. Inflation rate is also an important factor affecting macroeconomics. Inflation within a certain range may have a certain role in promoting macroeconomics, but excessive inflation will greatly negatively impact economic development. Employment is an important factor in economic development. High unemployment often represents the emergence of many economic and social problems. Therefore, unemployment is also one of the important factors affecting macroeconomic risks. Based on the above analysis, this paper selects three indicators of regional GDP growth rate (W11), inflation rate (W12) and rate of unemployment (W13) as secondary indicators under macroeconomic risk [22].

### **2.3.2. Operational Risks of Commercial Banks in the Region**

Commercial bank is the pillar industry and main component of China's financial industry. Capital adequacy ratio (W21), non-performing loan ratio (W22), return on assets (W23), capital-income ratio (W24) and liquidity ratio (W25) are important indicators to reflect the operational risk of commercial banks. Therefore, this paper selects the above five indicators as secondary indicators under the operational risk of regional commercial banks [23].

### **2.3.3. Regional Financial Ecology**

Financial ecology refers to the ecological chain composed of the financial system and other related systems. Regional financial ecology is an important factor affecting regional financial risks. This paper selects the regional economic prosperity index (W31) and enterprise asset-liability ratio (W32) to measure regional financial ecology [24].

To sum up, this paper selects ten first-level indicators and 19 second-level indicators under the subsystem of digital finance, regional economic development and regional financial risk, and constructs the index system as shown in table 1.

**Table 1.** Index System of Digital Finance, Regional Economic Development and Regional Financial Risk Subsystem

Subsystem	First level indicator	Second level indicator	Unit	Positive/negative indicators
Digital financial indicator system (U)	Combined index (U1)	Combined index (U1)	1	+
	Coverage breadth (U2)	Coverage breadth (U2)	1	+
	Used depth (U3)	Used depth (U3)	1	+
	Digitized degree (U4)	Digitized degree (U4)	1	+
Regional Economic Development indicator system (V)	Economic development structure (V1)	Proportion of secondary industry to GDP (V11)	%	+
		Proportion of tertiary industry to GDP (V12)	%	+
		Consumption ratio of urban and rural residents (V13)	%	-
	Scale of economic development (V2)	Regional GDP (V21)	100 million yuan	+
		Total investment in fixed assets (V22)	100 million yuan	+
		Retail sales of social consumer goods (V23)	100 million yuan	+
	Economic development benefits (V3)	Per capita GDP (V31)	yuan	+
		Per capita disposable income of urban residents (V32)	yuan	+
		Regional fiscal revenue (V33)	100 million yuan	+
Regional financial risk indicator system (W)	Macroeconomic risk (W1)	Regional GDP growth rate (W11)	%	+
		Inflation rate (W12)	%	-
		Rate of unemployment (W13)	%	-
	Operational Risks of Commercial Banks in the Region (W2)	Capital adequacy ratio (W21)	%	+
		Non-performing loan ratio (W22)	%	-
		Return on assets (W23)	%	+
		Capital-income ratio (W24)	%	+
	Regional financial ecology (W3)	Liquidity ratio (W25)	%	+
		Regional economic prosperity index (W31)	1	+
Enterprise asset-liability ratio (W32)		%	-	

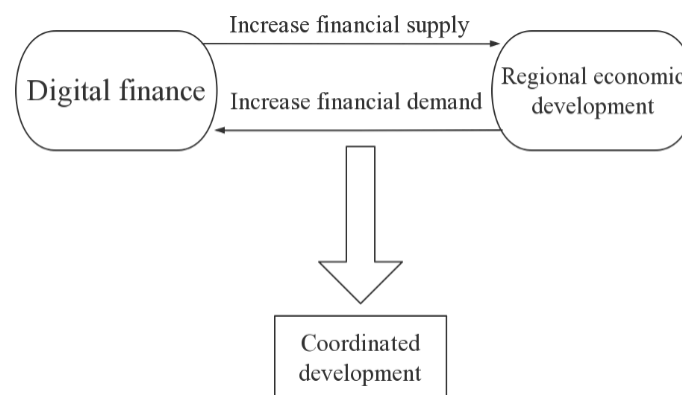
### 3. Synergistic Effect Among Digital Finance, Regional Financial Risks and Regional Economic Development

