ATLANTIS PRESS
Advances in Economics, Business and Management Research, volume 217
Proceedings of the 2022 International Conference on Urban Planning and Regional Economy (UPRE 2022)

Synergistic Coupling Analysis of Digital Inclusive Finance and Regional Financial Development Based on FAHP

Siyu Liu*

School of Finance, Shanghai Lixin University of Accounting and Finance, 201209, Shanghai, China
**Corresponding author. Email: (liusiyu0212@163.com)*

ABSTRACT
In order to explore the synergistic development relationship between inclusive digital finance and regional finance, based on the analysis of the synergistic effect of inclusive digital finance and regional finance development, the method of synergistic degree model of fuzzy hierarchical analysis (FAHP) is applied to construct a synergistic degree evaluation model of inclusive digital finance and regional finance development, and the model is applied to the study of inclusive digital finance and regional finance development in Shanghai. The results show that the synergy degree of the compound system of inclusive digital finance and regional finance has an M-shaped fluctuation and an overall positive value. The study is useful to test the specific impact of inclusive digital finance on regional financial development by reducing risk and expanding the scope of benefits through digital means. It can provide new ideas and thoughts for promoting inclusive digital finance and regional financial development in the new era and improving the efficiency of social operation.

Keywords: *FAHP; inclusive digital finance; regional finance; synergy analysis*

1. INTRODUCTION

Numerous studies have shown that inclusive digital finance is a key factor for high-quality economic development and plays a more important role in boosting regional financial development. Therefore, exploring the status of inclusive digital finance, regional financial development, and the synergistic development capacity between them is conducive to discovering the interaction between digital inclusive finance models and regional financial development, which is of great guiding significance.

Numerous experts and scholars have made a series of studies on inclusive digital finance and regional financial development. For example, Teng et al. [1]established a regression analysis model to explore the impact of inclusive finance coverage. Yu et al. [2]used a conditional efficiency-based data envelopment analysis model to detect the impact of inclusive digital finance on local economic growth. Zhang et al. [3]set up an econometric model to analyze the impact of inclusive digital finance on the quality of regional economic development. Zhang et al.[4] measured digital inclusive finance and regional economic development and their spatial and temporal coupling coordination analysis by establishing a coupled coordination and comprehensive evaluation model. Kapoor[5] argued that the digital finance model has inclusive growth characteristics, which can effectively improve the financial accessibility of low-income groups. Ozili[6] explored the inclusive type of digital finance for financial institutions, governments, and consumers, which is significant for improving the inclusiveness of financial development. From the perspective of policy support, Hu et al.[7] study the necessity and feasibility of building a long-term regulatory mechanism for inclusive digital finance, vigorously building a digital inclusive financial infrastructure. Recently, many scholars have argued the relationship between inclusive digital finance and regional financial development from multiple perspectives. However, each indicator is influenced by many comprehensive indicator sets. A comprehensive set of indicators influences each indicator, and not one or a few intermediary factors can completely determine it. Because of the comprehensive problems of the two influencing factors, this paper uses the fuzzy analytic hierarchy process to scientifically and reasonably select the order parameter indexes of the two systems and determine the weight of each index to solve the problem

of simplification of influencing factors creatively. Meanwhile, this paper takes inclusive digital finance and regional finance as the research objects, which constructs the synergistic effect model of the two to directly measure the synergistic coupling relationship. It achieves a higher level of integration and promotion by determining the synergistic relationship between the two. Finally, this paper applies the model to Shanghai, China, to provide an empirical reference for the collaborative relationship between regional financial development and inclusive digital finance to apply the research results to other financial development cities, and use policy recommendations to help the coordinated development.

2. ANALYSIS OF THE SYNERGY EFFECT OF DIGITAL INCLUSIVE FINANCE AND REGIONAL FINANCIAL DEVELOPMENT

Digital inclusive finance applies a series of Internet-related technologies to promote information sharing and effectively reduce transaction costs and the threshold of financial services, thus meeting the need to expand the scope of financial services and reduce risks. Based on Yang et al. [8].'s study, analyzed from a qualitative perspective, on the one hand, inclusive digital finance uses technologies to powerfully break down information barriers, expand the scope of financial service benefits, and drive regional financial development. On the other hand, with the increasing vitality of regional finance, the expanding demand for financial services in the market also effectively directs a large flow of resources to the development of inclusive digital finance, thus promoting the development of inclusive digital finance, as shown in Figure 1.

