Research on the Impact of Digital Finance on the Improvement of Regional Innovation Capabilities ——An Empirical Test Based on the Yangtze River Delta Urban Agglomeration

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Abstract: This paper takes the urban agglomeration composed of 26 cities in the Yangtze River Delta as an example, discusses the impact of digital finance on the improvement of regional innovation ability empirically through dynamic panel regression measurement analysis. The results show that digital finance can significantly promote the improvement of regional innovation ability, and the promotion role of each sub dimension of digital finance is heterogeneous, in which the promotion role of coverage is the largest, the promotion role of use depth is the second, and the role of financial digitization is the smallest. Further using GMM method, it is found that in the impact mechanism of digital finance on regional innovation ability, regional credit resource allocation, urban infrastructure construction and residents' consumption level all play a significant intermediary role, and the intermediary effects of the three decrease in turn.

Keywords: Digital finance; Innovation ability; Financial constraint; Regional economies

1   Introduction

Finance is the key factor of economic development, and innovation is the first driving force of economic development. Since the reform and opening up, China has begun to attach importance to the use of finance to drive innovation, thereby driving overall economic development. Under the guidance of this concept, China has become the second largest economy in the world. However, the extensive mode of economic growth for a long time has

led to distortions in the allocation of financial resources in different regions, restricting regional economic development. Efficiently allocating financial resources and improving the financial " blood supply " capability is an important way for China to solve the problems of capital shortage and distorted allocation of financial resources, and to promote the healthy and coordinated development of the regional economy. Therefore, it is of great practical significance to deeply explore the impact of digital finance on regional innovation capabilities, as well as the influencing factors and mechanism of digital finance on regional innovation capabilities.

Regarding the microeconomic effects of digital finance, the academic community has carried out many discussions and formed relatively rich research results. However, there are relatively few studies on whether digital finance can enhance regional innovation capabilities, and it is still difficult to draw a conclusion [1]. Nie Xiuhua (2020) believes that digital finance can use the advantages of low threshold and convenience to improve the inclusiveness of financial services, effectively alleviate the financing constraints of small and medium-sized enterprises, increase enterprises' innovation investment, and then improve their innovation level [2]. Yang Xianming and Yang Juan (2021) found that digital finance can significantly stimulate innovation of small and medium-sized enterprises, and this incentive effect has existed for a long time. It has structural characteristics and enterprise heterogeneity characteristics, and will show a trend of first increase and then decrease with the improvement of enterprise innovation level [3]. The main innovation of the article is: taking the impact of digital finance on regional innovation capabilities as the main research issue, analyzing its impact path and mechanism, and deducing it through empirical analysis.

2   Model structures

According to the above analysis, taking into account the cumulative effect of innovation and the timeliness of invention patents, this paper introduces the explained variable lag term for investigation in the process of constructing a dynamic panel model of the impact of digital finance on regional innovation capabilities [4]. In order to reduce the interference caused by the reverse causality of the model to the research results and ensure the accuracy of the research results, the lag terms of all independent variables are controlled here. The specific model settings are as follows:

$$
\begin{aligned}
innovate_{i,t} = \alpha + \sum\nolimits_{j=1}^{n} \beta_j innovate_{i,t-j} \\
+ \chi digital_{i,t-1} + \eta_k X_{k,i,t-1} + \lambda_i + \mu_t \theta_{i,t}
\end{aligned}
\tag{1}
$$

Among them, X is the set of control variables, λ_i is the individual fixed effect, μ_t are time fixed effects, $\theta_{i,t}$ are error disturbance terms, β, χ, η are parameters to be estimated. If the χ in formula (1) is significant, it means that digital finance has a significant impact on regional innovation capabilities.

In order to deeply explore the specific impact path of digital finance on regional innovation ability, this paper introduces three interaction terms to test the mediation effect on the basis of model (1).