#### 3.1. Research on the Synergy Between Digital Finance and Regional Economic Development

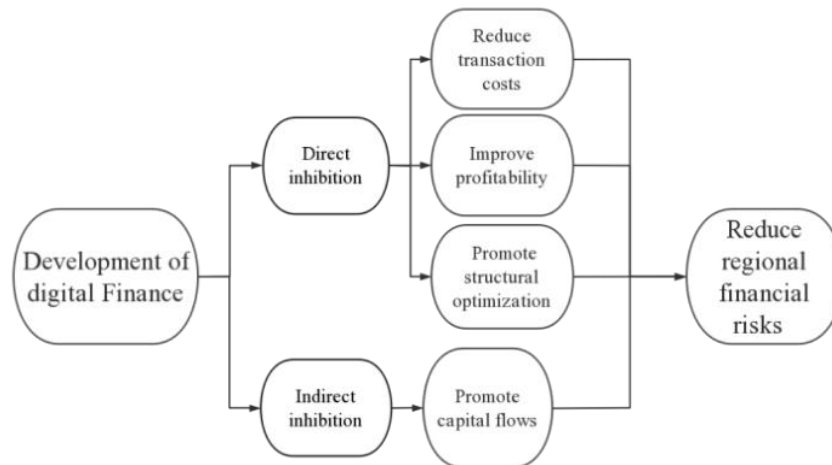
In recent years, as digital technology developed rapidly, digital finance is sharply changing the current situation of China's financial industry and regional economic development. The rise of digital finance makes the payment more convenient and microfinance easier. However, for digital financial enterprises different from traditional banks, the relevant laws and regulations are not perfect, and the supervision is relatively loose, so the prevention of regional financial risks is imminent. This section mainly discusses the synergy between digital finance and regional economic development.

According to the 2011-2020 Peking University Digital inclusive finance index and China Financial Yearbook (Statistics), it is concluded that the digital inclusive finance index level and regional economic development in central and western China are lagging behind the eastern coastal areas, but the relative gap has been narrowing. At the same time, the digital inclusive financial index has grown steadily across regions. Digital finance has the effect of slowing down the geographical exclusion of traditional finance, which can alleviate the consumption gap between urban and rural residents and optimize the structure of economic development. Digital finance is an important driving force to promote the integrated development of rural industries [1].

Scholars [2] use models such as comprehensive evaluation and coupling coordination degree to find that the development of digital Inclusive Finance shows obvious regional convergence and spatial agglomeration, and the development of digital finance and regional economic development promote each other. On the one hand, digital finance enhances the financial supply. It reduces the threshold of entering the financial industry, reduces the cost of a large number of financial services, and expands the audience of financial services, thereby contributing to regional economic development. On the other hand, with the development of regional economy, the demand for finance also increases, making a large number of resources flow into the field of digital finance, which in turn promotes the development of digital finance. To sum up, as shown in Figure 1, the supply of digital finance drives regional economic development, and the demand for regional economic growth drives the progress of digital finance. They form a virtuous circle and achieve common and coordinated development.



**Figure 1.** Synergy between digital finance and regional economic development



**Figure 2.** Inhibitory effect of digital financial development on regional financial risk

### 3.2. Research on the Synergy Between Digital Finance And Regional Financial Risks

With the development of digital finance, the prevention of regional financial risks has become an important issue. What is the relationship between the development of digital finance and regional financial risks? Through the analysis of China's digital financial development index & its changes and systemic financial risks index & its changes from 2011 to 2018, and the empirical analysis of the impact of inclusive finance on regional financial risks, Literature [3] found that there was a significant reverse change between the two. The development of digital finance has a significant inhibitory effect on regional financial risks. Its effect is divided into direct and indirect inhibition, as shown in Figure 2.

Firstly, the development of digital finance accelerates the development of financial intermediaries, thereby enhancing their ability to obtain information and reducing transaction costs. Secondly, digital finance promotes financial innovation, thereby improving profitability. Thirdly, digital finance encourages the optimization of financial structure and distribution of capital. These three together constitute the factors that directly inhibit regional financial risks. Furthermore, the development of digital finance promotes the transfer of capital to high-profit industries and improves the liquidity and efficiency of capital use. Since China's capital has not been so surplus that fraudulent speculation has been triggered, it has indirectly curbed regional financial risks.

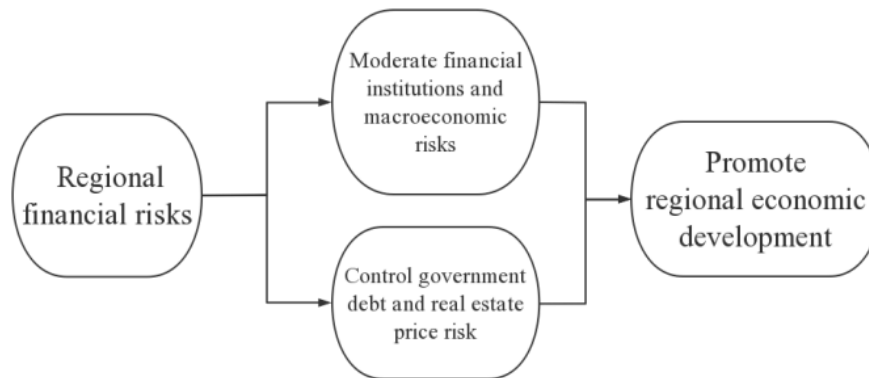
### 3.3. Research on the Synergy Between Regional Economic Development And Regional Financial Risks

With the continuous development of the regional economy, accompanied by systemic financial risks in the region, too fast economic growth rate indicates inflation risk. Ensuring the development speed of the regional economy and preventing potential financial risks has become an extremely important issue. Many scholars have studied it.