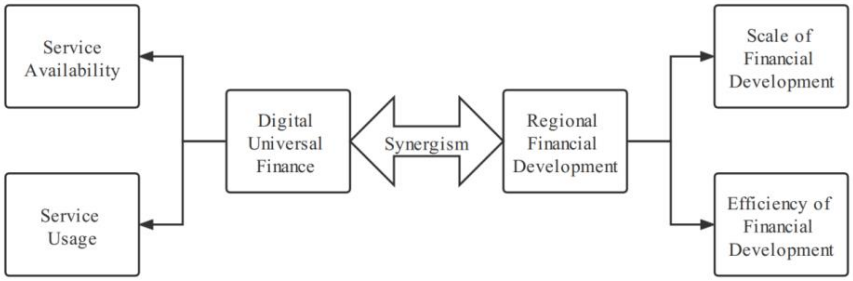

Figure1 Synergy between inclusive digital finance and regional financial development

3. FAHP-BASED SYNERGY MODEL CONSTRUCTION

In this paper, we study the synergy of two subsystems, inclusive digital finance and regional finance, and construct a synergy evaluation model of inclusive digital finance and regional finance to reveal the evolution pattern and trend of the system.

3.1. Determination of sequence parameters

3.1.1. Digital Inclusive Finance Sequential

Parametric Profile

The academic community has not formed a unified measurement standard to measure the development of inclusive digital finance. Therefore, this paper uses the ' Peking University Digital Inclusive Finance Index ' compiled by the Digital Finance Research Center of Peking University, which is highly recognized by the academic community, to measure the development of inclusive digital finance. Also, this paper mainly refers to Guo et al.[9] and Chen et al.[10] It constructs the digital inclusive finance index system according to the scientific, dynamic, typical, and systematic principles, as shown in Table 1.

Table 1 Sequential covariates of inclusive digital finance

	Tier 1 Indicators	Secondary indicators	Unit
Digital Inclusive Finance Sequential Parameters (X)	Total Index (X_1)	Total Index (X_{11})	-
	The breadth of coverage (X_2)	The breadth of coverage (X_{21})	-
	Depth of use (X_3)	Payments (X_{31})	-
		Insurance (X_{32})	-

		Credit (X_{33})	-
	Degree of digitization (X_4)	Degree of digitization (X_{41})	-

3.1.2. Regional financial sequence covariates

To establish regional financial sequential covariates, this paper mainly refers to the studies of Guo et al.[11], Su et al.[12] on regional financial development indicators, and measures regional financial development based on financial development scale and financial development efficiency to meet the conditions of objectivity, comprehensiveness, and accessibility. The specific indicators are shown in Table 2.

Table 2 Regional financial development sequential covariates

	Tier 1 Indicators	Secondary indicators	Unit
Regional Financial Subsystem (Y)	The scale of financial development (Y_1)	Balance of domestic and foreign currency deposits (Y_{11})	Billion
		Balance of domestic and foreign currency loans (Y_{12})	Billion
		Premium income (Y_{13})	Billion
		Total stock market value (Y_{14})	Billion
	Financial development efficiency (Y_2)	Financial depth (Y_{21})	-
		Insurance depth (Y_{22})	-
		Securitization rate (Y_{23})	-
		Industry Scale (Y_{24})	-

3.2. Subsystem orderliness model

Consider inclusive digital finance and regional finance as a composite system $S=\{S_1,S_2\}$, where S_1 is the digital inclusive finance subsystem an S_2 d is the regional finance subsystem. Consider the subsystem $S_j\left(j\in[1,2]\right)$, let its order parameter be $e_j=\left(e_{j1},e_{j2},\ldots,e_{jn}\right)$, where are e_{ji} the critical values when the system is instability, $\beta_{ji}\le e_{ji}\le\alpha_{ji},n\ge1,i=1,2,\ldots,n,$ α_{ji}、β_{ji} respectively. Assume $\left(e_{j1},e_{j2},\ldots,e_{ji}\right)$ that it is a positive indicator, and the magnitude of its value is positively correlated with the orderliness; $\left(e_{jl+1},e_{jl+2},\ldots,e_{jn}\right)$ it is an inverse value, and its value is negatively correlated with the orderliness of the system. Then the systematic orderliness of the order parameter component e_{ji} of the subsystem S_j is

