Accounting, Auditing and Finance (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/accaf.2024.050208
ISSN 2616-3136 Vol. 5 Num. 2

The Research of Coupling Coordination Mechanism for Digital Economic Development Environment and Inclusive Finance and Regional Economic Innovation Capability

Zhenhan Chen[1], Jiaru Wang[2]

[1]*School of Economics, Xinjiang University of Finance and Economics, Urumqi, 830000, China*
[2]*School of Applied Mathematics, Shanxi University of Finance and Economics, Taiyuan, 030000, China*

Keywords: Digital Economic Development environment, Digital Economic Development environment, Inclusive Finance, Comprehensive Measurement, Coupling and Coordination

Abstract: Exploring the coupling coordination mechanism of regional economic innovation, digital economic development environment and inclusive finance is of great significance to promote the overall and sustainable development of economy. Based on provincial data from 2013-2020, the study used an entropy weight-based composite index method to measure regional economic innovation ability, digital development level, and inclusive finance synthesis level, respectively. The time difference between regions was also studied based on discrete coefficients, variability factors, and Theil index. Then, the coupling coordination degree between the three systems is measured by the coupling coordination degree model, and the influence degree of all indexes in the three subsystems on the coupling coordination degree is obtained by using the random forest model. The empirical results show that: First of all, in terms of the digital economy development environment and inclusive finance, the development gap between different regions is gradually narrowing over time, but the difference level of regional economic innovation ability still fluctuates. Secondly, the coupling and coordination between the three systems in each region have been consistently enhancing annually, with a decreasing trend in regional disparities. In addition, the input of R&D personnel and R&D funds has a great impact on the coupling and coordination between the three systems. Finally, based on the above conclusions and from the perspective of high-quality economic development, this paper puts forward relevant policy recommendations.

1. Introduction

With the implementation of the national "14th Five-Year Plan" and the deepening of the "innovation-driven development strategy", regional economic innovation capability has been placed at an unprecedented strategic height. On the other hand, as the core driving force of the new round of scientific and technological revolution and industrial revolution, the development of digital economy has also become an important embodiment of national competitiveness. At the same time,

inclusive finance, as an important means to serve the real economy and promote common prosperity, has also attracted increasing attention from the government and all sectors of society. As the global economic pattern is constantly changing and the domestic economic development has entered the new normal, it is of great significance to study the coupling coordination mechanism among the three systems of regional economic innovation ability, digital development and inclusive finance for China's high-quality economic development.

Guo Feng, Wang Jingyi, and Wang Fang [1] conducted a study on the progress of digital inclusive finance across different regions in China, compiling a "Digital Inclusive Finance Index" that revealed significant spatial clustering and heterogeneity. Xue Menglu and her team [2] conducted a thorough investigation into the dynamic evolution and convergence trends of inclusive finance, particularly from the vantage point of digital economy growth. Jiao Yunxia [3] conducted a meticulous study on the regional disparities and convergence trends of inclusive finance, adopting a unique perspective centered on China's digital economy development. Moreover, in terms of regional economic innovation capability, a comprehensive evaluation methodology was employed to measure China's regional economic innovation capacity [4]. This method provided a quantitative assessment of the various factors that contribute to economic innovation. The measurement results were then subjected to both horizontal and vertical comparisons and analyses, revealing patterns and trends in regional economic innovation capabilities. Zhao Tao, Zhang Zhi, and their team [5] explored the relationship between the digital economy, entrepreneurial activities, and high-quality development. Utilizing panel data from 30 provinces in China, Li Baiyu, Zhang Meili, and others [6] empirically tested the impact of digital economy development on high-quality regional economic growth, employing the system generalized moment estimation method and quantile regression. Chen Boqiang [7] enhanced empirical research on the agricultural digital economy's level through digital inclusive finance, suggesting that inclusive finance can drive rural digital economy growth.