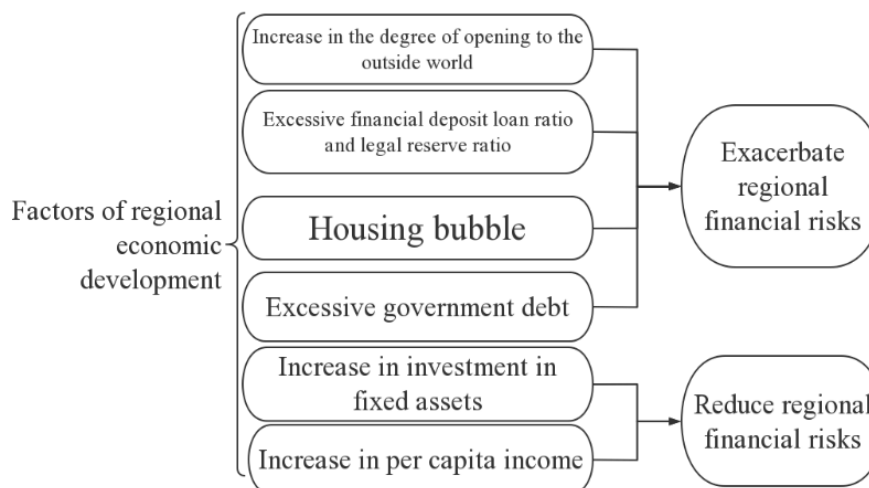
Some scholars [4] pointed out that the spatial spillover effect of financial risks on regional economic development is quite significant. As shown in Figure 3, the effective control of real estate prices and local government debt risk will help regional economic development. However, moderate financial and real estate institutional and macroeconomic risks also contribute to regional economic development. What we need to do is to prevent the accumulation of financial risks across regions. Financial risks are often transmitted through the linked real economy and financial markets.

Furthermore, the literature [5], through the correlation study between the regional financial risks and regional economic development, found that some factors affect regional economic

development. As shown in Figure 4, the increase in the degree of opening up to the outside world of the region, the high financial deposit-loan ratio and the statutory reserve ratio, the increase in the proportion of real estate investment caused by the real estate bubble, will aggravate the regional financial risks to a certain extent. In addition, the local government's debt is huge and heavily dependent on land resources. With the introduction of strictly real estate market regulation policies, government debt has a certain risk of default. On the contrary, fixed asset investment and per capita income can reduce regional financial risks.



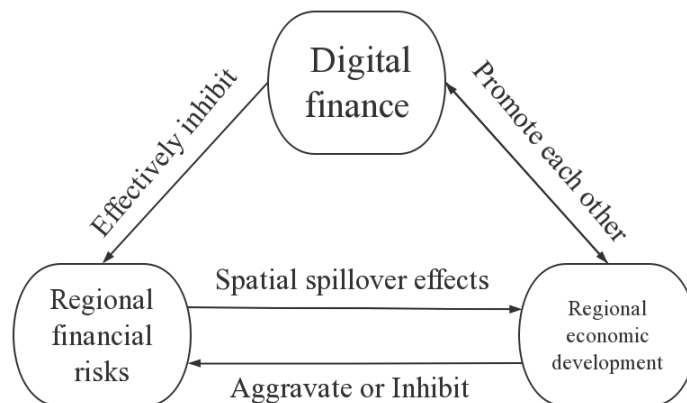
**Figure 3.** Effect of regional financial risks on regional economic development



**Figure 4.** Effects of different factors of regional economic development on regional financial risks

### 3.4. Research on the Synergistic Effect Among Regional Economic Development, Regional Financial Risks and Digital Finance

Based on the above research, as shown in Figure 5, this paper can draw the following conclusions: there is a bidirectionally promoted spatial-temporal coupling synergy between the development of regional economy and the popularization of digital finance. The development of digital finance can effectively restrain regional financial risks. The development of regional economy can aggravate and reduce the risk of regional amount, which depends on the health of regional economic development model. Regional financial risk has a spatial spillover effect on regional economic development.



**Figure 5.** Synergy among regional economic development, regional financial risk and digital Finance

## 4. Construction of coupling model based on AHM-CRITIC

### 4.1. Attribute Hierarchical Model

The index system of digital finance, regional economic development and regional financial risks has been established above. However, the dimensions of these indicators are not equal, and it is difficult to determine the weight, which is also difficult to be directly used for coupling collaborative analysis. In this paper, the AHM-CRITIC comprehensive weighting method is used to determine the data weight, and the Lagrange multiplier method is used to optimize the solution. The method is introduced as follows: AHM (Attribute Hierarchical Model) is a method for solving the index weight [6] proposed by Professor Cheng Qiansheng on the basis of AHP (Analytic Hierarchy Process) proposed by Professor Satty. Its basic principles are as follows [7]: Step1: Let A be the target layer and B be the criterion layer. The indexes are  $X_1, X_2 \dots X_n$ . C is the index layer, where  $X_j$  corresponds to  $X_{j1}, X_{j2} \dots X_{jm}$ . First, we compare any two elements  $X_i, X_j (i \neq j)$  in the criterion layer B pairwise. The relative importance of  $X_i$  to  $X_j$  is denoted as  $a_{ij}$ , it conforms to the following formula:

