Research on the Tripartite Synergy of Regional Innovation, Regional Risk and Digital Finance from the Perspective of Coupling

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Abstract. In recent decades, the organic combination of digital technology and finance has spawned digital finance's rapid development and transformation. Innovation, as the primary productivity, is deeply influenced by the development of digital finance in China. With the leapfrog development of digital finance and innovation, regional risks are also profoundly affected. Based on the sample of Beijing from 2011 to 2020, this paper uses the AHM-CRITIC weighted method to empirically test the synergy among digital finance, regional innovation, and regional risk. This paper concludes as follows: the synergy of the three indexes is on the rise over time. Digital finance promotes the level of regional innovation and vice versa. The improvement of regional innovation level and the development of digital finance inhibit regional risks, help maintain the regional economy and financial security, but also increase the financial risk boundary.

This paper innovatively uses the coupling weight method of AHM-CRITIC, and simultaneously explores the synergistic relationship between Regional innovation, Digital finance and Regional risk. The significance of this study is to help broaden the ways of regional innovation, promote the further development of digital finance, and provide relevant suggestions to curb regional risks for the government to formulate policies and for the benign development of financial institutions.

Keywords: AHM-CRITIC · Coordination Analysis · Digital Finance · Regional Innovation · Regional Risk

1 Introduction

Over the past decade, digital finance has emerged due to the combination of Internet technology and finance. The rapid development of digital finance in China has greatly improved the inclusiveness and convenience of financial services. China is committed to deepening economic transformation, driving growth by digital financial innovation,

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and improving the strategic position of innovation. Preventing regional economic and financial risks is a stabilizer to ensure financial security and a booster for innovative development.

At present, there are many studies on the impact of digital finance on regional innovation and regional risk. Fang Zou et al. (Zou et al. 2020) studied the relationship between digital finance development and economic growth, introduced the intermediary variable regional entrepreneurship, and confirmed that the development of digital finance is conducive to regional entrepreneurship and economic growth. Chuanzhong Du et al. (Du and Zhang 2020) found, through empirical analysis, that the development of digital finance has a significant indigenous innovation effect and can become a new driving force for improving the level of regional innovation. This conclusion is still valid, considering the endogeneity and robustness. Yaxin Zheng et al. (Zheng 2020) combined the digital financial index with the number of patent applications, and empirically tested that digital inclusive finance is conducive to the increase of regional innovation output. Min Lu et al. (Ou et al. 2021) used panel regression to explore the relationship between the development of digital inclusive finance and regional financial risks. The results show that the development of digital inclusive finance has inhibitory effects on regional financial risks in China. It is concluded that the development of digital finance has a significant negative effect on the risk of commercial banks, and the intervention of financial supervision can reduce the negative impact of digital finance to some extent.

At the same time, there are regional differences in the development of digital finance, and few studies on the impact of digital finance on urban regional innovation and risk. The research meaning of this paper is as follows: Take Beijing as an object, we empirically evaluate the positive effect of digital finance on regional innovation capability, hence broadening the way of increasing regional innovation achievements. At the same time, the inhibitory effect of digital finance and regional innovation on regional risks is studied and analyzed, enabling us to provide relevant suggestions for the government to enact regulatory policies and for the robust development of financial institutions. The method used in this paper is AHM and CRITIC method, and the evaluation model based on the AHM-CRITIC coupling weights is constructed, which is applied to the research on the collaborative relationship among digital finance, regional innovation, and regional risk.

2 Synergy Among Regional Innovation, Regional Risk, and Digital Finance

2.1 Index System Construction

Regional innovation refers to the general term of all innovative activities and achievements within a specific geographical scope. Through literature analysis and index innovation, this paper sets eight indicators to reflect regional innovation, including government intervention level (gov), regional industrial upgrading (na), regional scientific research level (rsr), regional entrepreneurship (re) (Liang and Zhang 2021, Guo et al. 2020), regional financial development (fd), urbanization rate (urb), human capital stock level (hum), opening up level (ope) (Zheng 2020).