Based on this, this study aims to explore the coupling coordination mechanism among the three index systems of regional economic innovation ability, digital economy development environment and inclusive finance, and explore the impact of each index in the three index systems on the coupling coordination degree. This paper has the following three marginal contributions: First, considering the information, volatility and correlation of indicators, a comprehensive index method based on entropy and critical weight is proposed, and it is applied to the measurement of regional economic innovation ability index, digital economy development environment level index and inclusive finance comprehensive index. Secondly, utilizing the coupling coordination degree model, the interaction and harmony among the three systems are examined. Furthermore, through the application of machine learning techniques, the extent of influence each index system has on the level of coupling coordination is determined. Finally, the Theil index, coefficient of variation and coefficient of dispersion are used to analyze the degree of regional differences in regional economic innovation ability, digital economy development environment, inclusive finance and the degree of regional differences in the coupling and coordination between the three systems. The empirical results show that the development environment level of digital economy and the comprehensive level of HP finance in different regions show an increasing trend year by year, and the difference degree among different regions shows a decreasing trend. For regional economic innovation ability, the differences between different regions show a fluctuating trend. For the coupling coordination degree of the three systems, the results show that the coupling coordination degree of each region increases gradually, and the difference between regions decreases year by year. In addition, the results of random forest model show that the degree of scientific research investment has an important influence on the further improvement of coupling coordination degree.

2. Theory and method

2.1 Principle of Research

The key factor driving regional economic growth is its capacity for innovation, encompassing aspects such as generating new knowledge, adapting and utilizing technology, and fostering a conducive innovation environment. The higher the level of economic innovation in a region, the greater its potential for sustained economic growth. This innovation capability is pivotal in propelling industrial advancements, enhancing production efficiency, spawning new job opportunities, and fostering the optimization and elevation of the regional economic structure. Table 1 below presents a detailed index system that outlines the various components of regional economic innovation ability.

Table 1: Index system of regional economic innovation ability

	Factor
regional economic innovation ability index	Innovation environment(X1)
	Enterprise innovation (X2)
	Innovation resource(X3)
	Knowledge Creation(X4)
	Enterprise performance (X5)

Enhancing the development environment of the digital economy can significantly contribute to high-quality economic growth. Leveraging digital technology can expedite information transmission and processing, streamline resource allocation, and boost production efficiency. Table 2 below outlines the indicator system for assessing the development environment of the digital economy.

Table 2: Digital economy development environment index system

	Factor
Digital economic environment index	
	R & D personnel full-time equivalent (person) (Y1)
	R & D expenses (ten thousand yuan) (Y2)
	Local financial Expenditure on science and technology (100 million yuan) (Y3)
	Acceptance of domestic patent applications (item)(Y4)
	Internet broadband access users (ten thousand households) (Y5)
	Number of mobile phone users at the end of the year (ten thousand households) (Y6)
	Number of computers used per 100 people (sets) (Y7)
	Number of websites per 100 enterprises (one) (Y8)
	Per capita disposable income of all residents (RMB) (Y9)
	Information transmission, software and information technology services in urban units (ten thousand people) (Y10)
	R & D Urban employees (ten thousand) (T11)
	Number of enterprises with e-commerce transactions (one) (Y12)

As an important part of the financial system, inclusive finance plays an important role in supporting regional economic innovation capacity and digital development. By providing extensive and inclusive financial services, inclusive finance has lowered the threshold of financial services and enabled more people and enterprises to enjoy the convenience of financial services. This is

conducive to stimulating the vitality of innovation and promoting the development of innovative activities. At the same time, inclusive finance can also provide necessary financial support and risk protection for digital development, and promote the application and promotion of digital technology in a wider range of fields. The index system for inclusive finance is shown in Table 3 below.

