

Research on the Influence of the Development of Digital Finance on Regional Innovation Performance

-- Based on China's Inter-provincial Panel Data

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Abstract: The improvement of regional innovation performance plays an important role in promoting high-quality economic development, while digital finance digitally reforms traditional finance and empowers regional innovation ability from the financial field. Based on the panel data of 31 provinces (excluding Hong Kong, Macao and Taiwan) from 2011 to 2020, this paper studies the impact of the development of digital finance on regional innovation performance by using random effect model. The results show that the development of digital finance will stimulate regional innovation, and there is a positive correlation between them, and this result still holds after the robustness test and endogenous test. Robustness analysis shows that the phenomenon of digital finance promoting regional innovation performance is not significant in the eastern region, but significant in the central and western regions. Finally, on the basis of the research conclusion, this paper puts forward some countermeasures and suggestions to establish regional coordinated innovation mechanism, promote the construction of digital infrastructure and strengthen the risk management of digital finance. This paper enriches the relevant research on the influence of digital finance development on regional innovation performance, and provides theoretical basis and policy reference for digital finance to promote the improvement of regional innovation level.

Keywords: Digital finance, Regional innovation performance, Random effect model, Robustness test, Digital technology.

1. Introduction

During the 14th Five-Year Plan period, it is proposed to speed up the implementation of innovation and development strategies in different provinces, create a unique regional innovation and development engine, and jointly create high-quality economic development and regional innovation layout. At present, China has shifted from high-speed development to high-quality development stage, focusing on the improvement of innovation level, but there is imbalance in regional development, which leads to the overall innovation ability still to be improved. Digital finance is the combination of traditional finance and digital technology, and it is the key factor of digital reform in the financial field. The central bank clearly stated in the Financial Science and Technology Development Plan (2019-2021) that the application of digital technology in the financial industry has effectively promoted the inclusive development of digital finance and broadened the service field of the financial industry. Regional innovation has become the main format of innovation and development, and digital finance also promotes the development of inclusive finance, so it is particularly important to study the influence between them. The existing research mostly analyzes the factors that affect the regional innovation performance from both macro and micro aspects, and the financial system is an important factor that affects the innovation ability. At present, most of them start with the traditional financial perspective, which lacks the characteristics of the times and progress, and there are still few studies from the digital financial perspective. Digital finance improves the financial market, promotes the construction of the financial system, and can also give financial support on the issue of regional innovation ability[1]. Most of the research on regional innovation is mainly at the

enterprise level, and the regional level lacks exploration [2]. Starting from 31 provinces in China, this paper studies the influence of digital finance development on regional innovation performance from a regional perspective, which enriches the research perspective and has theoretical significance.

The main content of this paper is divided into six parts, and two research methods are selected: literature review and empirical analysis. (1) Literature review: This paper collects several articles about the relationship between digital finance development and regional innovation performance, summarizes them, finds the research frontier and determines its own analysis goal. (2) Empirical analysis: This paper selects 31 provincial administrative regions (excluding Hong Kong, Macao and Taiwan) as the research object, and studies the impact of digital finance development on regional innovation performance from 2011 to 2020, and makes regression analysis, robustness and endogenous test, which proves the reliability of the conclusion.

The innovation of this paper is to analyze the impact of digital finance development on regional innovation performance from the regional macro level, but not from the micro level of enterprises. Among the influencing factors of regional innovation ability, this paper chooses digital finance, a relatively frontier influencing factor, to analyze and study, which embodies the advanced nature.

2. Literature Review

2.1. Definition of Digital Finance

With the development of Internet revolution, the application of information technology is becoming more and more common. More industries began to combine with the Internet, resulting in the fields of organic combination with the Internet, such as Internet insurance and Internet medical

care, which made more industrial development models closer to the Internet. Digital finance is a product based on the high combination of traditional financial activities and digital technologies such as big data and blockchain, and the financial industry is more transformed into digital finance. The digital transformation of the financial industry has also enabled more financial products to be continuously innovated, improving service efficiency, extending the use fields and expanding the use scenarios. Realizing the digital reform in the financial field also represents the development direction of the financial industry.