Digital finance employs a new information technology to carry out mobile payment, credit, investment, and other new financial businesses by combining IT industry and the

Table 1. Evaluation Index System of Synergy Degree of Digital Finance, Regional Innovation, and Regional Risk.

	Variables	Variable meaning	Measurement	Positive and negative
Regional innovation RIS	gov	Level of government intervention	Government expenditure on science and technology/total regional financial expenditure	+
	na	Regional industrial upgrading	Second and third industry GDP/regional GDP	+
	rsr	Regional scientific research level	Regional Patent Authorization/National Patent Authorization	+
	re	Regional entrepreneurship	Number of urban and private sector employees/total employment	+
	fd	Regional financial development	Regional GDP growth rate	+
	urb	Urbanization rate	Urban population/total population	+
	hum	Human capital stock level	The number of college students/regional total population	+
	ope	Level of openness	Total Regional Import and Export Trade/Regional GDP	+
Digital finance DF	DFIIC_A	Total index	Digital Inclusive Financial Index of Peking University	+
	DFIIC_C	Coverage breadth index		+
	DFIIC_U	Use depth index		+
	DFIIC_D	Digital degree index		+
Regional risk RER	rio	regional macroeconomic	Regional total import and export growth rate	–
	rin		Regional inflation rate	+
	ruu		Regional urban registered unemployment rate	+

(*continued*)

Table 1. (*continued*)

	Variables	Variable meaning	Measurement	Positive and negative
	rfi		The growth rate of regional fixed-asset investment	+
	rfr		Regional public finance income growth rate	–
	bnl	Regional micro-finance	Bank non-performing loan ratio	+
	bdl		Bank deposit and loan ratio	+
	cin	external economics	China's inflation rate	+
	cds		China's debt-paying rate	+

financial industry. This paper uses the 2011 – 2020 digital inclusive finance index measured by the Digital Finance Research Center in Peking University (Luo 2021) to measure the development level of regional digital finance. The index used the massive data of Ant Financial Services Group and the tool of AHP and index analysis. The construction of the index is fully associated with the principles of balance, comprehensiveness, continuity, comparability, and feasibility (Du and Zhang 2020). This paper selects four dimensions of the first-level indicators, including the total index (DFIIC_A), the coverage breadth index (DFIIC_C), the use depth index (DFIIC_U), and the digitization degree index (DFIIC_D), to effectively measure the level of regional digital finance.

Regional risk refers to the risk faced within an economic region. This paper confines it to economic and financial risks. Based on relevant literature, this paper divides regional risks into three parts: regional macro economy (mac), regional micro finance (micf), and external economy (exe)(Ling and Li 2021). Each sub-system contains multiple evaluation indexes. This paper will build a collaborative relationship evaluation index system from digital finance, regional innovation, and regional risk, and set the internal positive and negative indicators. The indicator system is shown in Table 1.

2.2 Qualitative Analysis of Digital Finance, Regional Innovation, and Regional Risk

Through literature analysis, digital finance has significantly promoted the improvement of regional innovation levels. From the perspective of different dimensions of digital finance, the total index, the coverage breadth, the depth of use, and the degree of digitalization have a positive impact on regional innovation. On the contrary, the improvement of regional innovation level further promotes the development of regional digital finance (Du and Zhang 2020). The improvement of regional innovation level and the development of digital finance inhibit regional risks. (Ou et al. 2021), help maintain the regional economy and financial security, but also increase the financial risk boundary. Preventing

regional risks is helpful to the robust development of digital finance and lays a solid foundation for regional innovation and development. Therefore, government regulation and the healthy development of financial institutions are crucial.