Table 3: Financial inclusion index system

	Factor
Financial inclusion index	Coverage breadth (Z1)
	Depth of Use (Z2)
	Payment Service (Z3)
	Insurance business (Z4)
	Credit business (Z5)
	Degree of digitalization (Z6)

2.2 Research method

2.2.1 Three-system measure based on the entropy Critic-composite index method

The entropy method is an objective approach to assigning weights. It computes the information entropy of each index and determines its weight based on its relative impact on the overall system. In this method, m evaluation schemes and n evaluation indicators are used to construct the original data matrix. The larger the variance in the index values, the greater role the index plays in the comprehensive evaluation and the lower its entropy value, resulting in a higher weight. Conversely, if all index values are identical, the index contributes little to the evaluation, leading to a lower weight. The calculation process involves several steps:

1) Calculate the proportion of item j in year i:

$$Y_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \tag{1}$$

2) Calculate the index information entropy:

$$e_j = -k\sum_{k=1}^{m}\left(Y_{ij} \times \ln Y_{ij}\right) \tag{2}$$

3) Calculate information entropy redundancy:

$$d_j = 1 - e_j \tag{3}$$

4) Calculate the index weight:

$$D_i = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{4}$$

X_{ij} is the value of item j, min $\{X_j\}$, and max $\{X_j\}$ are the minimum and maximum value of item j in all years, k=1 / ln m, where m is the number of evaluation years and n is the number of indicators.

Alternatively, the Critic assignment method relies on two fundamental principles: contrast

strength and the conflict among evaluation indicators.The calculation formula of the conflict quantitative index of the j th index and other indicators is as follows:

$$\sum_{i=1}^{n}(1-r_{ij}) \tag{5}$$

Where r_{ij} represents the correlation coefficient between the evaluation variables x_i and x_j. Setting C_j indicates the importance of the j th evaluation index:

$$C_j = \delta\sum_{i=1}^{n}(1-r_{ij}) \tag{6}$$

Where n is the number of evaluations for the same index.In general, as C_j increases, so does the information content within the jth evaluation index, indicating its greater relative significance. Finally, C_j is normalized, and W_j is the normalized version of the product of the entropy method of the critic method. The calculation formula of W_j:

$$W_j = \frac{C_j * D_j}{\sum_{j}^{m} C_j * D_j} \tag{7}$$

Utilizing the weights of each index, the comprehensive index method is employed to calculate the overall index. The measurement formula is shown as follows:

$$F_{ij} = 1 - \frac{\sqrt{(w_1 - E_{1,ij})^2 + (w_2 - E_{2,ij})^2 + \cdots + (w_k - E_{k,ij})^2}}{\sqrt{w_1^2 + w_2^2 + \cdots + w_k^2}} \tag{8}$$

In the above equation, wk represents the weight of the k-th dimension. The index ranges from 0-1, and F=1 is the highest composite index, and when F= 0, the composite index is the lowest. E{k, ij} = wk * X{{k, ij}, where X{{k, ij} is expressed as the value of the k th item index in year j of the i th province.

2.2.2 Coupled coordination degree model of the three systems

The coupled coordination degree model of three systems serves as a tool for assessing the extent of coordinated development among various entities.This model can quantify the interaction between the elements in the system and calculates the degree of coordination between them. X is the coupling degree of the system:

$$X = [\frac{f(x) \bullet g(y) \bullet h(z)}{(f(x) + g(y) + h(z))^3}]^{\frac{1}{3}} \tag{9}$$

Coupling degree quantifies the interaction between subsystems, revealing their strong or weak relationships. Therefore, the strength of interaction between subsystems can be determined solely through the coupling degree value. This paper aims to assess the coordination degree between subsystems, utilizing the coupling coordination degree model. Specifically, X represents the system's coupling degree, which serves as a metric for interaction among subsystems. Here, we introduce the coupling coordination degree model to calculate the coordination level among subsystems.

$$D = \sqrt{X \times T} \tag{10}$$

$$T = \alpha f(x) + \beta g(y) + \varphi h(x) \tag{11}$$

Where D is the coupling coordination degree, T is the comprehensive coordination index of

H-T-R system;α, β, and φ represent undetermined coefficients, while the weights of the three systems are determined through the computational outcomes obtained using the entropy method.