2.2. Development course of digital finance

The development of digital finance can be divided into four stages, and the development of digital finance is a process of continuous improvement and optimization. From the end of 1990s to 2007, it was the first stage and the initial stage. During this period, the Internet just integrated into people's lives, and online services in the financial industry rose. 2008-2013 is the second stage, which is the period of internet financial innovation. The financial crisis has done great harm to the financial systems of various countries. With the development of internet technology, some internet financial platforms have emerged, providing financing channels for enterprises. The third stage is 2014-2017. With the development of the Internet financial platform, some financial chaos emerges one after another. At this stage, the government has strengthened supervision and rectification, which is the period when the platform is cleared. The fourth stage is from 2018 to now. With the development of big data and blockchain technology, digital finance came into being. Today's financial system is developing in a highly digital direction, and the application scenarios of digital finance are increasing. Generally speaking, digital finance is in a period of rapid development.

2.3. Influencing factors of regional innovation performance

Generally speaking, the influencing factors of regional innovation performance are divided into micro and macro aspects. At the micro level, the main body is the enterprise, that is, the factors that affect the innovation performance of the enterprise are analyzed. We can start with government, market and social culture. From the government's perspective, Wang Yongjin and others (2018) confirmed that the reform of administrative examination and approval system can promote enterprise innovation[3]. From the market point of view, some scholars believe that large-scale enterprises have strong innovation ability. In terms of social culture, Zhao Zile and others (2019) analyzed that enterprises with the background of marine culture groups invest more in innovation[4].

From a macro perspective, Liu Xielin (2003) thinks that the environment and infrastructure suitable for innovation are one of the key factors in the construction of regional innovation system. Audretsch and Feldman(1996, 2004) pointed out that knowledge spillover is closely related to regional innovation output, and the spillover effect usually depends on three factors, namely, the stock of knowledge capital, the level of human capital and the R&D investment density of enterprises in the region[5].

2.4. Literature review

Ren Jiao and others (2023) think that digital finance has significantly improved the regional innovation performance,

and the promotion effect is stronger in the southern region, areas with weak financial foundation and the later stage of digital finance development, and digital finance can promote the innovation performance of surrounding areas through spatial spillover effect[6]. Lv Yanwei et al. (2023) found that digital finance can significantly promote regional innovation output, and the promotion effect still exists after considering spatial factors [7]. Du Chuanzhong and others believe that the development of digital finance has a significant innovation effect and can become a new kinetic energy to improve the level of regional innovation. After considering the endogenous and robust issues, this conclusion still holds [8]. Nie Xiuhua and other studies show that digital finance has significantly improved the level of regional technological innovation by relaxing financing constraints and optimizing industrial structure. With the mature development of digital finance and high level of human capital, the "incentive effect" of digital finance innovation is more prominent[9]. Liu Jiixin and others believe that the development of various businesses of digital finance will help ease the financing constraints from the supply side, and then directly promote the improvement of regional innovation level[10]. Xu Ziyao and other researchers found that the development of digital inclusive finance has significantly promoted the regional innovation ability, and this effect has obvious regional heterogeneity due to different urban geographical location, administrative level and initial innovation level[11].

3. Data Processing and Descriptive Statistics

3.1. Data source and processing

This paper uses the panel data of 31 provinces (excluding Hong Kong, Macao and Taiwan) in China from 2011 to 2020, and the vacancy data is supplemented by interpolation[12]. Among them, the development index of digital finance comes from the Peking University Digital inclusive finance Index published by the Digital Finance Research Center of Peking University, and the original data of regional innovation performance and control variables are from the National Bureau of Statistics, the China Statistical Yearbook and the statistical yearbooks of China provinces. Among them, some control variables are divided by the GDP of each province.

3.2. Selection and construction of main indexes

3.2.1. Explained variable:

regional innovation performance. Most of the existing articles measure the regional innovation ability by the amount of invention patents granted, the innovation index of China city or the sales revenue of new products. Based on the above considerations, this paper chooses the amount of invention patent authorization as the proxy variable of regional performance innovation. At the same time, in order to smooth the data, logarithmic processing is carried out [13].

3.2.2. Explanatory variable:

digital financial development index. By using big data technology, this indicator depicts the development level of digital finance in various provinces by numbers. This paper analyzes that digital technology can empower financial development, strengthen the alliance and boost the development of the real economy.

