

The Impact of China's Digital Finance on R&D Investment and Regional Innovation Performance

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Abstract

We use a mediation effect model to explore the impact of digital finance on regional innovation based on the China digital finance index and interprovincial panel data from 2011 to 2021. We find that the development of digital finance in China is conducive to promoting regional innovation performance, and there is regional heterogeneity. The breadth of digital finance coverage does not significantly impact regional innovation performance. In contrast, the depth and degree of digital finance use substantially impact regional innovation performance. The impact of digital finance on regional innovation performance is not significant in the eastern region but is more important in other regions. At the same time, digital finance promotes regional innovation performance through the intermediary effect of R&D investment, and R&D investment plays a mediating role in promoting regional innovation performance through the depth of digital finance use and the degree of digital support services. The Chinese government should fully understand the role and mechanism of digital finance in promoting regional innovation performance, formulate targeted and differentiated regional development policies, and help digital finance achieve regional innovation performance while developing digital finance.

Keywords: digital finance; R&D investment; region; innovation performance

Introduction

Innovative development has become the key to China's core economic competitiveness. At the end of 2012, the Chinese government proposed an innovation-driven development strategy, clearly stating that China's future development should rely on technological innovation. The 14th Five-Year Plan of China points out that China must adhere to the core position of innovation in the overall modernization construction, regard technological self-reliance and self-improvement as the strategic support for national development, and implement the strategy of innovation-driven development. The driving force of China's economic growth urgently needs to shift from "factor" and "investment" driven to "innovation" driven, and technological innovation is increasingly becoming a critical factor in promoting sustainable development of the Chinese economy. (Zhang & Gao, 2017).

R&D investment is a core factor in achieving technological innovation in China and a significant driving force for promoting sustainable economic development. Data shows that in 2021, China's total investment in research and experimental development (R&D) reached 2795.6 billion yuan, with an R&D investment intensity of 2.44% (China Bureau of Statistics, 2022). China's R&D investment scale is second only to the United States, firmly ranking second globally, but there is still a significant gap compared to developed countries.

Insufficient financial support is essential to technological innovation in China (Tang et al., 2020). The development of digital finance has made up for the shortcomings of traditional financial markets. Through digital technology, digital finance has spurred the continuous development of new financial formats, provided more diversified financing channels, and allowed enterprises to obtain more R&D investment funding support in the R&D process.

The related research on the relationship between digital finance and regional innovation performance mainly focuses on two aspects. One is the impact of digital finance on regional innovation performance. Digital finance positively promotes regional innovation performance but will exhibit heterogeneity due to geographical location, innovation subjects, and financial regulation (Zheng & Zhao, 2021; Zheng et al., 2021). The second is the mechanism by which digital finance affects regional innovation performance. Digital finance can enhance regional innovation performance by alleviating financing constraints (Liu & Li, 2021; Du & Zhang, 2020), improving consumer quality (Xu et al., 2020), and promoting industrial structure upgrading (Nie & Wu, 2021). There are other

issues related to the income gap between urban and rural residents in China's digital finance and entrepreneurship (Song, 2017), economic growth (Hao & Lei, 2018), etc.

Existing research has conducted many beneficial explorations on how digital finance in China affects regional innovation performance. In the context of the rapid development of digital finance, we explored whether and how China's digital finance development affects regional innovation performance. In particular, we explored an essential mechanism by which digital finance affects regional innovation: The R&D investment effect. Digital finance development has broadened regions' financing channels, alleviated their financing constraints, provided new ways for regions to increase R&D investment, and promoted innovation.

Research Objectives

1. To analyze China's digital finance's impact (relationship and heterogeneity) on regional innovation performance.
2. To analyze the mechanism of R&D investment in China's digital finance to promote regional innovation performance.
3. To identify the difference in the mechanism of R&D investment on the promotion of region innovation performance by China's digital finance. Moreover, it creates a new path for the government to use digital finance to promote regional innovation.

Research scope

China has 31 provinces, municipalities, and autonomous regions (excluding Hong Kong, Macau, and Taiwan).