$$a_{ij} \geq 0, a_{ji} \geq 0, a_{ij} + a_{ji} = 1, (i \neq j) \quad (1)$$

$$a_{ij} = 0, 0 \leq i \leq n, (i = j) \quad (2)$$

The matrix  $A_{n \times n}$  composed of  $a_{ij}$  is called the attribute judgment matrix.  $a_{ij}$  can be derived from the following algorithm (the value of  $b_{ij}$  in the formula is derived from the Saaty scale method):

① When  $i \neq j$

$$a_{ij} = \begin{cases} \frac{Uk}{Uk+1} & (b_{ij} = k) \\ 0.5 & (b_{ij} = 1) \\ \frac{1}{Uk+1} & (b_{ij} = \frac{1}{k}) \end{cases} \quad (3)$$

② When  $i = j, a_{ij} = 0$

Step2: Calculate the relative attribute weight vector  $W_A = (W_A(1), W_A(2), \dots, W_A(n))^T$  of matrix  $A_{n \times n}$ , which is the composite weight vector of layer B index relative to layer A. The formula is as follows:

$$W_A(i) = \frac{2}{n(n-1)} \sum_{j=1}^n a_{ij} \quad (4)$$

Step3: Compare the indexes corresponding to  $X_j(j = 1, 2, \dots, n)$ , and calculate their attribute judgment matrix  $C_j$  and relative attribute weight vector  $W_{C_j}(j = 1, 2, \dots, n)$  respectively by the above method.

Step4:  $W_C = (W_{C_1}, W_{C_2}, \dots, W_{C_n})$ ,  $W_{AC}$  is the composite weight vector of layer C index relative to layer A. The formula is:

$$W_{AC} = W_A \times W_C \quad (5)$$

## 4.2. CRITIC Method

CRITIC (*Criteria Importance Though Intercriteria Correlation*) is an objective weighting method proposed by Diakoulaki. It determines the objective weight according to the comparative strength and conflict between indicators. The former is reflected in the form of standard deviation between indicators. The greater the standard deviation, the greater the numerical fluctuation of each index, the greater the contrast strength. The latter is reflected by the correlation coefficient between indicators. The greater the correlation coefficient, the lower the conflict between indicators. The basic principle is as follows [8], Assuming that there are m schemes and n indexes, the evaluation matrix can be expressed as:

$$X = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \vdots & \vdots & \dots & \vdots \\ x_{n1} & x_{n2} & \dots & x_{nm} \end{pmatrix} \quad (6)$$

Step1: Index co-direction: positive index refers to the index that the greater the value is, the better the effect is. Negative index refers to the index that the smaller the value is, the better the effect is. Usually, co-direction processing is needed to transform the negative index into a positive index.  $\max|X_i|$  is set to represent the maximum value of line i of matrix X. p is the coordination coefficient. The matrix processed by co-direction is  $X'$ , and the conversion formula is:

$$x_{ij}' = \frac{1}{p + \max|X_i| + x_{ij}} \quad (7)$$

Step2: dimensionless index data: the meaning and unit of each index in matrix  $X'$  are different, so dimensionless processing is required to obtain the standard matrix  $X''$ . The processing formula is:

$$x_{ij}'' = \frac{x_{ij}'}{\sqrt{\sum_{j=1}^m (x_{ij}')^2}} \quad (8)$$

Step3: Calculate the objective weight of the index: set  $\bar{x}_i''$  as the mean value of the i-th row element of matrix  $X''$ ;  $cov(X_i'', X_j'')$  is the covariance of rows i and j of the standard matrix  $X''$ . The standard deviation  $s_i$  of each index data and the correlation coefficient  $\rho_{ij}$  between the indexes can be obtained:

$$s_i = \sqrt{\frac{1}{m} \sum_{j=1}^m (x_{ij}'' - \bar{x}_i'')^2} \quad (9)$$

$$\rho_{ij} = \frac{\text{cov}(X_i'', X_j'')}{s_i s_j} \quad (10)$$

Step4: Calculate the information content and objective weight of the index: let the information content of the i-th index be  $G_i$  and the objective weight be  $\beta_i$ . The greater the  $G_i$ , the greater the amount of information contained in the i-th index and the greater the weighting of the index. The formula is as follows:

$$G_i = s_i \sum_{j=1}^n (1 - \rho_{ij}) \quad (11)$$

$$\beta_i = \frac{G_i}{\sum_{j=1}^n G_j} \quad (12)$$

### 4.3. Lagrange Multiplier Method

Suppose there are m indexes in total, and the subjective weight of the i-th main index obtained by AHM-CRITIC method is  $w_{1i}$  and the objective weight is  $w_{2i}$ . In order to make the two as close as possible, the combined weight  $w_i$  can be obtained by Lagrange multiplier method [9]:

$$w_i = \frac{\sqrt{w_{1i} w_{2i}}}{\sum_i^m \sqrt{w_{1i} w_{2i}}} \quad (13)$$

## 5. Synergy Evaluation Model of Regional Financial Risks and Regional Economy

This part will start from the order parameters of the two subsystems of regional financial risks and regional economy, studying the synergy degree of the composite system of regional financial risks and regional economy, constructing the synergy degree evaluation model of regional financial risks and regional economy, and revealing the evolution law and trend of the system [34].