3 Coupling Weights

3.1 Coupling Weight Calculation

To make the weight of the evaluation index can not only reflect the subjective judgment of the decision-maker, but also contain objective constraints, and can calculate the relevant coupling weight, this paper uses the multiplier synthesis method to obtain the coupling weight (Ling and Li 2021)

$$W = \frac{W_{\mathrm{AHM}} W_{\boldsymbol{CRI}}}{\sum_{j=1}^{n} W_{\mathrm{AHM}} W_{CRI}} \tag{1}$$

3.2 Subjective Method AHM

Attribute Hierarchy Model (AHM) was proposed by Cheng in 1997. It is a simple and easy subjective weighting method. It not only has the advantages of analytic hierarchy process but also has the characteristics of simple and fast, no need to calculate feature vectors and test consistency. The specific steps of this method are as follows:

Step1: Determine the evaluation index weight. Before establishing the attribute discriminant matrix, AHM should determine the relative importance scale between each evaluation index. In this paper, using the Saaty scale, the n-th AHP discriminant matrix is obtained by the expert scoring method. $\boldsymbol{K} = \left(k_{ij}\right)_{n\times n}$. Where *kij* represents the importance of factor i compared with factor j. And AHP discriminant matrix $\boldsymbol{K} = \left(k_{ij}\right)_{n\times n}$ has the following properties:

$$\begin{cases} \mathrm{k_{ij}} > 0 \\ \mathrm{k_{ij}} = 0 \\ \mathrm{k_{ij}} = 1/\mathrm{k_{ij}} \end{cases} \tag{2}$$

Step2: Constructing attribute discriminant matrix. In AHM, the relative attribute l_{ij} constitutes the n-order attribute discriminant matrix $\boldsymbol{L} = \left(l_{ij}\right)_{n\times n}$, Moreover, there is a conversion relationship between the relative attribute l_{ij} and the scale k_{ij} in Eq. (3): In the formula: q is a positive integer not less than 2.

$$l_{ij} = \begin{cases} 2q/(2q+1) & k_{ij} = q, i \neq j \\ 1/(2q+1) & k_{ij} = 1/q, i \neq j \\ 0.5 & k_{ij} = 1, i \neq j \\ 0 & k_{ij} = 1, i = j \end{cases} \tag{3}$$

Step3: Calculate the relative attribute weights of each index. Calculate the relative attribute weights of each index. According to the AHM algorithm process, the relative

attribute weight W-*AHM* of each index is calculated through Eq. (4). In the formula: i = 1,2,…, n, n is the number of indicators.

$$W_{AHM} = \frac{2}{n(n-1)} \sum_{j=1}^{n} l_{ij} \tag{4}$$

3.3 Objective Approach CRITIC

Criteria Importance Through Intercriteria Correlation (CRITIC) method is an objective weight weighting method proposed by Diakoulaki, which is based on the contrast strength of evaluation indicators and the conflict between indicators to comprehensively measure the objective weight of indicators. Considering the variability of indicators and the correlation between indicators is an effective method to determine the objective weight of indicators. The specific steps of this method are as follows:

Step1: Calculate the standard deviation. In the formula: $\overline{x_j}$ overline is the average value of index *Xj* in m schemes; σ_j is the standard deviation of *Xj*.

$$\sigma_j = \sqrt{\frac{1}{m-1} \sum_{i=1}^{m} \left(x_{ij} - \overline{x}_j\right)^2} \tag{5}$$

Step2: Construct the correlation coefficient matrix.

$$r_{ij} = \frac{\sum_{i=1}^{n} (x_i - \overline{x_i})\left(x_j - \overline{x_j}\right)}{\sqrt{\sum_{i=1}^{n} (x_i - \overline{x_i})^2 \sum_{j=1}^{n} \left(x_j - \overline{x_j}\right)^2}} \tag{6}$$

Where: $\overline{x_i}$ is the average value of index *Xi* in all schemes; $\overline{x_j}$ is the average value of index *Xj* in all schemes; r_{ij} is the correlation coefficient of index *Xi* and index *Xj*.