2.2.3 Random forest model

Feature selection is one of the most important links in the construction of random forest. Therefore, the selection of feature selection methods is also one of the important topics of decision tree research. At present, information gain (Information gain) and Gini coefficient (Gini index) are commonly used in decision tree algorithms. In the random forest, the Gini coefficient is mainly used, so the Gini coefficient is briefly introduced below. For a given sample set D, its Gini coefficient is:

$$Gini(D) = 1 - \sum_{k=1}^{K} \left(\frac{|C_k|}{|D|}\right)^2 \tag{12}$$

Here, C_k is the subset of samples where D belongs to class K, and K is the number of classes. In the condition of feature A, the Gini coefficient of bound D is defined as

$$Gini(D, A) = \frac{|D_1|}{|D|} Gini(D) + \frac{|D_2|}{|D|} Gini(D) \tag{13}$$

The Gini coefficient Gin (D) represents the uncertainty of set D, and the Gini coefficient Gini (D, A) indicates the uncertainty of set D after A = a segmentation. The larger the Gini coefficient value, the greater the uncertainty of the sample set. By using the random forest model, the indicators in the three subsystems as predictive variables, the coupling coordination as a response variable, in the case of high prediction accuracy, the greater the gini coefficient value, said the greater the index to the response variable contribution, based on this, we can use the random forest for the subsystem index of coupling coordination contribution is quantified.

3. Empirical analysis

3.1 Data source and preprocessing

The data source of this experiment mainly mainly three parts. They are from the Peking University Digital Inclusive Finance Index (2012-2022), which is mainly based on the Alipay ecosystem, and from the China Regional Innovation Capacity Report (2012-2022) of the NBS. The Digital economy index data of 31 provinces and cities in China (2012-2022) obtained the measurement index data of digital Internet development through China City Statistical Yearbook and relevant statistical data, and obtained the China Digital Inclusive Finance Index through the Digital Finance Research Center of Peking University. This paper comprehensively evaluates the digital development environment, inclusive finance and scientific and technological innovation ability, with the coefficient of variation, theil index and dispersion coefficient respectively.

3.2 Measurement results and difference analysis of the three systems

As can be seen from Table 4,Table 5,Table 6.To comprehensively showcase the operational status and characteristics of the digital economic development environment, inclusive finance, and regional economic innovation capabilities, we employ two distinct data analysis methods. Initially, this paper calculates the exponential weight of each factor within each system, with the objective of precisely quantifying the individual factor's contribution to its respective system.At the same time,

the relative importance of each factor is considered, and the overall structure and operation mechanism of the system are fully combined to ensure the objectivity and accuracy of the evaluation results. Through the calculation of each factor, we can more clearly understand the role of each factor in promoting the development of the system, so as to provide strong support for policy making and decision-making, and also provide a solid foundation for our subsequent in-depth analysis and comparison.

In addition, for the digital economic development environment and inclusive finance and regional economic innovation capability,through these three statistical indicators, the complexity, the degree of inequality, and the dispersion of the data distribution can be revealed from multiple dimensions. Calculating the coefficient of variation offers insights into data volatility and stability within each system, exposing financial inclusion system disparities. Meanwhile, determining the discrete coefficient reveals data distribution and complexity. These calculations comprehensively assess each system's operational status, thereby providing robust data support and decision-making foundations for future policymaking and strategic decisions.