The first is to introduce regional credit constraints to test whether digital finance can improve regional innovation capabilities by improving the allocation of regional credit resources. The model settings are as follows:

$$
\begin{aligned}
innovate_{i,t} = {} & \alpha + \sum\nolimits_{j=1}^{n} \beta_j innovate_{i,t-j} + \chi digital_{i,t-1} \\
& + a(digital_{i,t-1} \times constraints_{i,t-1}) \\
& + \eta_k X_{k,i,t-1} + \lambda_i + \mu_t + \theta_{i,t}
\end{aligned}
\tag{2}
$$

Second is the introduction of the urbanization rate (urbanization) to test whether digital finance can enhance regional innovation capabilities by improving infrastructure construction methods. The model settings are as follows:

$$
\begin{aligned}
innovate_{i,t} = {} & \alpha + \sum\nolimits_{j=1}^{n} \beta_j innovate_{i,t-j} + \chi_1 digital_{i,t-1} \\
& + b(digital_{i,t-1} \times urbanization_{i,t-1}) \\
& + \eta_k X_{k,i,t-1} + \lambda_i + \mu_t + \theta_{i,t}
\end{aligned}
\tag{3}
$$

to test whether digital finance can enhance regional innovation capabilities by improving residents' consumption levels. The model settings are as follows:

$$
\begin{aligned}
innovate_{i,t} = {} & \alpha + \sum\nolimits_{j=1}^{n} \beta_j innovate_{i,t-j} + \chi_1 digital_{i,t-1} \\
& + c(digital_{i,t-1} \times consumption_{i,t-1}) \\
& + \eta_k X_{k,i,t-1} + \lambda_i + \mu_t + \theta_{i,t}
\end{aligned}
\tag{4}
$$

Model (2) Research on digital financial pair the impact of regional credit resource allocation, a represents the impact coefficient of digital finance on regional credit resource allocation. Model (3) studies the impact of digital finance on infrastructure construction, and b represents the impact coefficient of digital finance on infrastructure construction. Model (4) studies the impact of digital finance on household consumption level, and c represents the influence coefficient of digital finance on household consumption level. Models (2), (3), (4) can be combined with model (1) to test the mediating effects of regional credit resource allocation, infrastructure construction, and household consumption levels. Further test the model, b, c in (2), (3), (4). If a , b , and c are significant, it means that the intermediary effect of regional credit resource allocation, infrastructure construction, and household consumption level exists; if a , b , and c are significant, and |a| , |b| , |c|<|χ | , it means that the allocation of regional credit resources, infrastructure construction, and the level of household consumption are partial mediating variables; if a , b , and c are not significant, it means the allocation of regional resources, infrastructure constructions, and the level of household consumption are

complete mediating variables. In addition, considering that the endogeneity problem may arise due to the addition of the lag term of the explained variable in the model, the two-stage system GMM method proposed by Blundell & Bond and Baron & Kenny was used to analyse the model (2) to model (4) The valuation process is carried out to eliminate the endogeneity problem in the model.

In order to reduce the influence of other irrelevant factors on the verification of causality, 6 control variables were added to the regression model: one is industrial structure. The ratio of the output value of the secondary and tertiary industries to GDP is used to measure the industrial upgrading of the region [5] Theoretically speaking, cities with a higher proportion of secondary and tertiary industries have higher innovation output capacity than cities with a higher proportion of primary industries. The second is the investment in science and education, which is expressed by the proportion of the total expenditure on science and education in the city in the fiscal budget expenditure. From the perspective of science and technology and knowledge output, cities with more investment in science and education have relatively high levels of science and technology and education, and their R&D capabilities and knowledge output capabilities are also relatively developed, which is more conducive to the improvement of innovation efficiency. The third is the level of economic development (economic), expressed by the logarithm of the city's per capita GDP. Theoretically, cities with higher economic development levels have relatively higher resource allocation capabilities, which has a positive effect on the improvement of regional innovation capabilities. The fourth is the level of financial development, which is measured by the ratio of the year-end loan balance of regional financial institutions to GDP. The level of financial development is closely related to innovation investment. The higher the financial development level, the greater the regional innovation investment, which in turn provides support for regional innovation activities. The fifth is the degree of opening to the outside world. The higher the degree of opening to the outside world, the greater the influence of foreign knowledge and technological innovation, and the higher the availability of innovation resources. Six is human capital, expressed as the proportion of the number of students in local colleges and universities to the total number of students in the region. From the perspective of realization, college students are the main human capital for regional innovation. The more students in local colleges and universities, the higher the human capital investment in regional innovation, and the regional output capacity will also be improved.