Step3: Comprehensive Weight W*CRI* for Each Index

$$\begin{cases} W_{CRI} = \frac{C_j}{\sum_{i=1}^{n} C_j} \\ C_j = \sigma_j \sum_{j=1}^{n} \left(1 - r_{ij}\right) \end{cases} \tag{7}$$

4 Research on Collaborative Model

4.1 Subsystem

According to the evaluation method of synergy degree and the above index system, this paper divides the composite system into three subsystems: regional innovation, regional risk, and digital economy. The order degree of the composite system is represented by the order degree of the interaction of the above three subsystems. S = {S1, S2, S3}, S1 is regional innovation; S2 is regional risk; S3 is the digital economy. Each group

of subsystems can be determined by a set of order parameters. It is assumed that the variables of the order parameters of the subsystem in the development process can be expressed as $e_j = (e_{j1}, e_{j2}, \cdots, e_{ji}), n \geq 1, \beta_{ji} \leq e_{ji} \leq \alpha_{ji}, i \in [1, n]$. Assuming that $e_{j1}, e_{j2}, \cdots, e_{ji}$ are positive correlation indicators, that is, the larger the value of the relevant variables, the higher the degree of system coordination; the smaller the variable value, the lower the coordination degree; conversely, if $e_{j1}, e_{j2}, \cdots, e_{ji}$ are negatively correlated indicators, that is, the larger the value of the relevant variables, the lower the system coordination degree; the larger the variable value, the lower the coordination degree. The order degree of the subsystem order parameter e_{jk} is defined as:

$$\mu_j(e_{jk}) = \begin{cases} \frac{e_{jk} - \beta_{jk}}{\alpha_{jk} - \beta_{ki}}, & e_{jk}\ Positive\ correlation \\ \frac{\alpha_{jk} - e_{jk}}{\alpha_{jk} - \beta_{jk}}, & e_{jk}\ Negative\ correlation \end{cases} \tag{8}$$

α_{ji}, β_{ji} are the upper and lower extreme values of the ith order parameter of the jth subsystem. From formula (8), $\mu_j(e_{jk}) \in [0,1]$ can be obtained, and the larger the value, the greater the contribution to system order. Not only should you consider different contributions to the subsystems, but also consider the weight of all steps. In this paper, the linear weighting method is used to set the order degree of Sj of the subsystem as $\mu_j(e_j)$.

$$\mu_j(e_j) = \sum_{k=1}^{n} \lambda_k \mu_j(e_{jk}) \tag{9}$$

4.2 Collaborative System

For a certain initial time, it is assumed that the system order of the order parameters of each subsystem of the composite system is $\mu_{\mathrm{i}}^0(\mathrm{e_i})(\mathrm{j} = 1, 2, \cdots, \mathrm{m})$. When the overall system develops to time t, the system order of the order parameters of each subsystem is $\mu_{\mathrm{i}}^1(\mathrm{e_i})(\mathrm{j} = 1, 2, \cdots, \mathrm{m})$. The coordination degree D of the composite system is shown in (10)

$$D = \eta \sum_{j=1}^{m} \omega_j \left| \mu_j^1(e_j) - \mu_j^0(e_j) \right| \tag{10}$$

In Formula (10). $\eta = \begin{cases} 1, \mu_j^1(e_j) - \mu_j^0(e_j) > 0 \\ -1, \text{ other} \end{cases}$.

According to $\mathrm{D} \in [-1, 1]$ in Eq. (10), if the value of D is larger, the coordination degree of the whole system is higher; the smaller the value is, the lower the whole system is. In addition, the overall coordination of the composite system is determined by all subsystems. If the order degree of one subsystem is high, while that of the other subsystem is low, and the coordination degree of the whole composite system $\mathrm{C} \in [-1, 0]$, the coordination degree range of the composite system is narrowed, which also indicates that the order degree of the composite system is not high.

The coordination degree between the two subsystems is:

$$C = \left| \frac{\mu_1(e_1)\mu_2(e_2)}{\left[\frac{\mu_1(e_1)+\mu_2(e_2)}{2}\right]^2} \right|^k \tag{11}$$

To obtain the coordination degree between subsystems, the coordination degree relationship between two subsystems is established, as shown in (11). $\mu_1(e_1)$ and $\mu_2(e_2)$ are the coordination degrees of the two subsystems, respectively. k The general value is 1.