### 5.1. Subsystem

Regarding regional financial risks and regional economy as a complex system  $S = \{S_1, S_2\}$ , where  $S_1$  is the regional financial risks subsystem and  $S_2$  is the regional economic subsystem. Consider the subsystem  $S_j$  ( $j \in [1, 2]$ ), set  $e_j = (e_{j1}, e_{j2}, \dots, e_{jn})$  its order parameter as  $\beta_{ji} \leq e_{ji} \leq \alpha_{ji}$ ,  $n \geq 1, i=1, 2, \dots, n$ , among them,  $\alpha_{ji}$  and  $\beta_{ji}$  are the critical values of  $e_{ji}$  when the system is stable.

Suppose  $(e_{j1}, e_{j2}, \dots, e_{jn})$  is a positive index, and its value is similar to the order degree is positively correlated;  $(e_{j1} + 1, e_{j2} + 1, \dots, e_{jn})$  is the inverse index, and its value is the degree of system order is a negative correlation [35].

When the system order degree  $e_j$  of the order parameter component  $u_j(e_j)$  of the subsystem  $S_j$  is:

$$u_j(e_{ji}) = \begin{cases} \frac{e_{ji} - \beta_{ji}}{\alpha_{ji} - \beta_{ji}}, & i \in [1, l] \\ \frac{\alpha_{ji} - e_{ji}}{\alpha_{ji} - \beta_{ji}}, & i \in [l + 1, n] \end{cases} \quad (14)$$

Based on the synergetic theory, the contribution of the sequence parameter to the system can be calculated by the method of "integrating" each sequence parameter component. In this paper, the linear weighting method is used for integration, that is, the system order degree of the order parameter variable is:

$$u_j(e_j) = \sum^n w_j u_j(e_{ji}), w_j \geq 0, \sum^n w_j = 1 \quad (15)$$

In the formula,  $w_j$  is the weight of each order parameter.  $w_j$  is determined by the AHM-CRITICT.

## 5.2. Synergy Model of Collaborative System

The degree of synergy between the regional financial risks and the regional economic complex system reflects the degree of comprehensive coordination between the development of regional financial risks and the operation of the regional economic system, namely:

$$U_1(t) = sig(\cdot) \sqrt{|U_1(t) - U_1(t-1)| \cdot |U_2(t) - U_2(t-1)|} \quad (16)$$

$$\begin{aligned} sig(\cdot) &= 1, U_1(t) - U_1(t-1) \geq 0, U_2(t) - U_2(t-1) \geq 0 \\ &= -1, else \end{aligned} \quad (17)$$

$U_1(t)$  refers to the orderly contribution degree of the regional financial risks subsystem at time  $t$ ,  $U_2(t)$  is the orderly contribution degree of the regional economic subsystem at time  $t$ ,  $U(t) \in [-1, 1]$ . When  $U(t)$  tends to 1, it indicates that the greater the degree of synergy between regional financial risks and regional economy, the more effective the coordinated development between regional financial risks system and regional economic system or between internal factors. The smaller  $U(t)$ , the smaller the degree of coordination between the two systems, and the disordered development between regional financial risks and regional economic systems [35].

## 6. Regional digital finance, regional financial risks, and coordination of regional economic development

### 6.1. Study Area

Beijing is the capital of China, with 16 districts under its jurisdiction, with a total area of 16410.54 square kilometers. In 2020, the permanent population of Beijing was 21,189,095 people. The region's GDP is 361.255 billion yuan, of which the added value of the primary industry is 10.761 billion yuan, the added value of the secondary industry is 571.637 billion yuan, and the added value of the tertiary industry is 3,027.857 billion yuan. Considering that Beijing is the capital of China, it is beneficial to promote it to other regions by taking Beijing as a city.

### 6.2. Data Sources

The data in this article comes from the resources mentioned above and the public data of the Beijing Municipal Bureau of Statistics.