$$u_j\left(e_{ji}\right)=\begin{cases}\dfrac{e_{ji}-\beta_{ji}}{\alpha_{ji}-\beta_{ji}},\ \mathrm{i}\in[1,l]\\ \dfrac{\alpha_{ji}-e_{ji}}{\alpha_{ji}-\beta_{ji}},\ \mathrm{i}\in[l+1,n]\end{cases}\tag{1}$$

Based on the covariate theory, the contribution of the ordinal covariates to the system can be calculated by "integrating" each ordinal covariate component. In this paper, the linear weighting method is used for integration. w_j The fuzzy hierarchical analysis method is applied to determine it. First, the judgment matrix is established as in equation (2). where $a_{ij}>0,\ a_{ii}=1,\ a_{ij}=\dfrac{1}{a_{ji}},\ i,j=1,2,\ldots,\mathrm{n}$. Second, the maximum characteristic root is calculated and passes the consistency test. Finally, the fuzzy judgment matrix is established.

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} \end{bmatrix} \quad (2)$$

$$a_{ij}=\frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} \quad (3)$$

$$w_i=\sum_{j=1}^{n} a_{ij} \quad (4)$$

$$w_i=\frac{w_i}{\sum_{j=1}^{n} w_j} \quad (5)$$

$$\lambda_{max}=\sum \frac{(Bw)_i}{nw_i} \quad (6)$$

$$CI=\frac{\lambda_{max}-n}{n-1} \quad (7)$$

$$CR=\frac{CI}{RI} \quad (8)$$

$$R=\begin{bmatrix} r11 & r12 & \cdots & r1j \\ r21 & r22 & \cdots & r2j \\ \vdots & \vdots & \ddots & \vdots \\ ri1 & ri2 & \cdots & rij \end{bmatrix} \quad (9)$$

3.3. Composite system synergy model

In order to reasonably measure the comprehensive development of the two systems, this paper adopts the synergy degree model to describe the degree of mutual influence between the two systems and reflect their mutual level of coordinated development to reasonably analyze the current situation and trend.

$$U(t)=sig(\square)\sqrt{|U_1(t)-U_1(t-1)|\square|U_2(t)-U_2(t-1)|} \quad (10)$$

$$sig(\square)=\begin{cases} 1, U_1(t)-U_1(t-1)\geq 0, U_2(t)-U_2(t-1)\geq 0 \\ -1, \text{Else} \end{cases} \quad (11)$$

4. EMPIRICAL ANALYSIS

4.1. Study area

As the most representative city in China's financial development, Shanghai, with its advanced digital technology base and urban location advantage, has formed a large-scale, clearly divided, and digitally inclusive financial market system, which leads to the financial development of other regions in China. Therefore, this paper takes Shanghai as the object of empirical research. The research results reflect the synergistic relationship between the two composite systems and provide guiding ideas and suggestions for developing inclusive digital finance and regional finance in other Chinese cities.

4.2. Data sources

The data of inclusive digital finance and regional financial sequential covariates in Shanghai are obtained from the "Peking University Digital Inclusive Finance Index" from 2011 to 2020, the Shanghai Statistical Yearbook, and the statistical bulletin of national economic and social development in the corresponding years, and the specific index data are shown in Table 3.