3.2.3. Control variables:

Combining with previous studies, this paper selects the

following control variables: (1) Industrial structure (is). According to the ratio of output value of secondary and tertiary industries, we can see the industrial structure, and a reasonable industrial structure is more conducive to improving regional innovation ability; (2) Government investment in science and technology (gist). The government's financial support is the weather vane, guiding the public's attention, and then investing in innovation and promoting innovation in all directions; (3) Infrastructure (infra). Infrastructure is an important factor affecting the performance of regional innovation. Having a complete infrastructure can provide all conveniences under physical conditions and reduce the cost of innovation flow. (4) Economic development level (led). The level of economic development in a province can be seen from GDP, with high level of economic development and strong natural innovation ability; (5) Human capital (hc). Human resources play a decisive role in regional innovation, leading the output of regional innovation achievements; (6) R&D investment intensity (rd). R&D investment and expenditure can directly show whether to pay attention to regional innovation, and the level of regional innovation will naturally improve with continuous effective R&D investment; (7) Traditional financial development level (tf). The level of financial development determines the source of enterprise funds. The high level of traditional financial development and smooth financing channels are more conducive to regional innovation. (8) The level of foreign direct investment (fdi). Opening to

the outside world affects innovation to a certain extent, and accepting foreign investment is conducive to learning foreign advanced technology and management experience and promoting regional innovation.

3.3. Descriptive statistic

Descriptive statistics of variables in this paper are shown in Table 1. As can be seen from the table, the average value of digital financial index (X) is 216.2352, the standard deviation is 97.0303, and the maximum value is nearly 27 times of the minimum value. It shows that the development level of digital finance in different provinces is far from each other and there is a problem of regional differentiation. Similarly, the average value of economic development level (led) is 55,695.8, and the standard deviation is 27,191.76. The difference between the maximum value and the minimum value is nearly 10 times. It shows that the per capita GDP level of different provinces is different, and the provinces with high GDP and good economic development are more conducive to regional innovation. The average value of human capital (hc) is 4362, the standard deviation is 2706, the minimum value is 55, and the maximum value is 15431. The level of higher education varies among provinces, which is also related to the different population bases in each province. However, the more people with higher education, the more they can promote the improvement of regional innovation ability. The values of other indicators tend to be stable.

Table 1. Related variables and descriptive statistics

Name	Number	Mean	SD	Mix	Max
lny	310	8.0427	1.5868	3.2958	11.1661
x	310	216.2352	97.0303	16.2200	431.9276
is	310	0.9712	0.3430	0.1888	1.9304
gist	310	0.0046	0.0027	0.0014	0.0140
infra	310	0.0642	0.0570	0.0143	0.2896
led	310	55695.8000	27191.7600	16413.0000	164889.5000
hc	310	4362	2706	55	15431
rd	310	0.0163	0.0114	0.0019	0.0644
tf	310	1.4140	0.4807	0.6500	3.0830
fdi	310	0.0199	0.0187	0.0001	0.1210

4. Measurement Model and Estimation Method

4.1. Benchmark model

This paper makes a regression study on the influence of the development of digital finance on regional innovation performance.

$$\ln y_{it} = \alpha_0 + \alpha_1 x_{it} + \alpha_2 X_{it} + \delta_i + \mu_t + \theta_{it}$$

In order to estimate the impact of the development of digital finance on regional innovation performance, this paper adopts benchmark regression measurement model. In order to

make the variable stable, the interpreted variable y is logarithm. Where I represents the region, T represents the year, α represents the regression coefficient, θ_{it} represents the random interference term, regional innovation performance (Y) is the explained variable, digital financial development index (X) is the explained variable, and δ_i and μ_t are the regional fixed effect and time fixed effect respectively. X is a control variable at the provincial level, which mainly includes: industrial structure, government investment in science and technology, infrastructure, economic development level, human capital, R&D investment intensity, traditional financial development level and foreign direct investment. The following is a variable selection table.

Table 2. Specific definition of main variables

Type	Name	Symbol	Definition
Explained variable	Regional innovation performance	y	Authorized quantity of invention patents (units)
Explanatory variable	Digital financial index	x	Digital financial development index
Control variable	industrial structure	is	Output value of secondary industry/tertiary industry
	Government investment in science and technology	gist	Local government expenditure on science and technology /GDP
	infrastructure	infra	Post and telecommunications business volume /GDP
	Level of economic development	led	Real GDP per capita (yuan)
	Manpower capital	hc	Population with college degree or above
	R&D investment intensity	rd	Internal expenditure of R&D funds /GDP
	Traditional financial development level	tf	Loan balance of financial institutions /GDP
	Foreign direct investment	fdi	Actual amount of foreign investment × current exchange rate /GDP

4.2. Estimation method

In the choice of fixed effect and random effect, this paper makes the following considerations: the results of Hausmann test on the model show that the Hausmann test value is less than the critical value of significance level (5%), and we cannot reject the zero hypothesis. Therefore, the random effect model should be selected as the benchmark model for estimation.