**Table 2.** Beijing's regional economy, regional financial risks, and regional digital financial subsystem order data indicators

First level indicator	Second level indicator	2011	2012	2013	2014	2015	2016	2017	2018	2019
U1	U1	0.00	0.22	0.43	0.49	0.62	0.65	0.78	0.90	1.00
U2	U2	0.00	0.20	0.34	0.51	0.60	0.66	0.76	0.89	1.00
U3	U3	0.00	0.26	0.53	0.45	0.49	0.58	0.86	0.89	1.00
U4	U4	0.00	0.21	0.48	0.50	0.85	0.73	0.72	0.95	1.00
V1	V11	1.00	0.89	0.80	0.64	0.31	0.10	0.00	0.01	0.15
	V12	0.00	0.06	0.19	0.34	0.68	0.91	0.98	1.00	0.88
	V13	0.00	0.11	0.22	0.33	0.44	0.56	0.67	0.89	1.00
V2	V21	0.00	0.10	0.22	0.32	0.42	0.54	0.70	0.88	1.00
	V22	0.00	0.18	0.37	0.54	0.68	0.84	1.00	0.71	0.64
	V23	0.52	0.59	0.65	0.76	0.83	0.89	0.94	0.00	1.00
V3	V31	0.00	0.08	0.17	0.24	0.32	0.43	0.56	0.70	1.00
	V32	0.00	0.10	0.21	0.32	0.85	0.70	0.56	0.45	1.00
	V33	0.11	0.21	0.00	0.43	0.65	0.77	0.88	0.99	1.00
W1	W11	1.00	0.51	0.49	0.37	0.26	0.20	0.23	0.17	0.00
	W12	0.18	0.73	1.00	0.55	0.18	0.09	0.00	0.14	0.59
	W13	0.00	0.70	0.70	0.85	1.00	0.85	0.95	0.82	0.62
W2	W21	0.68	1.00	0.33	0.00	0.68	0.60	0.27	0.55	0.61
	W22	0.95	1.00	0.95	0.85	0.57	0.33	0.27	0.21	0.00
	W23	0.24	0.11	0.58	0.00	0.06	0.34	0.23	0.23	1.00
	W24	0.52	0.07	0.10	0.11	0.11	0.18	0.27	1.00	0.00
	W25	1.00	0.94	0.80	0.60	0.46	0.31	0.16	0.05	0.00
W3	W31	0.00	1.00	0.98	0.89	0.35	0.10	0.50	0.62	0.65
	W32	0.00	0.06	0.13	0.40	0.65	0.97	0.92	1.00	1.00

**6.3. Determine the Index Weight**

Use the AHP-CRITIC method mentioned above to calculate the weight of the system order parameter index in the Beijing area. When getting the AHP indicator weight, we do the below assumptions by matrix, and then we get the target table.