Table 3 Shanghai Digital Inclusive Finance and Regional Financial System Sequential Parametric Index Data

Indicator/Unit	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
X_{11}/-	80.19	150.77	222.14	239.53	278.11	282.22	336.65	377.73	410.28	431.93
X_{21}/-	98.85	149.35	187.31	237.02	258.98	274.25	305.89	346.33	378.25	395.20
X_{31}/-	100.00	136.14	169.95	225.10	268.49	309.09	333.43	356.14	365.22	368.97
X_{32}/-	72.82	227.70	680.74	725.26	521.32	615.25	785.39	849.62	932.26	945.37
X_{33}/-	90.30	156.94	156.87	142.88	201.70	190.79	231.81	243.08	282.23	296.03
X_{41}/-	75.80	111.94	230.30	241.88	374.54	309.94	330.31	440.26	462.23	450.08
Y_{11}/billion	58186.50	63555.25	69256.32	73882.45	103760.6	110511.0	112461.70	121112.30	132820.30	155865.1
Y_{12}/billion	37196.80	40982.48	44357.88	47915.81	53387.20	59982.25	67182.01	73272.40	79843.01	84643.04
Y_{13}/billion	753.11	820.64	821.43	986.75	1125.16	1529.26	1587.20	1405.79	1720.00	1864.99
Y_{14}/billion	19442.00	21395.00	26957.00	43141.00	61384.00	55556.00	58307.00	43959.00	53044.00	76500.00
Y_{21}/-	1.94	1.99	1.99	1.99	2.08	2.13	2.19	2.24	2.09	2.19
Y_{22}/-	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.05	0.05

Y_{23}/-	1.01	1.04	1.21	1.79	2.39	1.97	1.90	1.35	1.39	1.98
Y_{24}/-	3.03	3.09	3.11	3.07	4.04	3.92	3.67	3.71	3.48	4.03

4.3. Determination of weighting indicators

After filling the judgment matrix with the indicators of inclusive digital finance and regional financial development in Shanghai, a consistency test is conducted to determine whether CR is less than 0.1. The judgment matrix of digital inclusive finance indicators is shown in (12) and the judgment matrix of regional financial indicators (13).

$$\begin{pmatrix} 1 & 2 & 8 & 6 & 4 & 8 \\ \frac{1}{2} & 1 & 6 & 4 & 3 & 6 \\ \frac{1}{8} & \frac{1}{6} & 1 & \frac{1}{3} & \frac{1}{7} & \frac{1}{4} \\ \frac{1}{6} & \frac{1}{4} & 3 & 1 & \frac{1}{2} & 2 \\ \frac{1}{4} & \frac{1}{3} & 7 & 2 & 1 & 3 \\ \frac{1}{8} & \frac{1}{6} & 4 & \frac{1}{2} & \frac{1}{3} & 1 \end{pmatrix} \quad (12)$$

$$\begin{pmatrix} 1 & 3 & 7 & 6 & 5 & 7 & 4 & 7 \\ \frac{1}{3} & 1 & 5 & 4 & 3 & 6 & 2 & 6 \\ \frac{1}{7} & \frac{1}{5} & 1 & \frac{1}{3} & \frac{1}{4} & 1 & \frac{1}{5} & 1 \\ \frac{1}{6} & \frac{1}{4} & 3 & 1 & \frac{1}{2} & 2 & \frac{1}{4} & \frac{1}{3} \\ \frac{1}{5} & \frac{1}{3} & 4 & 2 & 1 & 3 & \frac{1}{2} & 6 \\ \frac{1}{7} & \frac{1}{6} & 1 & \frac{1}{2} & \frac{1}{3} & 1 & \frac{1}{6} & \frac{1}{2} \\ \frac{1}{4} & \frac{1}{2} & 5 & 4 & 2 & 6 & 1 & 4 \\ \frac{1}{7} & \frac{1}{6} & 1 & 3 & \frac{1}{6} & 2 & \frac{1}{4} & 1 \end{pmatrix} \quad (13)$$

Based on the FAHP model calculation, the CR sizes of matrix 13 and 14 were obtained as 0.0499 and 0.0689 were less than 0.1. The constructed matrix passed the consistency test, and the index weights were obtained, as shown in the table.4

Table 4 Weighting of inclusive digital finance and regional financial order covariates in Shanghai

	Indicators	Indicator weights
Digital Inclusive Finance Subsystem (X)	Total Index (X_{11})	0.1837
	The breadth of coverage (X_{21})	0.2035
	Payments (X_{31})	0.1090
	Insurance (X_{32})	0.1715
	Credit (X_{33})	0.1762
	Degree of digitization (X_{41})	0.1561
Regional Financial Subsystem (Y)	Balance of domestic and foreign currency deposits (Y_{11})	0.1452
	Balance of domestic and foreign currency loans (Y_{12})	0.1849
	Premium income (Y_{13})	0.0887
	Total stock market value (Y_{14})	0.0986
	Financial depth (Y_{21})	0.1401
	Insurance depth (Y_{22})	0.0856
	Securitization rate (Y_{23})	0.1640
	Industry Scale (Y_{24})	0.0928