Literature Review

Theory development

As an innovative result of the digital transformation of traditional financial institutions (Wu et al., 2020); the development of digital technology has effectively improved the risk control capabilities of financial institutions, reduced transaction costs, improved operational efficiency, and expanded the supply range of financial services (Feng & Guo, 2019). Digital finance utilizes advantages such as scenarios and services to reach a broader range of enterprise customer groups,

providing financial services to more financing entities and effectively alleviating financing constraints on financing entities. The development of digital finance has expanded the sources and quantity of financing funds and increased the financing channels for the physical economy (Zhang et al., 2019). We believe that the contribution of digital finance may affect regional innovation performance by promoting increased R&D investment.

R&D investment effect

The long-term structural imbalance and resource mismatch between the traditional financial sector and the financial market in China have caused certain constraints on the R&D investment (Wang & Pan, 2015). The development of digital finance has made up for the shortcomings of traditional financial markets. Through the use of digital technology, digital finance has spurred continuous innovation in finance, solved problems such as information asymmetry between supply and demand in the financing process, provided more diversified financing channels for financing entities, and provided more R&D investment funding support, which is conducive to carrying out innovation activities and improving innovation output.

Research Methods

Documentary Study

1) Digital Finance and regional Innovation Performance

Existing research on the relationship between digital finance and regional innovation has found that digital finance can significantly promote regional innovation performance. Digital finance can indirectly promote regional innovation level and performance through regional credit resource allocation, urban infrastructure construction, resident consumption level (Liang et al., 2022), digital finance network centrality (Li, 2022), financial development, stimulating consumer demand and enhancing human capital channels (Lv & Zhang, 2023), high-tech industry agglomeration, strengthening agglomeration economies of scale, and diversified knowledge spillover effects (Ren et al., 2023), and other aspects; Liu and Li (2021) believe that digital finance can alleviate financing constraints from the supply side and directly promote the improvement of regional innovation level. Digital finance can indirectly promote the improvement of regional innovation level by promoting the increase of consumer demand; Zhang et al. (2021) found that digital finance exhibits the “Matthew effect” at the level of regional innovation by studying the impact and mechanism of digital finance

on regional innovation gaps. The “Matthew effect” of digital finance on regional innovation is mainly achieved through the siphoning effect on human and financial factors (Meng & Wu, 2022). Research shows that digital finance can significantly promote the improvement of regional innovation ecology and indirectly improve regional innovation ecology by improving the level of “Internet plus” and regulating government science and technology spending.

The development of digital finance can significantly improve the efficiency of regional technological innovation (Zhou et al., 2021; Liu & Li, 2021; Nie et al., 2021), and there is a Non-linear effect between the two (Zou & Huang, 2021). The incentive effect of digital finance on technological innovation is constrained by factors such as company size and regional heterogeneity (Nie & Wu, 2021), as well as government intervention (Zheng et al., 2021). At the same time, digital finance can influence the innovation incentive level of enterprises through government subsidies as a mediating effect (Chen & Miao, 2021). Digital finance has a promoting effect on the transformation of innovation achievements, while there are mediating effects and regional heterogeneity (Zhuang & Wang, 2021).

Regional heterogeneity. There is a regional imbalance in China’s economic development. The eastern region’s economic development level, innovation environment, and talent resources have huge advantages. The financial support for the real economy is relatively high, and there is a trend of tilting financial resources and policies towards the eastern region. The development level of digital finance in the eastern region is high. With abundant financial resources, the service cost of finance is relatively low, and the willingness to participate in regional innovation is also more robust. There are also many enterprises carrying out innovation activities. The development level of digital finance in the central and western regions is relatively low, and the problem of information asymmetry between enterprises in the region and local banks and other financial institutions has not been effectively solved. The relative lack of financial resources has led to a low level of regional innovation. The development of digital finance provides more resources and paths for improving the investment and financing of financing entities in the region. Suppose the development of digital finance can alleviate the financing constraints of financing entities in the central and western regions. In that case, it can release the innovative vitality of the central and western regions. Therefore, the regional environment will affect regional innovation performance, and there is heterogeneity in the

impact of digital finance on regional innovation performance. The development of digital finance has a more positive effect on promoting innovation performance in non-eastern regions.

Based on the above understanding, Formally, hypothesis 1 is proposed.

Hypothesis 1: The development of digital finance can promote regional innovation performance, and there is heterogeneity.