**Table 3.** Assumption Matrix 1 for Digital financial indicator system (U)

	U1	U2	U3	U4
U1	1	3	3	5
U2	1/3	1	1	5/3
U3	1/3	1	1	5/3
U4	1/5	3/5	3/5	1

**Table 4.** Assumption Matrix 2 for Economic development structure (V1)

	V11	V12	V13
V11	1	3	1
V12	1/3	1	1/3
V13	1	1	1

**Table 5.** Assumption Matrix 3 for Scale of economic development (V2)

	V23	V22	V21
V23	1	3	3
V22	1/3	1	1
V21	1/3	1	1

**Table 6.** Assumption Matrix 4 for Economic development benefits (V3)

	V31	V32	V33
V31	1	1	1
V32	1	1	1
V33	1	1	1

**Table 7.** Assumption Matrix 5 for Macroeconomic risk (W1)

	W12	V13	V11
V12	1	3	3
V13	1/3	1	1
V11	1/3	1	1

**Table 8.** Assumption Matrix 6 for Operational Risks of Commercial Banks in the Region (W2)

	W22	W23	W24	W25	W21
W22	1	1	3	3	3
W23	1	1	3	3	3
W24	1/3	1/3	1	1	1
W25	1/3	1/3	1	1	1
W21	1/3	1/3	1	1	1

**Table 9.** Assumption Matrix 7 for Regional financial ecology (W3)

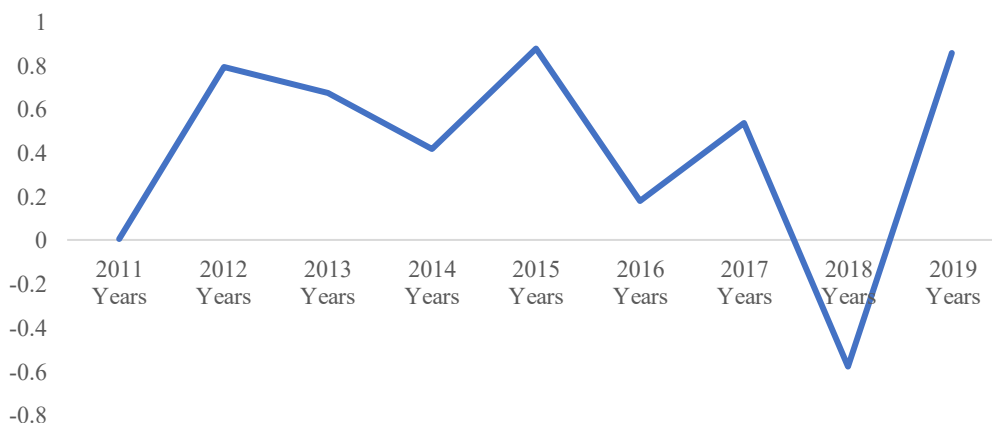
	W31	W32
V31	1	3
V32	1/3	3

**Table 10.** System sequence parameter index weights in Beijing area

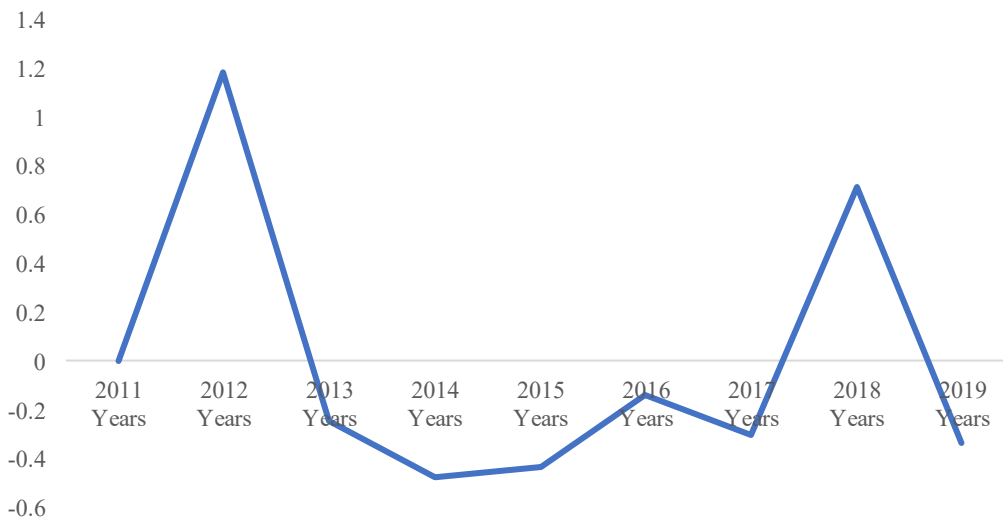
Subsystem	First level indicator	Second level indicator	CRITIC	AHP	AHP-CRITIC
Digital financial indicator system (U)	Combined index (U1)	Combined index (U1)	11.54%	53.57%	28.87%
	Coverage breadth (U2)	Coverage breadth (U2)	14.90%	17.86%	18.94%
	Used depth (U3)	Used depth (U3)	31.46%	17.86%	27.52%
	Digitized degree (U4)	Digitized degree (U4)	42.09%	10.71%	24.66%
Regional Economic Development indicator system (V)	Economic development structure (V1)	Proportion of secondary industry to GDP (V11)	19.66%	42.86%	17.06%
		Proportion of tertiary industry to GDP (V12)	8.30%	14.29%	6.40%
		Consumption ratio of urban and rural residents (V13)	19.50%	42.86%	16.99%
	Scale of economic development (V2)	Regional GDP (V21)	8.46%	20.00%	7.65%
		Total investment in fixed assets (V22)	8.45%	20.00%	7.64%
		Retail sales of social consumer goods (V23)	10.75%	60.00%	14.93%
	Economic development benefits (V3)	Per capita GDP (V31)	8.50%	33.33%	9.89%
		Per capita disposable income of urban residents (V32)	8.02%	33.33%	9.61%
		Regional fiscal revenue (V33)	8.36%	33.33%	9.81%
Regional financial risk indicator system (W)	Macroeconomic risk (W1)	Regional GDP growth rate (W11)	8.46%	20.00%	7.81%
		Inflation rate (W12)	11.40%	60.00%	15.71%
		Rate of unemployment (W13)	8.02%	20.00%	7.61%
	Operational Risks of Commercial Banks in the Region (W2)	Capital adequacy ratio (W21)	9.17%	11.111%	6.06%
		Non-performing loan ratio (W22)	12.44%	33.33%	12.23%
		Return on assets (W23)	10.78%	33.33%	11.39%
		Capital-income ratio (W24)	9.79%	11.111%	6.26%
	Regional financial ecology (W3)	Liquidity ratio (W25)	9.14%	11.111%	6.05%
		Regional economic prosperity index (W31)	11.76%	75.00%	17.84%
		Enterprise asset-liability ratio (W32)	9.04%	25.00%	9.03%

