A study on digital finance's impact on regional innovation ecosystem resilience

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Abstract. With the rapid development of digital finance, the impact of digital finance on the Regional Innovation Ecosystem Resilience (RIER) is becoming increasingly scrutinized. The primary objective of this study is to conduct an analysis of the influence of digital finance on the RIER. Based on the construction of indicators of China's interprovincial RIER, the empirical research utilizes panel data from thirty provinces covering the period from 2014 to 2023, with the use of a fixed-effects model. According to the findings of the study, there is a considerable positive association between RIER and digital finance. In addition, the influence of digital finance on the RIER demonstrates a clear regional heterogeneity, with digital finance's development in the eastern region having a greater impact on the RIER than in other regions. The findings presented above are important for understanding the development of digital finance in regional innovation ecosystems and establishing related policies. Additionally, they provide new perspectives and potential approaches to enhance the RIER.

Keywords: Regional innovation, Ecosystem resilience, Digital finance.

1. Introduction

In the wave of accelerated digital transformation of the global economy in the 21st century, digital finance has evolved from a technology-driven innovation experiment to a core force in reshaping the economic ecology. Through the use of technologies like blockchain, artificial intelligence, and any other relevant technology, it will boost economic development while also enhancing the effectiveness and accessibility of financial services. And the innovation ecosystem, as a core force in promoting economic growth and enhancing competitiveness, its resilience-related research is particularly important in the face of the huge impact of events such as "black swans" and "gray rhinoceros" on the stability and sustainability of economic development.

Academic research on the RIER mainly analyzes it from the aspects of measuring the RIER and influencing factors. Liang Lin et al. concluded that innovation ecosystem resilience can be measured by four dimensions: diversity, buffering, evolution, and liquidity [1]. Chen et al. further defined the RIER as the multidimensional ability of the system to withstand shocks brought about by the external environment through self-adaptation, self-regulation, and so on [2]. In their investigation of the effects of governance niche grouping patterns on digital innovation ecosystems, Yang Wei et al. employed the fsQCA approach, measuring the resilience of these ecosystems for the first time using an indicator evaluation method [3]. The impact of neoplastic productivity on the RIER and the mechanisms of action were the subject of a study by Kehl et al. [4]. The impact of digital finance on the RIER is not as extensively studied, based on this, this research experimentally investigates the correlation between digital finance and the RIER utilizing provincial data. By constructing a regression model to examine the influence of digital finance on the RIER, considering both direct effects and heterogeneity analysis, it provides a new perspective on improving the RIER. At the theoretical level, this paper further enriches the literature system of RIER's research and expands the research dimension in this field; at the practical level, the research results help to improve the risk resistance capacity of regional innovation ecosystems and offer a scientific and rational basis for policy makers to optimize digital financial workers.

2. Research Design

2.1. Research Hypothesis

Both the dichotomy and the trichotomy are the primary methods that are utilized in the academic research that is currently being conducted on innovation ecosystems [5,6]. The tripartite approach compensates for the neglect of external constraints in the dichotomous approach by incorporating the innovation environment dimension, and thus this paper chooses to use the tripartite approach for its analysis. In terms of innovation subjects, digital finance enhances its capacity for innovation while also broadening the range of innovation topics. While digital finance can help more subjects engage in innovation activities and broaden the diversity of innovation ecosystems by covering small and micro innovation topics that traditional finance finds difficult to cover, it can also help innovation ecosystems evolve by boosting the technological innovation capacity of businesses, management innovation of banks, and product innovation capacity [7,8]. By reducing the capital-labor mismatch and increasing the effectiveness of resource allocation, digital finance can improve the mobility of innovation ecosystems in terms of innovation resources [9]. Regarding the environment for innovating, digital finance mitigates information asymmetry between innovators and banking institutions via digital platforms and information-sharing mechanisms, thereby lowering the financing costs and risks associated with innovation activities and fostering a more equitable and transparent innovation environment, ultimately enhancing the RIER. To sum up, this research assumes that digital finance can enhance the RIER.

2.2. Modeling

Since all the data used are panel, this paper uses panel regression analysis, and the outcomes of the Hausman test prompted us to select the fixed effects model. This paper's model is described as follows:

$$RIERI_{it} = \alpha_0 + +\alpha_1 DIFI_{it} + \beta_i \sum Control_{it} + u_i + v_t + \varepsilon_{it} \quad (1)$$

Among them, $RIERI_{it}$ represents the RIER of province *i* in period *t*; $DIFI_{it}$ is the level of digital finance development of province *i* during period *t*; $Control_{it}$ is the control variables of province *i* during period *t*; μ_i and v_t are individual fixed and time-fixed effects, ε_{it} is the random error term.