2) The mediating role of R&D investment in promoting regional innovation performance through digital finance

The development of digital finance has expanded the scope of financial supply entities (Gomber et al., 2018), expanded the sources and quantity of financing funds, increased the financing channels for the real economy (Zhang et al., 2019), broken through the dependence on traditional financing models, and promoted the cross-regional flow and optimized allocation of financial resources. Digital finance can achieve incentive effects on regional technological innovation levels by alleviating financing constraints and unleashing capital potential (Wen, 2021); digital finance can improve the regional innovation environment and enhance regional innovation performance, which is conducive to the innovative development of enterprises. It is difficult for enterprises to meet their own funding needs solely through internal financing. When obtaining bank credit, enterprises can increase their enthusiasm for research and development activities and improve their innovation by increasing research and development investment (Ma et al., 2014). In the digital economy's development context, enterprises face pressure from information transparency and intensified competition. They urgently need to increase innovation investment to promote new product development, which forces them to pay more attention to their transformation, upgrading, and competitive advantages and encourages them to continuously increase their investment in research and development innovation (Xia et al., 2021).

R&D innovation investment can effectively promote the growth of innovation output. Enterprise innovation investment can significantly promote corporate performance (Chen et al., 2015; Xia & Xiao, 2019) and mediate between venture capital and technological innovation. Venture capital can promote technological innovation output by increasing innovation investment in startups (Ma et al., 2018). Therefore, digital finance can alleviate regional financial resource constraints and increase regional R&D investment to promote regional innovation.

Based on the above understanding, this article proposes hypothesis 2.

Hypothesis 2: The development of digital finance can promote regional R&D investment, and R&D investment has a mediating effect on the impact of digital finance on regional innovation performance.

2. Research tools

After collecting secondary data, we process it using econometric software, which mainly includes descriptive statistics, correlation analysis, multiple regression analysis, and mediation effect testing.

3. Data Collection

The data used for analysis are from the China Statistical Yearbook, the Digital Inclusive Finance Research Center of Peking University, the Guotai An Database (CSMAR), and iFin database. Including the following data.

- 1) Peking University Digital Finance Index Data (2011–2021)
- 2) Invention Patent, R&D investment, and other macro data of China (2011–2021)

We winsorized all continuous variables at this research's 1% and 99% levels.

4. Data Processing and Analysis

This research starts with a statistical description of the variables selected. Tabulation explains the maximum, minimum, mean, median, and standard deviation of variable data and explains the characteristics of variable data. Further, We use a table to list the correlation coefficient between variables and explain the correlation between variables

To test the impact and heterogeneity of digital finance development on regional innovation performance, we estimate the following fixed effects model:

$$RIP_{i,t} = \alpha_0 + \alpha_1 DFT_{i,t} + \alpha_2 REG_{i,t} + \alpha_3 Ctr_{i,t} + u_i + v_t + \varepsilon_{i,t} \quad (1)$$

Where $RIP_{i,t}$ represents the number of invention patent applications in I province, municipality, or autonomous region of China during the t period, $DFT_{i,t}$ represents the total index of digital financial development level in I province, autonomous city, or municipality where the listed company is located during period t and $REG_{i,t}$ represents the regional dummy variable. If the province, city, or autonomous region belongs to the eastern region, it is 1. Otherwise, it is 0. Control

$I_{i,t}$ represents a series of control variables; based on related studies (Nie & Wu, 2019), we choose the following region-level characteristics as control variables, including regional economic development level (AGDP), human capital level (HCL), urbanization rate (UR). U_i is province-, year fixed effects, respectively, and $\varepsilon_{i,t}$ is a random perturbation term.

Based on the established model (1), fixed effects were selected for the primary regression of core variables, and the impact of digital finance development on the region was examined from the digital finance total Index (DFT). Referring to the research (Guo et al., 2020), we use the index of different dimensions in digital finance, digital finance coverage breadth (DFC), digital finance usage depth (DFU), and digital finance usage degree (DFD), to replace the core explanatory variable (DFT) in the basic model for empirical testing, to examine the impact of different dimensions of digital finance development on regional innovation performance. Moreover, make robustness testing to verify hypothesis 1.