5 Research on the Tripartite Synergy of Regional Innovation, Regional Risk, and Digital Finance from the Perspective of Coupling

5.1 Introduction to Research Objects and Data

Taking Beijing as an example, this paper discusses the relationship between regional innovation, regional risk, and digital finance. Using the relevant annual data of Beijing from 2011 to 2020 and some annual data of China, the data are derived from the 'Beijing Statistical Yearbook' and 'China Statistical Yearbook' from 2011 to 2020. Since the units of the order parameters of each system are inconsistent, all the obtained data are dimensionless. In this paper, the Min-Max method is used to standardize(Yue et al. 2020), and some dimensionless results are shown in Fig. 1.

5.2 Weight Calculation Based on AHM-CRITIC Method

In this paper, the AHM-CRITIC method is used to calculate the weight of AHM. In calculating AHM weight, the Saaty scale method and expert scoring method are used to obtain six AHP discriminant matrices of regional innovation, digital finance, and regional risk. The attribute discriminant matrix is obtained by the formula in Sect. 3.2.

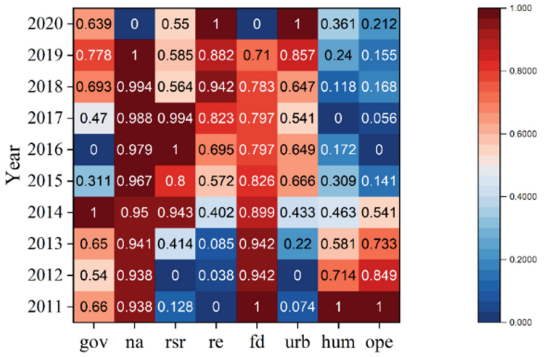

Fig. 1. The Standardized Data Heat Map of Beijing Regional Innovation Evaluation Index.

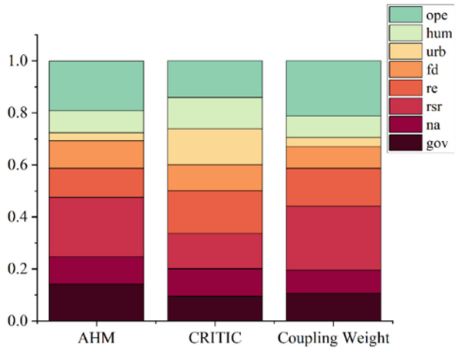

Fig. 2. Relevant Weights of Regional Innovation.

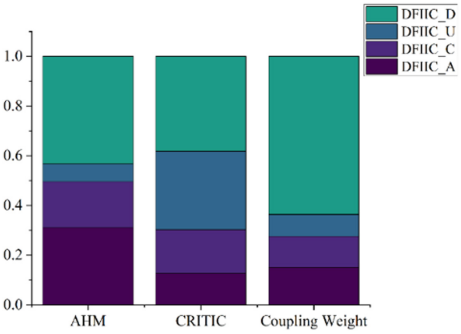

Fig. 3. Relevant Weights of Digital Finance

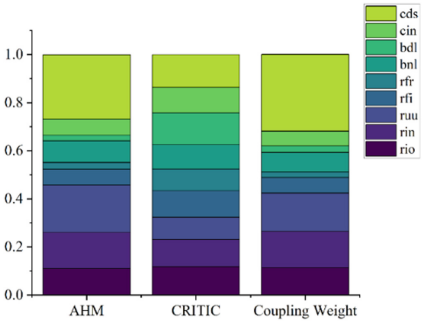

Fig. 4. Relevant Weights of Regional Risk

Finally, AHM weight is obtained. The CRITIC weights of the three systems are obtained by the formula in Sect. 3.3, and the coupling weights of the three systems are obtained by the formula in Sect. 3.1. The results are shown in Figs. 2, 3, and 4.

The AHM-CRITIC method can better determine the weight. Since the subjective judgment of experts limits the AHM method, and the CRITIC method lacks some recognized cognition, the final result may not be consistent with reality. After combining the two, the two situations are comprehensively considered, making the weight more reasonable. It can be seen from the results that among the sub-index weights of regional innovation, the weight of regional scientific research level is the largest, reaching 0.246, followed by the level of opening up. Among the sub-index weights of digital finance, the weight of digitalization degree is the highest, reaching 0.636. Among the relevant weights of regional risks, the weight of China's debt repayment rate is the largest, reaching 0.319, followed by the regional inflation rate and the regional registered urban unemployment rate.