2.3. Variables

2.3.1. Dependent variable

RIER Index(RIERI): This paper builds on Liang Lin's research and extends it to construct a RIER's evaluation index system from four dimensions: buffering, liquidity, evolution and diversity (see Table 1), and selects the entropy value method to measure the RIER's index [1].

Table 1. Indicators for Measuring RIER

Primary Indicators	Secondary Indicators	Specific Indicators	Indicator Properties
Buffering	Technical Resources	Domestic patent granted per capita (units per ten thousand persons)	+
	Economic Resources	GDP per capita (yuan per person)	+
	Knowledge Resource	Public library holdings per capita (books per hundred people)	+
Liquidity	Information Flow	Internet broadband port access number (ten thousand)	+
	Technology Flows	Value of contract exportation from domestic technical markets (hundred million yuan)	+
		Value of contract inflows to domestic technical markets (hundred million yuan)	+
	Financial Flows	Fixed asset investment (hundred million yuan)	+
	Talent Flow	Number of college students per hundred thousand people (persons)	+
Evolution	Manpower Inputs	Full-time Equivalent of R&D Personnel (person-years)	+
		Number of employees in the information transmission, software, and information technology services industry per hundred thousand people (persons)	+
	Capital Investment	Intramural expenditure on R&D (hundred million yuan)	+
	Technical Outputs	Domestic patent applications (piece)	+
		Scientific papers issued in higher education institutions (piece)	+
		Publication on S&T in higher education institutions (kind)	+
	Economic Outputs	New product sales revenue in high-tech industry (ten thousand yuan)	+
		Technology market turnover (ten thousand yuan)	+
Diversity	Enterprise	Number of high-tech enterprises (units)	+
	Research Institutes	Number of R&D institutions (units)	+
	Universities & Colleges	Number of higher education institutions (units)	+

2.3.2. Independent variables

Digital Inclusive Finance Index (DIFI): The "Peking University Digital Inclusive Finance Index", which was created by Peking University's Digital Finance Research Center, is the explanatory variable used in this study [10]. DIFI consists of three secondary indicators: breadth of coverage (DIFI1), depth of use (DIFI2), and level of digitization (DIFI3). The first two indicators measure coverage and depth of use from a two-dimensional perspective, while the last one measures the overall level, with higher levels of digitization indicating higher levels of efficiency for digitized users.

2.3.3. Control variables

The following are the primary control variables used for this paper: (1) government intervention (GOV): it is expressed as general government expenditure as a percentage of GDP; (2) market openness (OPEN): it is expressed as the value of exports and imports of goods as a percentage of regional GDP; (3) urbanization rate (URBAN): it is expressed as the ratio of urban population to total population. (4) inflation rate (INFLA): it is expressed as the Consumer Price Index divided by 100;

(5) infrastructure level ((INFRA): it is measured by the logarithmic form of the total freight volume [11].

2.4. Data

This work's empirical analysis is based on panel data for 30 Chinese province-level administrative units (Hong Kong, Macao, Taiwan, and Tibet are excluded because of data availability issues). The time frame covered by the study is 2014–2023. Ant Open Research Lab provided the DIFI and its sub-dimensions, the coverage breadth index, usage depth index, and digitization degree index. Other pertinent data were sourced from the "China Statistical Yearbook," "China Fixed Assets Statistical Yearbook," and "China Science and Technology Statistical Yearbook." The missing data was interpolated using an interpolation technique. Table 2 displays the descriptive statistics for all aforementioned variables:

Table 2. Variable description statistics

Variable type	Variables	Observation	Mean	Std. Dev.	Min.	Max.
Dependent variable	RIERI	300	0.1313	0 .1318	0.0088	0.7085
Independent variables	DIFI	300	3.0239	0 .7596	1.4593	4.7383
	DIFI1	300	2.8886	0.8241	1.3924	4.6654
	DIFI2	300	2.8636	0 .8700	1.0729	5.1069
	DIFI3	300	3.7619	0.5671	2.3071	4.7690
Control variables	GOV	300	0.2504	0 .1015	0.1066	0.6430
	OPEN	300	0.5532	0 .1703	0.1500	0.8959
	URBAN	300	0.6165	0 .1118	0 .3747	0.8960
	INFLA	300	1.0171	0 .0080	0.9970	1.0372
	INFRA	300	11.6954	0 .8365	9.5804	12.9815