In order to test the mediating effect of R&D investment on the impact of digital finance on regional innovation performance. Referring to the mediation effect testing method and steps (Wen & Ye, 2014), we estimate the following Simultaneous equation model:

$$RIP_{i,t} = \gamma_0 + \gamma_1 FDT_{i,t} + \gamma_2 Ctr_{i,t} + u_i + v_t + \varepsilon_{i,t} \quad (2)$$

$$RRG_{i,t} = \delta_0 + \delta_1 FDT_{i,t} + \delta_2 Ctr_{i,t} + u_i + v_t + \varepsilon_{i,t} \quad (3)$$

$$RIP_{i,t} = \eta_0 + \eta_1 RRG_{i,t} + \eta_2 FDT_{i,t} + \eta_3 Ctr_{i,t} + u_i + v_t + \varepsilon_{i,t} \quad (4)$$

Where $RIP_{i,t}$ represents the number of invention patent applications in I province, municipality, or autonomous region of China during the t period, $FDT_{i,t}$ represents the total index of digital financial development level in I province, autonomous city, or municipality where the listed company is located during period t , $RRG_{i,t}$ represents R&D investment in China's I provinces, municipalities, and autonomous regions during the period t , $Ctr_{i,t}$ represents a series of control variables, including regional economic development level (AGDP), human capital level (HCL), urbanization rate (UR). U_i , v_t are province-, year fixed effects, respectively, and $\varepsilon_{i,t}$ is a random perturbation term.

Based on the established models (2), (3), and (4), we examine the mediating effect of R&D investment on regional R&D investment and innovation performance and perform regional heterogeneity analysis to verify hypotheses 1 and 2.

Research results

Table 1 reports the descriptive statistical results of variables related to empirical data. The values and standard errors of the indicators are within a reasonable range, meeting the requirements of empirical analysis for data stability.

Table 1 Summary statistics

Variable	Observations	Minimum	Maximum	Mean	Median	SD
RIP	341	0.810	2425.510	327.078	146.400	444.293
DFT	341	16.220	458.970	230.461	237.530	103.363
DFC	341	1.960	433.423	211.646	215.550	103.923
DFU	341	6.760	510.694	225.922	227.520	105.876
DFD	341	7.580	462.230	300.846	332.660	116.925
RRG	341	19.032	652.929	165.866	138.777	115.471
REG	341	0.000	1.000	0.355	0.000	0.479
AGDP	341	9.691	12.123	10.819	10.786	0.458
UR	341	0.227	0.896	0.580	0.568	0.131
HCL	341	0.008	0.042	0.020	0.020	0.006

Table 2 reports the variable correlation analysis results of the Pearson test (Pearson correlation coefficient method). The data is highly credible and has passed the correlation test. There is a significant positive correlation between digital finance and regional innovation performance, indicating that digital finance positively impacts regional innovation performance, but further testing is needed.

Table 2 Pearson correlation coefficients between variables

Variabl	RIP	DFT	DFC	DFU	DFD	RRG	REG	AGDP	UR	HCL
RIP	1									
DFT	0.398*	1								
DFC	0.388*	0.993*	1							
DFU	0.461**	0.969*	0.953*	1						
DFD	0.258*	0.900*	0.870*	0.798*	1					
RRG	0.647**	0.353*	0.364*	0.418**	0.154**	1				
REG	0.506*	0.178**	0.186**	0.245**	0.012**	0.560*	1			
AGDP	0.646*	0.704**	0.717**	0.742**	0.479**	0.770**	0.591**	1		
UR	0.492**	0.470**	0.495*	0.504**	0.260*	0.800*	0.640*	0.845*	1	
HCL	0.154**	0.425**	0.443**	0.424**	0.298*	0.536*	0.228*	0.505*	0.641**	1

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3 reports the impact of digital finance on regional innovation performance.

Column (1) reports the impact of the total digital finance index on regional innovation performance. The Digital Finance Total Index (DFT) coefficient is significantly positive at the 1% level, indicating that the development of Digital Finance (DFT) significantly promotes regional innovation performance. The coefficient of the Regional Characteristics (REG) of the dummy variable in column (2) is significantly positive at the 1% level, indicating regional heterogeneity in the impact of China's digital finance development on regional innovation performance. The above results support hypothesis 1.