As shown in Table 4, in the digital inclusive finance subsystem, the breadth of coverage indicator has the most considerable weight of 0.2035. The indicator of the breadth of coverage is important compared with other indicators. On the contrary, the payment indicator has the smallest weight. In the regional finance subsystem, the domestic and foreign currency loan balance indicator has the largest weight of 0.1849. The second most important

indicator is the securitization rate at 0.1640, which is second only to the local and foreign currency loan balance.

4.4. System orderliness and synergy analysis

Using equation (2) to calculate the orderliness of inclusive digital finance and regional financial subsystem respectively; on this basis, equation (11) is used to calculate the Synergy of inclusive digital finance and regional financial composite system, as shown in Figure 2.

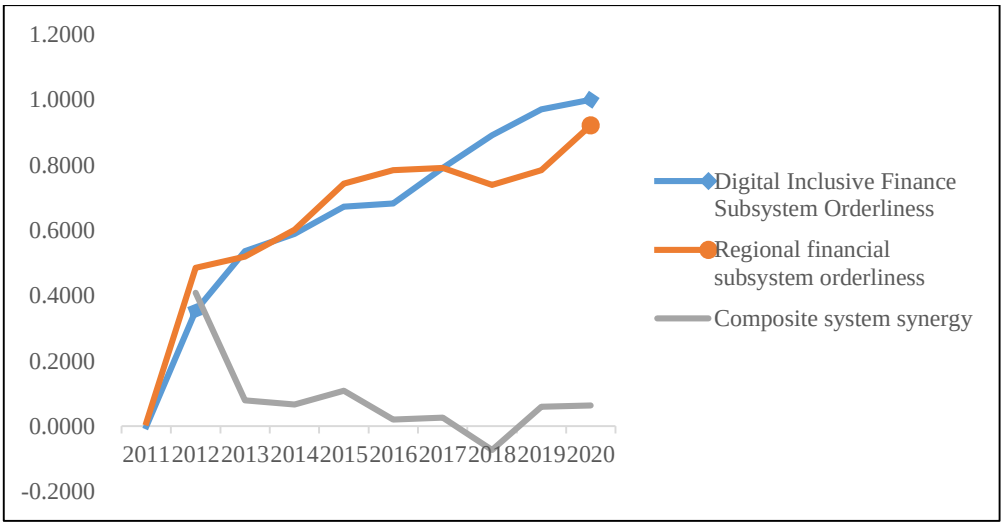

Figure 2 Changes in the orderliness and synergy between inclusive digital finance and regional finance in Shanghai, 2011-2020

4.4.1. Subsystem orderliness analysis

As shown in Figure 2, the overall orderliness shows an upward trend. The orderliness of the digital inclusive finance subsystem grows faster than that of the regional finance subsystem. The orderliness of the digital inclusive financial subsystem grew from 0 to 1 in 2011. The orderliness of the regional financial subsystem increased from 0.0115 in 2011 to 0.9219 in 2020, where it peaked in 2020. It is indicated that the contribution is of the two subsystems to the composite system is increasing. By comparing the orderliness of the two subsystems, it can be seen that: in 2011-2017, the orderliness of the regional finance subsystem is generally higher than that of the digital inclusive finance subsystem, indicating that regional finance has a supporting and boosting effect on inclusive digital finance; in 2018-2020, the orderliness of the digital inclusive finance subsystem is significantly higher than that of the regional finance subsystem, proving that inclusive digital finance is developing well.

4.4.2. Analysis of the Synergy of composite systems

As shown in Figure 2, the synergy shows an M-shaped development trend and is generally at a low level of synergy. The overall trend of the synergistic attitude of the composite system can be divided into four stages.

Phase I: From 2012 to 2013, the orderliness of the digital financial inclusion subsystem and the orderliness of the regional financial subsystem grew slowly, and the composite system synergy declined sharply but was still at a positive value.