4.3. Possible problems and solutions of the model

4.3.1. Multicollinearity

The VIF value of explanatory variable X is 3.99, the variance expansion factor VIF of all indicators is less than 10, and the multicollinearity is weak, which passes the test.

Table 3. Multiple collinearity test

Variable	VIF	1/VIF
rd	5.68	0.176032
led	4.42	0.226358
x	3.99	0.250513
tf	3.05	0.328076
gist	2.69	0.371818
hc	2.64	0.379361
is	2.51	0.398345
infra	2.11	0.473975
fdi	1.48	0.674478
Mean VIF	3.17	-

4.3.2. 4.3.2 Robustness test

According to the previous literature, the methods of robustness test include sub-sample regression, eliminating special samples, changing the research period and replacing the explained variables. In this paper, sub-sample regression method and special sample elimination method are used. Firstly, 31 provinces were divided into eastern, central and western regions, and then one province was excluded from each part. After screening and comparison, Hebei Province was excluded from the eastern region, Jiangxi Province was excluded from the central region, and Inner Mongolia Autonomous Region was excluded from the western region, and the data of the remaining provinces were regressed. It can

be seen from Table 4 that the eastern region is not significant after excluding Hebei Province, while the central and western regions are significant after excluding provinces. The reason is that the economic development level of the central and western regions is lower than that of the eastern region, which is in the primary stage of life development theory, and the development effect of digital finance is remarkable, which has a greater impact on the incentive of regional innovation level. As can be seen from the table, the coefficients of the three parts of sub-sample regression X are all positive, which reflects the positive promotion of digital finance development to regional innovation performance. The better the development of digital finance, the higher the regional innovation performance.

Table 4. Robustness test

	Excluding Hebei province in the east lny	Excluding Jiangxi province in middle lny	Excluding inner Mongolia autonomous in the west lny
x	0.00160 (1.67)	0.00259* (2.36)	0.0137*** (7.09)
_cons	3.838*** (10.24)	6.783*** (11.53)	6.648*** (8.51)
is	1.715*** (8.40)	-0.346** (-2.73)	0.264 (0.57)
gist	64.37** (3.24)	56.42 (1.91)	-94.38* (-2.19)
infra	-1.926 (-1.41)	-0.326 (-0.36)	-1.848 (-1.98)
led	0.00000864** (2.75)	8.69e-08 (0.01)	-0.0000450*** (-5.78)
hc	0.000250*** (11.73)	0.000111** (3.28)	0.000153** (2.88)
rd	26.21*** (4.41)	52.23*** (3.82)	105.6*** (10.11)
tf	0.437* (2.51)	-0.386 (-1.39)	-1.306*** (-6.60)
fdi	-10.64*** (-5.70)	16.58* (2.55)	29.56** (2.78)
N	100	70	110
R2	0.9485	0.9211	0.8905

Note: *, ** and *** indicate significant at the level of 10%, 5% and 1% respectively, and t value is in brackets, the same below.

4.3.3. Endogenous test

The endogenous problems caused by missing variables can be solved by the fixed effect model of panel. This paper selects eight control variables: industrial structure, government investment in science and technology, infrastructure, economic development level, human capital, R&D investment intensity, traditional financial development level and foreign direct investment. Selecting control variables from micro to macro, from input to output, and increasing the number of control variables, to some extent,

alleviated the endogenous problem of missing variables.

For the endogenous problems caused by two-way causality, we can use the instrumental variable method and learn from Sun Churen's land method[14]. It is a reasonable tool variable to use the lagging period of the core explanatory variable X as a tool variable to avoid endogeneity, and the lagging period index satisfies the correlation with the current index and the exclusiveness with the explained variable. According to Table 5, after the introduction of instrumental variables, the coefficient of explanatory variable X is significant at 1% level.

Table 5. Results of Endogenous test

Variable	lny
x	0.00466*** (5.53)
is	-0.306* (-2.26)
gist	12.24 (0.74)
infra	-1.611*** (-4.00)
led	-0.00000380 (-1.29)
hc	0.0000909*** (4.37)
rd	56.23*** (6.49)
tf	-0.340*** (-3.47)
fdi	2.449 (1.68)
_cons	6.700*** (26.94)
N	279

5. Results of Empirical Analysis

After testing the houseman effect, this paper chooses the random effect model. As can be seen from Table 6, the regression coefficient of digital financial development index is positive 0.0034745, which is significant at the level of 1%. It shows that the development of digital finance will stimulate regional innovation, and there is a positive correlation between them. With the development of digital finance, financial technology has been continuously used and combined with traditional financial departments, which has

promoted innovation and entrepreneurship activities, accelerated economic development and promoted the improvement of innovation ability. Among the control variables, the regression coefficients of industrial structure, infrastructure, human capital, R&D investment intensity, traditional financial development level and foreign direct investment are all significant, which have positive and negative effects on regional innovation performance to varying degrees.