Table 3 Chinese digital finance and regional innovation performance

Variable	RIP (1)	RIP (2)	RIP (3)	RIP (4)
DFT	1.13*** (11.98)	1.24*** (4.24)	6.68*** (4.84)	6.68*** (4.40)
REG		443.58*** (3.29)	0.00	0.00
AGDP		311.31** (2.21)	54.39 (0.34)	54.39 (0.29)
UR		-629.30 (-1.15)	-1262.54* (-1.83)	-1262.54 (-0.87)
HCL		-3.2e+04*** (-5.21)	-3.3e+04*** (-4.22)	-3.3e+04** (-2.15)
_cons	66.24 (1.13)	-2473.58* (-1.88)	532.55 (0.35)	532.55 (0.27)
Control	No	Yes	Yes	Yes
Individual effects	No	No	Yes	Yes
Time effect	No	No	Yes	Yes
Robust	No	No	No	Yes
N	341	341	341	341
R-squared			0.490	0.490
F			20.34***	7.18***

Standard errors clustered at the firm level in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

Table 4 reports the impact of different dimensions of digital finance development indices DFC, DFU, and DFD on regional innovation performance.

Column (1) reports the impact of the Digital Finance Coverage Breadth Index (DFC) on regional innovation performance. The Digital Finance Index (DFC) coefficient is positive but insignificant. This indicates that digital finance (DFC) development does not significantly promote regional innovation performance. The possible reason is that the promotion and coverage of digital finance cannot fully leverage its empowering role, and its impact on regional innovation performance is limited.

Column (2) reports the impact of the Digital Finance Usage Depth Index (DFU) on regional innovation performance. The Digital Finance Index (DFU) coefficient is significantly positive at 5%. This indicates that digital finance (DFU) development significantly promotes regional innovation performance.

Column (3) reports the impact of the Digital Finance Digitalization Index (DFD) on regional innovation performance. The Digital Finance Index (DFD) coefficient is significantly positive at 1%. This indicates that the development of digital finance (DFD) has a significant promoting effect on the innovation performance of enterprises.

The above empirical results indicate that the development of digital finance can promote regional innovation performance, further supporting hypothesis 1.

Table 4 The robustness test results of China's digital finance

Variable	RIP (1)	RIP (2)	RIP (3)
DFC	2.47 (1.09)		
DFU		2.87** (2.57)	
DFD			2.62*** (3.49)
AGDP	236.94 (1.09)	187.03 (1.00)	151.05 (0.78)
UR	-2322.51 (-1.51)	-1180.58 (-0.86)	-999.32 (-0.62)
HCL	-4.2e+04** (-2.38)	-3.3e+04* (-1.90)	-4.0e+04*** (-2.91)
_cons	-477.83 (-0.20)	-754.34 (-0.36)	-350.17 (-0.19)
Control	Yes	Yes	Yes
Individual effects	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
Robust	Yes	Yes	Yes
N	341	341	341
R-squared	0.453	0.472	0.499
F	3.01***	5.90***	6.44***

Standard errors clustered at the firm level in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

Table 5 reports the empirical results of the relationship between digital finance, R&D investment, and regional innovation performance.

According to the mediation effect testing procedure, the first step is to examine the relationship between digital finance and regional innovation performance. The test results in column (1) indicate that the development of digital finance can significantly improve regional innovation performance at the 5% level. The second step is to add R&D investment to the regress model (3). The test results in column (2) show that the estimated coefficient of the digital finance index is significantly positive at the 10% level. The third step is to examine whether R&D investment is mediating in promoting regional innovation performance through digital finance. The test results in columns (1) – (3) show that the estimated coefficients of γ_1 , δ_1 , and η_1 are all positive. After

adding the R&D investment variable to the econometric model, the estimated coefficients of the digital finance index η_2 are significant and decreasing, indicating that R&D investment plays a partial mediating role in enhancing regional innovation performance through digital finance. The above results indicate that R&D investment is a channel for digital finance to promote regional innovation, which verifies hypothesis 2.