Table 4: Weight of digital Development environment Index

TIME	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12
2014	0.09	0.08	0.010	0.024	0.059	0.148	0.189	0.155	0.084	0.068	9.25e-8	0.078
2016	0.07	0.09	0.036	0.040	0.130	0.100	0.152	0.110	0.086	0.069	9.67e-8	0.099
2018	0.09	0.10	0.052	0.058	0.163	0.098	0.112	0.077	0.086	0.087	7.62e-8	0.070
2020	0.10	0.11	0.036	0.067	0.175	0.073	0.096	0.069	0.084	0.099	3.92e-8	0.084

Table 5: Regional economic innovation ability index weight

TIME	X1	X2	XY3	X4	X5
2014	0.2003	0.2411	0.2565	0.1539	0.1479
2016	0.2345	0.2100	0.2317	0.1541	0.1694
2018	0.2321	0.1894	0.2739	0.1649	0.1395
2020	0.2525	0.2222	0.2412	0.1612	0.1227

Table 6: Financial inclusion index weight

TIME	Z1	Z2	Z3	Z4	Z5	Z6
2014	0.1178	0.1836	0.1351	0.2369	0.2423	0.0840
2016	0.1652	0.1455	0.2196	0.1487	0.1413	0.1794
2018	0.0811	0.1998	0.2219	0.2817	0.1276	0.0876
2020	0.0782	0.2699	0.1277	0.3257	0.1165	0.0816

The study of the three systems, discrete coefficient, coefficient of variation and Theil index, we find that the measurement results of the regional economic innovation ability system, digital development system and inclusive finance system all change dynamically. Both the development of digital economy and inclusive finance show a trend of seeking progress while maintaining stability, and the development of scientific and technological innovation level is in a state of fluctuation.

Among them, Figure 1 shows that the discrete level among various regions in the digital development environment is decreasing year by year, and tends to be steady year by year. As a result, the disparity in digital development among regions is gradually narrowing, while the overall development level across regions is consistently improving. Figure 2 shows that the trend of scientific and technological innovation capacity varies from 2013 to 2020, which reflects the complexity and uncertainty of the process of scientific and technological innovation, and also reveals the zigzag upward characteristics of scientific and technological progress. Figure 3 shows that the discrete level of finance among various regions of inclusive finance decreases year by year,

and shows steady state year by year, and the development of inclusive finance is gradually stable.

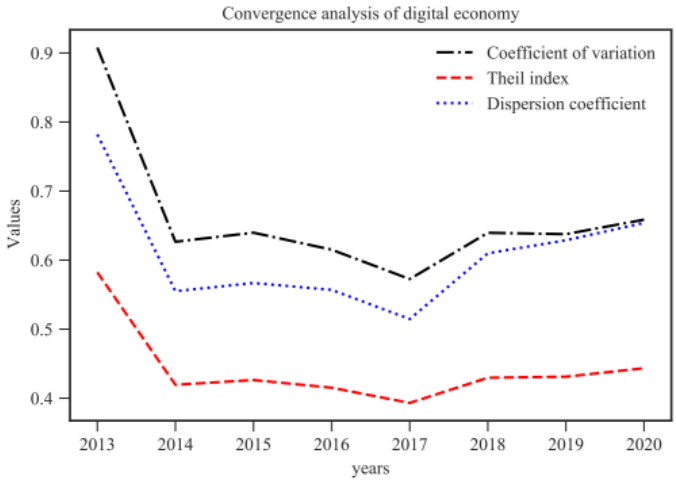

Figure 1: Convergence diagram of the digital development environment

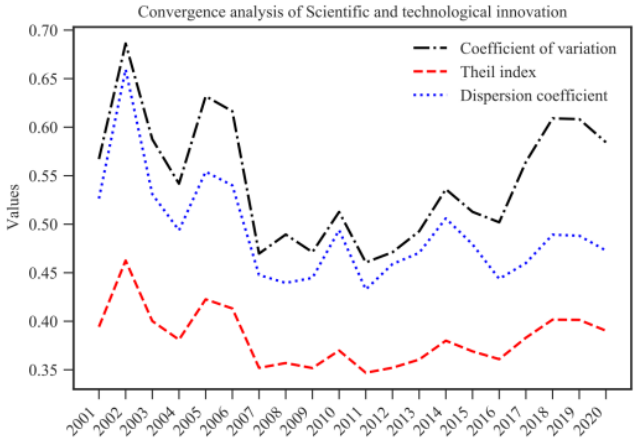

Figure 2: Index convergence diagram of scientific and technological innovation ability