3. Empirical Research

3.1. Return to baseline

Before the empirical regression, the variables involved in the benchmark model were first tested for correlation, and all variables passed significantly, which initially proved that the variables were correlated with each other. The Variance Inflation Factor (VIF) test was performed on the variables mentioned above, and the mean value of the VIF was 2.10, with a maximum value of 3.10, which was done in consideration of the impact that multicollinearity had on the empirical findings. All of them are less than the empirical value of 10, which indicates there is no multicollinearity among those variables. All passed the multicollinearity test in the following regressions and will not be repeated here.

The benchmark model is applied to test the direct impact of digital finance on the RIER, and Table 3 displays the test results. Model (1) considers only the impact of digital finance on the RIER, model (2) adds all control variables, and model (3) builds on model (2) by considering regional and time fixed effects. The findings support the original premise by demonstrating that, at the 1% significance level, digital finance strongly contributes to the RIER.

Since the DIFI is a composite of three sub-indicators evaluating breadth of coverage, depth of use, and level of digitization, the next step will be to further investigate which aspects of digital finance can boost the RIER. The regression is estimated using a fixed effects model. The results are shown in columns (4), (5), and (6) of Table 3. The results show that breadth of coverage significantly contributes to the RIER at a 5% significance level, while both depth of use and level of digitization significantly contribute to the RIER at a 1% significance level. Of the three dimensions, breadth of coverage contributes the most to the RIER, followed by depth of use, and finally level of digitization.

Table 3. Base Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)
DIFI	0.0587***	0.0588***	0.3840***			
	(0.0096)	(0.0119)	(0.0836)			
DIFI1				0.2067**		
				(0.0814)		
DIFI2					0.2024***	
					(0.0639)	
DIFI3						0.1110***
						(0.0264)
GOV		-0.2774*	0.1608*	0.0096	0.0318	0.0109
		(0.1588)	(0.0905)	(0.1835)	(0.1033)	(0.1387)
OPEN		0.1329***	0.0046	0.1186*	0.0261	0.0569
		(0.0449)	(0.0333)	(0.0604)	(0.0421)	(0.0438)
URBAN		-0.0074	-0.1262	-0.3728	-0.0509	-0.1652
		(0.0796)	0.1077	(0.2357)	(0.0901)	(0.1432)
INFLATION		-0.4386*	0.2480	-0.4942	0.4366	0.0455
		(0.2346)	0.6989	(0.7032)	(0.6761)	(0.7382)
INFRA		-0.0047	-0.0765	-0.0255	-0.0489	-0.0251
		(0.0374)	0.0573	(0.0583)	(0.0622)	(0.0554)
CONS	-0.0462***	0.4554	0.0493	0.6646	-0.1081	0.0945
	(0.0117)	(0.5602)	(1.0594)	(1.3117)	(1.0360)	(1.1280)
Fixed area	No	No	Yes	Yes	Yes	Yes
Fixed time	No	No	Yes	Yes	Yes	Yes
N	300	300	300	300	300	300
R^2	0.5313	0.5674	0.7094	0.5847	0.6859	0.6532

Note: Robust standard errors are in parentheses, ***p<0.01, **p<0.05, *p<0.1.

3.2. Robustness check

This article makes use of the four tests that are listed below in order to guarantee the robustness of the empirical findings.

3.2.1. Substitution of explanatory variables

This paper remeasure regional innovation ecosystem resilience using the logarithmic value of RIER (ln RIER), as shown in Table 4's columns (1) and (2), and the robustness of this paper's findings is demonstrated by the fact that the parameter estimates and significance do not alter substantially.

3.2.2. Regressions after shrinking the tail

In this paper, the main explanatory variables are subjected to shrinkage at the 1 percent level and fitted through a panel fixed effects model regression, as shown in in Table 4's column (3), with no significant changes in the parameter estimates or significance, demonstrating the robustness of the research model and conclusions.

3.2.3. Major regions are excluded

Since municipalities have obvious advantages in political, economic, social, cultural and environmental aspects compared to other provinces, which may have an important impact on the results of the study, all data of the indicators located in the four municipalities in China are excluded, and then empirical tests are conducted. The parameter estimates and significance do not change significantly, indicating that the results of this paper are robust, as shown in Table 4's column (4).