Table 5 The relationship between digital finance, R&D investment, and regional innovation performance

Variable	RIP (1)	RRG (2)	RIP (3)
DFT	6.68*** (4.40)	0.62*** (3.03)	4.33** (2.69)
RRG			3.78** (2.27)
AGDP	54.39 (0.29)	0.03 (0.00)	54.27 (0.31)
UR	-1262.54 (-0.87)	-15.77 (-0.13)	-1202.85 (-0.78)
HCL	-3.3e+04** (-2.15)	44.38 (0.03)	-3.3e+04** (-2.71)
_cons	532.55 (0.27)	120.26 (0.41)	77.44 (0.05)
Control	Yes	Yes	Yes
Individual effects	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
Robust	Yes	Yes	Yes
N	341	341	341
R-squared	0.490	0.658	0.558
F	7.18***	28.41***	6.20***

The Digital Finance Index consists of three dimensional indicators: coverage, usage, and digital support service level. From the robustness of the above test, we found that the Digital Finance Coverage Breadth Index (DFC) does not significantly promote enterprise innovation performance. Therefore, we will not conduct a mediation effect test on the dimension of digital finance coverage breadth. Table 6 reports the empirical results of the relationship between the depth of digital financial use and the level of digital support services, R&D investment, and regional innovation performance.

Columns (1)–(6) indicate that R&D investment significantly mediates regional innovation performance in two dimensions: the depth of digital finance use and the degree of digital support services.

Table 6 The relationship between different dimensional index of China's digital finance and R&D investment and regional innovation performance

Variable	Usage (DFU)			Digit (DFD)		
	RIP	RRG	RIP	RIP	RRG	RIP
	(1)	(2)	(3)	(4)	(5)	(6)
DFU	2.87** (2.57)	0.37*** (3.36)	1.38 (1.36)			
DFD				2.62*** (3.49)	0.28*** (4.46)	1.60* (1.79)
RRG			3.99** (2.42)			3.63* (1.96)
_cons	-754.34 (-0.36)	17.58 (0.06)	-824.43 (-0.43)	-350.17 (-0.19)	50.37 (0.18)	-533.26 (-0.29)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Individual effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Robust	Yes	Yes	Yes	Yes	Yes	Yes
N	341	341	341	341	341	341
R-squared	0.472	0.660	0.547	0.499	0.673	0.558
F	5.90***	43.04***	7.16***	6.44***	24.22***	6.08***

Standard errors clustered at the firm level in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

Table 7 reports the regional sample regression results of China's digital finance on regional innovation performance. The regression coefficient (DFT) of Column (1) in the eastern region is insignificant. In other regions, the coefficient (DFT) of Column (2) is significantly positive at the 1% level. They indicate regional heterogeneity in digital finance's impact on regional innovation performance. The possible reason for this phenomenon is that the digital infrastructure and resource endowment in the eastern region are better than those in the central and western regions. When the financial resources in a region are sufficient, regional innovation can receive more financial support and carry out innovation activities.

Table 7 Regression results of regional heterogeneity

	Eastern Region	Other regions
Variable	RIP (1)	RIP (2)
DFT	4.11 (0.95)	3.59*** (3.36)
AGDP	321.36 (0.43)	98.33 (0.70)
UR	1024.12 (0.57)	367.19 (0.49)
HCL	-8.5e+04*** (-3.79)	-6170.16 (-0.61)
_cons	-2362.95 (-0.28)	-1125.28 (-0.88)
Control	Yes	Yes
Individual effects	Yes	Yes
Time effect	Yes	Yes
Robust	Yes	Yes
Group	Eastern_1	Eastern_0
N	121	220
R-squared	0.590	0.420
F	.	10.36***

Standard errors clustered at the firm level in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

Table 8 reports the results of the mediation effect test for regional samples. Columns (1)–(3) indicate digital finance has no significant impact on innovation performance in the eastern region, while in other regions, the estimated coefficients γ_1 , δ_1 , η_1 of columns (4)–(6) are significantly positive. After adding the R&D investment variable to the econometric model, the estimated coefficient of the digital finance index η_2 is significant at the 5% level, and the coefficient has decreased, indicating that R&D investment plays a partial mediating role in promoting innovation performance in noneastern regions of China's digital finance.