Table 6. Benchmark regression result

	lny
x	0.00347*** (6.58)
is	-0.316** (-2.78)
gist	22.56 (1.40)
infra	-1.141** (-3.10)
led	-0.00000446 (-0.19)
hc	0.0000899*** (4.42)
rd	46.90*** (5.68)
tf	-0.168* (-2.04)
fdi	2.609 (1.88)
_cons	6.623*** (29.08)
N	310

In the regression results of robustness test, the regression coefficients of digital financial development index are all positive, which are not significant in the eastern region, but significant in the central and western regions at 10% and 1% levels respectively. The regression coefficients of the three parts are in the same direction, all of which are positive effects, indicating that the improvement of the development level of digital finance can promote regional innovation. The reason why it is not obvious in the eastern region is that the level of economic development in the eastern region is generally high, and various factors that promote the improvement of innovation ability are actively developing, and digital finance accounts for a small proportion of them, and the promotion effect is not obvious. Among the control variables, only infrastructure is not significant, which has little influence on regional innovation ability. Therefore, in the eastern region, the development of digital finance has no obvious effect on regional innovation performance. It is obvious in the western region, because the overall economic development level in the western region is backward, and it is in the primary stage of life development theory, and the development of various behaviors to promote innovation ability is slightly backward, which magnifies the influence of the development of digital finance on the improvement of regional innovation ability. In addition, the regression coefficient between the economic development level and the traditional financial development level in the western region is significantly negative, which

hinders the improvement of innovation level, because the overall development of the western region is considerable, but the internal structure is unbalanced in quality.

6. Policy Advice

6.1. Establish regional coordination and innovation mechanism

First of all, we must formulate exclusive plans for the eastern, central and western regions according to local conditions, and we must not treat them equally. Promote the rational distribution of financial infrastructure and other resources, and backward areas should increase the development and utilization of financial resources. Secondly, establish a regional cooperation mechanism of overall financial resources, form an organic whole, promote the free flow of financial resources across regions, and break down administrative barriers between provinces. Dominant areas play a leading role, while imparting experience to the central and western regions, forming a good environment conducive to the development of digital finance in the market. By virtue of its own advantages, the eastern region can constantly upgrade and change old technologies to backward regions. The western region should also actively learn from advanced technical experience, actively explore the regular pattern of digital finance development, cultivate new formats suitable for digital finance development, continuously extend the

application fields and scope of digital finance, and promote application scenarios. So as to narrow the gap between the eastern, central and western regions, promote balanced and mutually beneficial development, establish a regional coordinated innovation mechanism, and give better play to the effect of digital finance in promoting regional innovation ability.

6.2. Promote the construction of digital infrastructure

Promote the combination of digital finance and regional innovation, give play to the role of digital finance between them in improving regional innovation ability, and promote the sound development of provincial economy. Accelerate the construction of financial infrastructure, form the layout of digital finance, a new service model, in China, and improve the rational layout, which can better play the role of digital finance in promoting the overall regional innovation level[15]. At the same time, financial technology can empower the development of digital finance, give full play to the role of financial technology in the field of financial services, promote the process of digital reform of traditional financial institutions, promote the high-quality development of digital finance, apply it to suitable scenarios more efficiently, and improve the application ability in actual operation.

6.3. Strengthen the risk management of digital finance

While promoting the digital reform of digital finance, strengthen the control and management of financial risks. With the development of digital finance, business contacts between financial institutions are increasing, which increases the possibility of systemic financial risks. On the one hand, promote digital finance to improve regional innovation capability, improve financial infrastructure construction, increase the application scenarios of digital finance in financial markets, and improve new financial services of digital finance. On the other hand, with the improvement of financial risks, it is necessary to strengthen the construction of risk management in the financial system. Strengthen the construction of digital risk control ability, and timely predict, supervise and report risks. From the micro and macro aspects, improve the risk monitoring system to ensure that digital finance plays an active role while reducing the negative impact[16]. Pay attention to supervision, control the spread of financial risks, ensure the safe and stable operation of the entire financial system, and prevent the occurrence of systemic financial risks.

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