Phase 2: From 2014 to 2016, there were fluctuations in the growth rate of the orderliness of the two system, as well as fluctuations in the Synergy of the composite system, but the two systems have been in a synergistic state.

Phase 3: In 2017-2018, the orderliness of the digital financial inclusion subsystem has been growing, but the orderliness of the regional financial subsystem has slightly declined. At this time, the composite system synergy is negative, i.e., the two systems appear to be uncoordinated.

Phase 4: In 2019-2020, inclusive digital finance and regional financial system orderliness grow, with inclusive digital finance ahead of regional finance; the composite system synergy is positive, and the development trend is good.

5. CONCLUSION

This paper combines theory and empirical evidence to analyze and demonstrate the synergistic coupling relationship. Figure 2 shows that inclusive digital finance is undergoing a rapid development process. Therefore, inclusive digital finance is leading the development of regional finance. Meanwhile, the composite system synergy of the two is mainly positive, indicating that inclusive digital finance and regional financial development are synergistic and have a good trend.

According to the above empirical test conclusions, there are three suggestions. First, improve the construction of a digital inclusive financial system. With the help of financial technology and digital technology, we will accelerate the construction of a multi-level capital market system, promote the transformation and upgrading of investment and financing models. Second, through the establishment of digital platforms, investment in digital finance can be effectively increased. The government will create a good environment for research and development of big data and artificial intelligence to solve the problems in weak areas. Third, promote the reform of the financial system and improve the mechanism of the financial system. For middle-income groups and below and small-scale private enterprises, services are seriously inadequate. Therefore, governments need to actively promote the formulation of policies and measures related to inclusive digital finance, fundamentally improve the development of digital finance, and provide a steady stream of power for China's financial growth.

REFERENCES

[1] Teng L., Zhang H. & Tang S.. (2021). Digital financial innovation and rural economic development in an inclusive perspective. Survey World(12),34-42.doi:10.13778/j.cnki.11-3705/c.2021.12.006.

[2] Yu, Zhiqian & Zhu, Ning. (2021). Digital Economy, Inclusive Finance and Economic Growth. Journal of Jinan (Philosophy and Social Science Edition) (11), 51-61. doi:

[3] Zhang, Q. J. & Huang, L.. (2021). Digital Inclusive Finance, Industrial Structure and High Quality Economic Development. Jianghan Forum (10), 41-51. doi:

[4] Zhang, H., Zhao, M. & Li, L.. (2021). A study on the spatio-temporal coupling and coordination of digital inclusive finance and regional economic development - based on provincial panel data empirical evidence from 2011-2019. New Finance (06), 47-53. doi:

[5] Kapoor, A. . (2014). Financial inclusion and the future of the indian economy. futures, 56(feb.), 35-42.

[6] Ozili, & Peterson, K. . (2018). Impact of digital finance on financial inclusion and stability. borsa Istanbul Review, S2214845017301503.

[7]HU Bin & CHENG Xuejun. (2020). Fintech, Digital Inclusive Finance and National Financial Competitiveness. Geomatics and Philosophy and Social Sciences of Wuhan University(03),130-141.] doi:10.14086/j.cnki.wujss.2020.03.013.

[8] Yang, Y. & Zhang, C. Rainbow. (2021). A study on digital inclusive finance and China's regional economic growth based on spatial Durbin model. China Business Journal (24), 109-113. doi:10.19699/j.cnki.issn2096-0298.2021.24.109.

[9] Guo F & Xiong YJ. (2021). A study on the measurement of digital inclusive finance and its impact in China: a literature review. Financial Review (06), 12-23+117-118. doi:

[10]Chen Qinghua, Wang Yan & He Jingyi. (2022). Digital inclusive finance, enterprise technology innovation and quality of economic growth. Contemporary financial research (01), 38-49. doi :

[11]Guo, Na & Guo, Z. P.. (2019). Research on innovative industrial clusters and regional financial development - A case study of innovative industrial clusters of next-generation Internet in Shenzhen. Regional Finance Research (06), 41-51. doi:

[12]Su Yamin & Chen Chen Chen (2017).On the evaluation and analysis of regional financial development level.Tech Entrepreneurship Monthly (04), 4-6.