**6.4. Analysis of Synergy of Composite System**

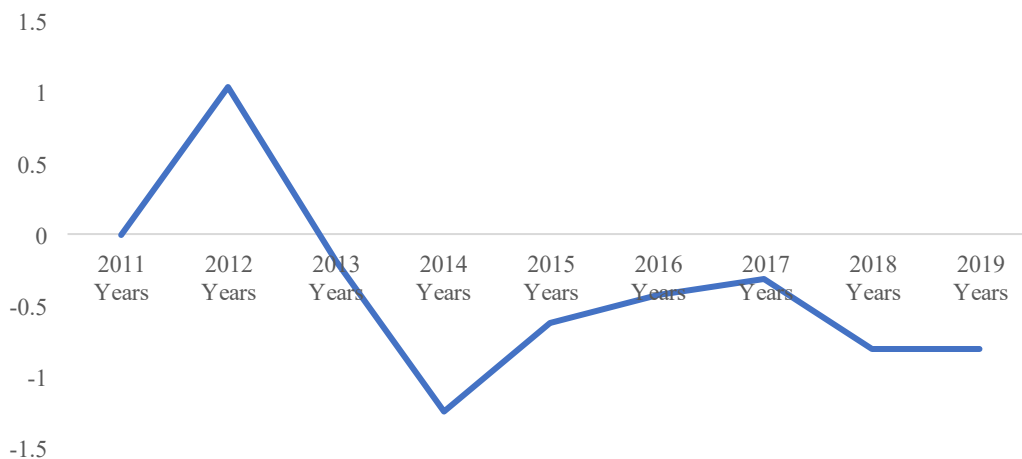
Formula (15) is used to determine the degree of order of the three major regional indicators; On this basis, formula (20) is used to calculate the degree of synergy of UV, UW and VW composite systems. The calculation results in Beijing are shown in the figure below.



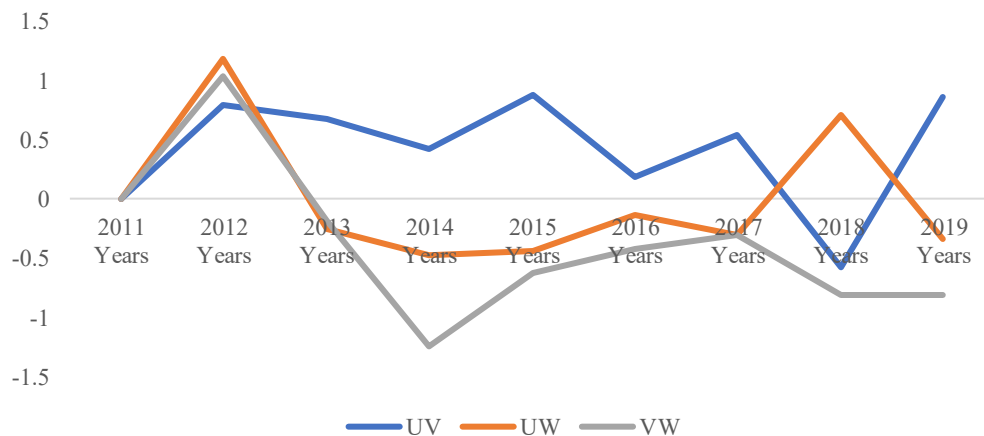
**Figure 6.** The composite synergy degree of the digital financial indicator system (U) and the regional economic development indicator system (V)



**Figure 7.** The degree of compound synergy between the digital financial indicator system (U) and the regional financial risk indicator system (W)



**Figure 8.** The compound synergy of the regional economic development indicator system (V) and the regional financial risk indicator system (W)



**Figure 9.** Comparison of the three figures

As can be seen from the figure, the coordination of Beijing's regional digital finance, regional economy and regional financial risk development has shown an M-shaped development trend of alternating increases and decreases, and the overall level of coordination is at a relatively high level. The overall change trend of the synergy degree of the composite system can be divided into five stages:

The first stage: From 2011 to 2012, the entire regional economic system is on the rise; at this time, the synergy of the composite system is a positive value on the rise, that is, the synergy of the three subsystems of UV, UW and VW is relatively high.

The second stage: From 2012 to 2014, the order of the entire regional economic system showed a downward trend; the synergy of the composite system has been declining during this stage, and UW and VW are negative, indicating that U and W, V and W of the two composite systems appear inconsistent; the composite effect of the UV composite system has been declining, but they are all at a positive value, indicating that the two subsystems have been in a cooperative state.

The third stage: From 2014 to 2017, the regional economic composite system did not rise significantly, but the UW composite system still has a downward trend. During this time period, the UV composite system has a positive synergy and continues to maintain a state of coordination; while the synergy degree of UW and VW composite system is negative, and the two subsystems are in a state of imbalance, so no synergy effect can be produced.

The fourth stage: From 2017 to 2018, the UW regional economic composite system showed an obvious upward trend, but the UV and VW composite system sanitation declined. During this time period, the UV composite system synergy becomes positive and negative, and the synergy effect fails; while UW The synergy of the composite system changes from negative to positive, and the two subsystems produce a synergistic effect, while the VW composite system is still negative and cannot produce a synergistic effect.

The fifth stage: From 2018 to 2019, the UV regional economic composite system showed an apparent upward trend, but the UW composite system showed a downward trend; during this time period, the UV composite system synergy degree changed from negative to positive, and the synergistic effect regenerated; while the system coordination degree of UW composite system changes from positive to negative, the two subsystems lose the synergy effect, and the VW composite system is still negative, so no synergy effect can be produced.

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The authors of this article are arranged in the order of their surnames, and each author's contribution is the same.

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