4. Removing the effect of the epidemic

This paper decided to exclude data from the post-epidemic years and re-run the regression analysis. On the basis of the results in Table 4's column (5), the estimates of the parameters and their significance are fundamentally unchanged, suggesting that the conclusions of this paper are still robust to the exclusion of the effect of the post-epidemic years.

Table 4. Robustness analysis

	(1)	(2)	(3)	(4)	(5)
	RIERI	LNRIERI	RIERI	RIERI	RIERI
DIFI	0.3840***	0.3611**	0.3634***	0.4194***	0.1874***
	(0.0836)	(0.1688)	(0.0851)	(0.1046)	(0.0569)
CONS	0.0493	-2.7544	0.1526	0.8172	-0.9725**
	(1.0594)	(2.4892)	(1.0857)	(1.3250)	(0.4555)
Control variables	Yes	Yes	Yes	Yes	Yes
Fixed area	Yes	Yes	Yes	Yes	Yes
Fixed time	Yes	Yes	Yes	Yes	Yes
N	300	300	300	260	180
R^2	0.7094	0.9229	0.7011	0.7004	0.6126

Note: Robust standard errors are in parentheses, ***p<0.01, **p<0.05, *p<0.1.

4.1. Heterogeneity Analysis

Due to the size of China's area, there are substantial differences across regions in terms of the resources that are endowed on them and the amount of economic development that they have achieved. Additionally, each region has various development characteristics overall. The authors of this research make reference to Nie Xiuhu et al. who categorised thirty provinces in China into eastern, central, and western portions in order to investigate the diverse impact that digital ffinance has had on the RIER [12]. The findings of their investigation are presented in Table 5. The regression coefficients of digital finance across all regions are markedly positive, signifying that the advancement of digital finance substantially enhances the RIER in the eastern, central, and western regions. Meanwhile, the coefficient of 0.546 for the eastern region is significantly larger than the coefficients of 0.2395 and 0.1935 for the other two regions. Therefore, it is possible to draw the conclusion that the influence of digital finance on the RIER in China is not uniform among regions. The eastern region is the one that has seen the greatest contributions, followed by the central region, while the western region has shown the least amount of support. This discrepancy can be caused by the eastern region's earlier adoption of digital finance and its higher degree of development compared to the other areas.

Table 5. Heterogeneity analysis

	(1)	(2)	(3)
	Eastern Part	Central Part	Western Part
DIFI	0.5460***	0.2395**	0.1935***
	(0.1388)	(0.0823)	(0.0515)
CONS	-1.0475	1.1882	0.6603
	(1.9430)	(1.4144)	(0.4561)
Control variables	Yes	Yes	Yes
Fixed area	Yes	Yes	Yes
Fixed time	Yes	Yes	Yes
N	110	90	100
R^2	0.7599	0.8171	0.7967

Note: Robust standard errors are in parentheses, ***p<0.01, **p<0.05, *p<0.1.

5. Conclusion

This study analyzes the influence of digital money on the RIER, utilizing inter-provincial panel data from 2014 to 2023. According to the findings of the study, digital finance may substantially enhance the RIER, with the extent of coverage being the most influential factor; Furthermore, in comparison to other regions, digital finance in the eastern region contributes the most to the RIER.

In light of the aforementioned findings, this study offers the following suggestions: Primarily, in order to enhance the RIER, it is necessary to further promote the optimization and upgrading of digital finance. To enhance coverage, it is essential to advance the digital financial infrastructure in geographically distant areas and promote the extensive adoption of digital financial services. With regard to depth of use, promote the integration of digital finance with the industrial Internet and the Internet of Things, and create diversified financial service solutions covering the industrial chain; In terms of the level of digitization, promote the digital transformation of financial institutions, improve their digital operation and service capabilities, and bring digital finance into the supervision in accordance with the law of innovative business. Second, the implementation of differentiated digital financial development strategies to achieve the coordinated development of RIER. Currently, the digital financial resources in the other areas are significantly deficient compared to those in the eastern region. Consequently, there is a significant delay in the advancement of digital finance on their RIER compared to those in the eastern region. As a result, the government should actively support the methodical growth of digital finance and related industries in developing regions, as well as the deep integration of digital finance with the conventional industries of the local community.

This study examines the relationship between digital finance and the RIER; its main limitation is that it only looks at the direct effects of digital finance on the RIER; it ignores the indirect effects, which may be investigated further in the future.

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