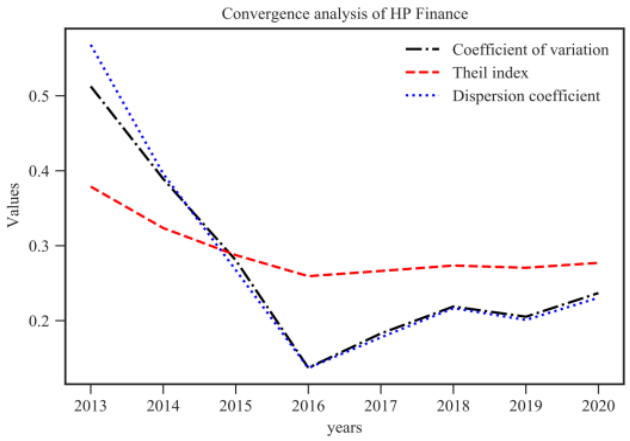

Figure 3: Convergence diagram of the Financial Inclusion Index

3.3 The coupling and coordination level and the index contribution degree of the three systems

The coupling and coordination among the digital economic development environment, inclusive finance, and regional economic innovation capability is continually improving year on year.This trend fully demonstrates the interdependence and close relationship among the three. The interactions and interactions among different systems are increasingly strengthened. This improvement of coordination helps to optimize the allocation of resources, optimize the financial environment, improve the overall economic efficiency, and promote the comprehensive and sustainable development of the economy and society. With the continuous progress of science and technology and the sustainable development of economy, this coupling and coordination level is expected to continue to maintain the growth trend, providing strong support for the prosperity and stability of regional economy.

As can be seen from Table 7. Indicators such as full-time equivalent R&D personnel, R&D funds, local financial science and technology expenditure, and domestic patent application acceptance contribute significantly to contingency and coordination. Among them, key indicators such as full-time equivalent for R & D personnel, R & D expenditure , local financial science and technology expenditure and the acceptance of domestic patent applications make an decisive contribution to promoting the innovation and coordinated development of regions or countries. These indicators not only showcase the investment and accumulation of scientific research personnel but also serve as a crucial basis for assessing technological innovation capabilities and development potential. Among them, the synergistic effect of these indicators jointly promotes the coordinated development of scientific and technological innovation and regional economy, and lays a solid foundation for the comprehensive progress of the society.

Table 7: Difference analysis of coupling coordination degree

Time	Degree of coupling	Coordination index	Coupling coordination
2013	0.264772882	0.241772027	0.251277624
2014	0.293657160	0.260087673	0.274003146
2015	0.307314730	0.269379097	0.285842777
2016	0.321320934	0.274447496	0.295201934
2017	0.324188400	0.293288029	0.307257157
2018	0.327368164	0.305925464	0.315195453
2019	0.329811741	0.315118956	0.315359619
2020	0.337386920	0.329730956	0.332478590

As can be seen from Table 8, R & D personnel full-time equivalent (person), R & D expenses (ten thousand yuan), Local financial Expenditure on science and technology (100 million yuan), Acceptance of domestic patent applications (item)and other indicators have a significant contribution to the contingency and coordination. Among them, key indicators such as full-time equivalent (person) for R & D personnel, R & D expenditure (10 thousand yuan), local financial science and technology expenditure (100 million yuan) and the acceptance of domestic patent applications (item) make an decisive contribution to promoting the innovation and coordinated development of regions or countries.These indicators reflect both the investment and accumulation of scientific research personnel, and constitute a significant basis for assessing scientific and technological innovation capabilities and developmental potential. Among them, the synergistic effect of these indicators jointly promotes the coordinated development of scientific and technological innovation and regional economy, and lays a solid foundation for the overall progress of the society.