Table 8 Mediation effect result of regional samples

Variable	Eastern Region			Other regions		
	RIP (1)	RRG (2)	RIP (3)	RIP (4)	RRG (5)	RIP (6)
DFT	4.11 (0.95)	0.12 (0.26)	3.56 (0.67)	3.59*** (3.36)	0.54* (1.94)	2.35** (2.15)
RRG			4.69 (1.31)			2.29** (2.33)
_cons	-2362.95 (-0.28)	183.85 (0.33)	-3225.59 (-0.41)	-1125.28 (-0.88)	-116.97 (-0.38)	-857.12 (-0.94)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Individual effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Robust	Yes	Yes	Yes	Yes	Yes	Yes
N	121	121	121	220	220	220
R-squared	0.590	0.746	0.638	0.420	0.636	0.493
F	.	.	.	10.36***	15.55***	22.64***

Standard errors clustered at the firm level in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01.

Conclusion

We study the impact of China's digital finance on regional innovation performance and the mechanism of R&D investment in China's digital finance on regional innovation performance. The following conclusion is drawn:

Firstly, developing digital finance in China is conducive to promoting regional innovation performance. The impact of different dimensions of digital finance on regional innovation performance varies and exhibits regional heterogeneity. The impact of the digital finance coverage breadth index on regional innovation performance is insignificant. In contrast, the impact of the digital finance usage depth index and digitalization degree index on regional innovation performance is more significant. The impact of digital finance on regional innovation performance is not significant in the eastern region but more significant in other regions.

Secondly, R&D investment plays a partial mediating role in promoting regional innovation performance in China's digital finance. The development of digital finance has promoted regional innovation performance by increasing regional R&D investment. There is a partial mediating effect

of R&D investment in promoting regional innovation performance through the depth of digital finance use and the degree of digital support services. Research and development investment plays a significant mediating role in promoting innovation performance in non-European regions of China's digital finance.

Suggestions

Suggestions from Research Results

Firstly, the Chinese government should continue to promote the infrastructure construction of digital finance, standardize and promote the development of digital finance, expand the service scope of digital finance, cultivate and promote new forms of digital finance, encourage banks and other financial institutions to undergo digital transformation, leverage the advantages of digital finance, promote the optimization of financial resources, improve the efficiency of digital finance, and promote regional innovation performance.

Secondly, the Chinese government should fully recognize the differences in promoting regional innovation through digital finance and formulate differentiated regional development policies. Digital finance should play a role in promoting regional innovation performance.

Thirdly, the Chinese government should accelerate the cultivation of digital talents by promoting digital technology, expanding the coverage of digital finance, enhancing the digital literacy of the whole society, expanding the application scenarios of digital finance, and improving the efficiency of digital finance use.

Fourthly, the Chinese government should strengthen supervision over the development of digital finance, ensure the security of its development and services, improve relevant rules and regulations, and create a favorable environment for innovative development. Promoting the development of digital finance in China also helps to promote high-quality, innovative development of the regional economy in China.

Recommendations for future research

By studying the relationship between digital finance, R&D investment, and regional innovation performance in China, we found that digital finance does not significantly promote regional innovation performance in the eastern region but is more significant in relatively backward other regions. The possible reason is that digital finance has a threshold effect on promoting regional

innovation performance. When the development of digital finance is at a high level and regional innovation investment is alleviated, other factors that affect regional innovation should also be given attention, which is an essential direction for future research.

New knowledge

Our study's novelties and contributions are threefold.

Firstly, previous research has explored the impact of digital finance on regional innovation. However, research on the relationship between digital finance, R&D investment, and regional innovation performance still lacks a unified analytical framework and empirical conclusions. Therefore, we will link China's digital finance with R&D investment and regional innovation performance, explore the impact and mechanism of China's digital finance on regional innovation performance, verify the paradigm framework of digital finance development R&D investment innovation performance, more intuitively reflect the internal relationship between digital finance and regional innovation performance, provide more convincing evidence and policy recommendations, and promote the development of China's digital finance, assist in achieving regional innovation.

Secondly, we explored an essential mechanism by which digital finance affects regional innovation: the R&D investment effect. China can promote regional innovation performance by developing digital finance, and there is a mediating effect of R&D investment in promoting regional innovation performance through digital finance in China.

Thirdly, we provide new evidence that the positive correlation between digital finance and regional innovation is more important for other regions. This evidence can help relevant authorities formulate differentiated regional policies to promote innovation among different groups. We need particular policies to help promote this transformation and moderately encourage the regions to engage in digital transformation to achieve high-quality, innovative development.

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