5.3 Research on Collaborative Analysis

The synergy degree of the system itself, the composite system, and the synergy degree between two systems can be calculated through the relevant formula in Sect. 4. When calculating the synergy degree of the composite system, the weights of the three systems are taken as 1/3. The final results are shown in Fig. 5 and Fig. 6. It can be seen from Fig. 5 that the fluctuation of regional innovation synergy degree is small, and it remains at the level of about 0.5 as a whole. It reaches the highest value in 2014 and then continues to maintain the original level of fluctuation. The overall degree of digital financial synergy has shown an upward trend and reached above 0.9 in 2018, mainly due to the rapid development of the Internet industry in recent years. The regional risk maintained a fluctuating change from 2011 to 2013, and then increased until 2016, and continued to fluctuate in the following years, reaching the highest value in 2020. The synergy degree of the composite system remains at a low level. From the overall trend, the synergy degree of the composite system has maintained a fluctuating upward trend from 2012 to 2020, indicating that the synergy degree between the three systems has been strengthened.

The coordination degree between the two is declining. Regional innovation and regional risk are declining from 2011 to 2013, reaching the lowest value in 2013, and rising to the highest value in 2015. At the same time, from 2015 to 2020, maintaining a high level of volatility, and the coordination degree between digital finance and regional risk is rising from 2013 to 2016. It then declined from 2017 to 2018 and rose from 2018 to 2020.

From 2012 to 2013, the synergy degree of regional innovation and digital finance increased, while the synergy degree of regional innovation and regional risk, digital finance and regional risk decreased, that is, the correlation degree with risk decreased. This result may be related to the implementation of the reform of the foreign exchange management system of goods trade in Beijing in the same year and the further improvement of relevant regulatory systems such as the reform of foreign exchange management of transnational corporations. From 2013 to 2016, the coordination degree of digital finance and regional risk and the coordination degree of regional innovation and regional risk continued to rise. 2013 was the first year of the development of the concept of Internet finance in China. In the early stage, the relevant financial system was not yet perfect. The disorderly development of P2P platforms and other platforms has laid hidden dangers for future thunderstorms, and the financial risks have been increasing. From 2016

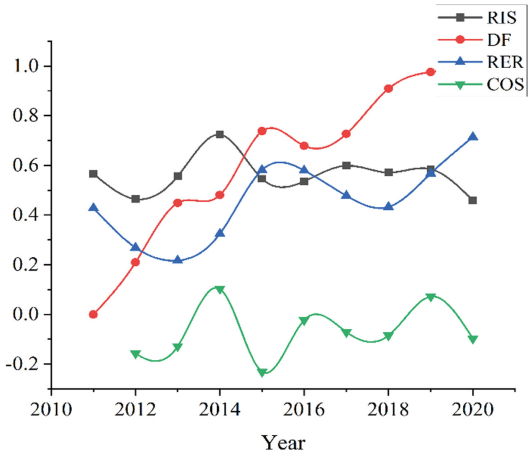

Fig. 5. System Synergy Degrees of Regional Innovation, Digital Finance, Regional Risk and the Composite System

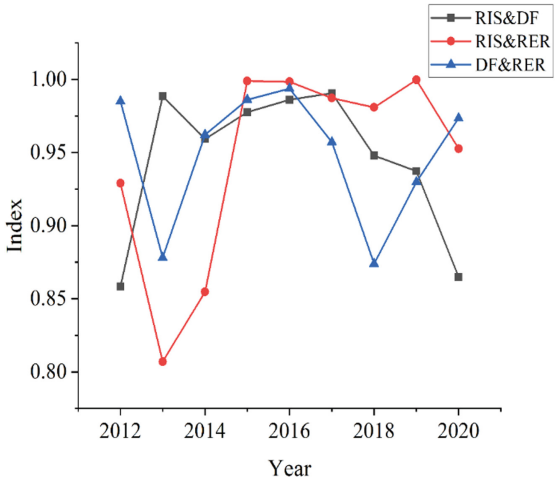

Fig. 6. Synergy Degrees between Systems

to 2020, the synergy degree of regional innovation and digital finance has maintained a high level on the whole, while the synergy degree of digital finance and regional risks has decreased first and then increased. Before 2018, Beijing has increased the intensity of Internet financial regulation, such as the 'Implementation plan of special regulation of Internet financial risks in Beijing' policy introduced in 2017. After that, the development of digital finance has slowed down, but the monopoly of technological giants and the ambiguity of relevant legal boundaries have increased the risk of using relevant funds.