Table 8: Three-system factor contributions based on the coupled coordination degree

Index	sorce	Index	sorce
Y1	0.022204	X1	0.002120
Y2	0.124677	X2	0.002120
Y3	0.088213	X3	0.001390
Y4	0.059315	X4	0.001328
X5	0.005525	X5	0.001207
Y6	0.002739	Z1	0.002641
Y7	0.002503	Z2	0.002236
Y8	0.014696	Z3	0.004810
Y9	0.014259	Z4	0.001188
Y10	0.534375	Z5	0.003768
Y11	0.002827	Z6	0.001668
Y12	0.104685		

4. Conclusion

There is a significant coupling and coordination relationship between regional economic innovation ability, digital development and inclusive finance. Digital development and inclusive finance can promote each other, form a virtuous cycle, and further promote the improvement of regional economic innovation capacity. Digital development can provide more data and information, and improve the efficiency and quality of financial services. The popularization of inclusive finance further promotes the innovation and application of digital technology, and at the same time, it expands the coverage of financial services, reduces the cost of financial services, and improves the efficiency of financial services, so as to provide strong support for regional economic development, and then promote the improvement of regional economic innovation ability. Regional economic innovation ability is an important support and basic driving force for the coupling and coordination of digital development and inclusive finance. Regions with strong innovation ability can often absorb and apply new technologies more quickly, so as to promote the deep integration of digital development and inclusive finance.

The government should improve the ability of innovation resources allocation, innovation environment construction ability and innovation achievements transformation ability, cultivating regional economic innovation ability, digital development and pratt & whitney financial coupling coordination momentum, increase investment in science and technology innovation, cultivate innovative talents, promote regional economy to innovation-driven transformation. Exploring the coupling and coordination mechanism between digital development and inclusive finance through the lens of regional economic innovation capability holds significant importance for advancing regional economic growth. The government should strengthen policy guidance, technology innovation, financial service system optimization, regional cooperation and exchanges and professional personnel training efforts, strengthen cooperation and exchanges, promote the depth of the digital development and pratt & whitney financial fusion.

References

[1] Guo Feng, Wang Jingyi, Wang Fang, et al. Measure the development of Digital inclusive finance in China: index compilation and spatial characteristics [J]. Economics (Quarterly Journal), 2020, 19(04):1401-1418.

[2] Xue Menglu. Dynamic Evolution and Convergence Analysis of Digital Inclusive Finance Development [C] China Society of Management Modernization, Fudan Management Award Foundation. Proceedings of the 17th (2022) China Management Annual Conference. School of Economics, Ocean University of China; 2022:10.

[3] Jiao Yunxia. Digital financial inclusion in China: development logic, spatial and temporal pattern and regional differences [J]. Journal of Lanzhou University (Social Science Edition), 2022, 50(03):52-66.
[4] Robel ni. Evaluation and analysis of national regional innovation capacity [C] Singapore Management and Sports Science Institute, Singapore, Information Engineering Research Institute, USA. Proceedings of 2019 7th ICASS International Conference on Humanities Science and Society evelopment(HSSD 2019). School of Economics, Shanghai University; 2019:6.
[5] Zhao Tao, Zhang Zhi, Liang Shangkun. Digital economy, entrepreneurial activity and high-quality development—Empirical evidence from Chinese cities [J]. Management the world, 2020, 36(10):65-76.
[6] Li Bozhou, Zhang Meili. Mechanism of digital transformation on high-quality development of regional economy — Regulation of regional innovation ability [J]. Systems Engineering, 2022, 40 (01): 57-68.
[7] Chen Boqiang. An Empirical Research on Improving the Level of Agricultural Digitalization by Digital Inclusive Finance [J]. Gansu Agriculture, 2024, (02):60-65.