6 Conclusion

To explore the relationship between regional innovation, digital finance, and regional risk, this paper takes the relevant data of Beijing from 2011 to 2020 as the sample and obtains the weights of the respective sequence variables of the three systems by combining the subjective and objective weights of AHM-CRITIC. Then, through collaborative analysis, the relationship between the composite system and the system is studied. The conclusions are as follows:

(1) Overall, the synergy degree of the composite system composed of regional innovation, digital finance, and regional risk is low. However, it shows an upward trend from 2011 to 2020, indicating that the coordination degree of the three systems has increased.
(2) The synergy between the two systems of regional innovation and digital finance has shown an overall trend of increasing first and then decreasing from 2012 to 2020, reaching its highest value in 2017. The level of synergy between regional innovation and regional risk is relatively high. Although the level decreased in 2013 and 2014, the overall synergy between the two systems is strong. The coordination relationship between the two systems of digital finance and regional risk has no obvious upward or downward trend from 2011 to 2020. However, there are trend changes in the short term at different stages, indicating that the degree of coordination between the two systems is related to exogenous variables such as social conditions and policies at that time.

References

Deng, Zhang, Ahmad, & Draz. (2019). Local government competition, environmental regulation intensity and regional innovation performance: an empirical investigation of Chinese provinces. International Journal of Environmental Research and Public Health, 16(12), 2130

Du Chuanzhong & Zhang Yuan. (20220). The Regional Innovation Effect of Digital Finance under the Background of ' New Infrastructure '.Financial Science (05), 30–42. doi : CNKI : SUN : CJKX.0.2020–05–004.

F.Zou, L.Zhang. & M. Fan. (2020) Impact of Digital Finance Development on Economic Growth: Empirical Analysis Based on Panel Data in Sichuan Province. International Conference on Big Data and Social Sciences (ICBDSS), pp. 165–168. DOI: 10.1109 / ICBDSS51270.2020.00044.

GUO Feng, WANG Jingyi, WANG Fang, KONG Tao, ZHANG Xun, &CHENG Zhiyun.(2020). Measuring China's Digital Financial Inclusion: Index Compilation and Spatial Characteristics. China Economic Quarterly, 19(4), 1401–1418.

Liang Hanshu & Zhang Yi. (2021).Digital financial development, financial supervision and risk of commercial banks in China.Finance and economy (01), 30–39.doi : 10.19622 / j.cnki.cn36-1005 / f.2021.004.

Lingyun & Li Yiying. (2021). Research on the evaluation of the coordination degree of community intelligent endowment resource allocation.Economic and management review (04), 149–160.doi : 10.13962 / j.cnki.37–1486 / f.2021.04.012.

Luo Yu. (2021).China ' s provincial financial risk early warning research - Hebei Province as an example. Hebei enterprise (01), 11–13.doi: 10.19885 / j.cnki.hbqy.2021.01.003.

Ouyang, Lu Min & Xiong Jiayi. (2021). Research on the impact of digital inclusive financial development on regional financial risks in China. Journal of Xi 'an University of Finance and Economics (05), 5–16.doi : 10.19331 / j.cnki.jxufe.2021.05.001.

Yue Lizhu, Licensing & Shi Guanglei. (2020). Nature analysis and method selection of dimensionless indicators. Forum on Statistics and Information (06), 3–9. Doi: CNKI: SUN: TJLT.0.2020-06-001

Zheng Yaxin. (2020). Can digital inclusive finance increase regional innovation output? Empirical research based on provincial panel data in China.Economic issues (10), 53–61.doi: 10.16011 / j.cnki.jjwt.2020.10.007.