3   Empirical analysis

Substitute the data of each variable into the model (1), The descriptive statistics of the main correlation analysis results are shown in Table 1. The regression results as shown in Table 2. Among them, the results of the composite index (digital) in the second column in Table 2 show that the regression coefficient of digital finance on the innovation capability of the Yangtze River Delta urban agglomeration is significantly positive at the level of 1%, indicating that digital finance has a significant role in promoting regional innovation capability. By observing the lag items in rows 6 and 7, it can be seen that the regression coefficients of lag one and two lags are significantly positive at the 1% level, and the regression coefficient of lag one is greater than the regression coefficient of two lags. Therefore, it shows that there is a cumulative effect of regional innovation, and this effect will

gradually diminish over time. The results in columns 3 to 5 in Table 3 show that the regression coefficients of the influence of coverage breadth, use depth and financial digitization degree on the innovation capability of the Yangtze River Delta urban agglomeration are all at the level of 1%.

Table 1 Correlation analysis results

	invention	licensing	authorize	digital	vegetation	profundity	digitalization	industrial	investment	economic	level	foreign	human
invention	1												
licensing	0.132***	1											
authorize	0.118***	0.113***	1										
digital	0.109***	0.144***	0.032**	1									
vegetation	0.101***	0.134***	0.152***	0.064***	1								
profundity	0.138***	0.031***	0.011**	0.126***	0.258***	1							
digitalization	0.112***	0.458***	0.128***	0.413***	0.392***	0.457***	1						
industrial	-0.002	0.256***	-0.202***	0.271***	0.078***	-0.156***	0.445***	1					
investment	0.018*	-0.277***	0.141***	0.047***	-0.381***	-0.241***	0.182***	-0.154***	1				
economic	0.029***	-0.005	-0.566***	0.441***	0.413***	0.568***	-0.418***	0.415***	0.212***	1			
level	0.027***	0.448***	-0.468***	0.462***	-0.147***	-0.126***	0.385***	-0.574***	0.156***	-0.381***	1		
foreign	-0.038***	-0.184***	0.610***	0.202***	0.355***	-0.458***	0.351***	-0.135***	0.006	0.484***	0.214***	1	
human	-0.021***	-0.075***	0.024**	0.401***	0.003	-0.158***	0.584***	-0.247***	0.153***	-0.441***	0.346***	-0.124	1

Table 2 Benchmark regression results

variable name	composite index (digital)	Breadth of coverage (vegetation)	use depth (profundity)	The degree of financial digitization (digitalization)
digital	1.096*** (0.265)			
vegetation		0.524*** (0.224)		
profundity			0.459*** (0.138)	
digitalization				0.368*** (0.082)
L invention	0.658*** (0.043)	0.678*** (0.047)	0.658*** (0.045)	0.644*** (0.045)
L2. invention	0.187*** (0.046)	0.204*** (0.049)	0.203*** (0.046)	0.216*** (0.049)
Constant term	-1.739*** (0.338)	-0.862** (0.395)	-1.919*** (0.408)	-1.654*** (0.418)
control variable	control	control	control	control
year fixed effects	control	control	control	control
Obs	1938	1938	1938	1938
N	276	276	276	276
Hansen test	0.669	0.401	0.568	0.698
HR (1)	0.00	0.00	0.00	0.00
HR (2)	0.385	0.424	0.419	0.440

The above is significantly positive, indicating that the three first-level sub-dimensions of digital finance all have a significant positive impact on the improvement of regional innovation capabilities. The reason may be that with the continuous expansion of the coverage of digital finance, more " long-tail customers " groups have been included in the coverage of financial services, thus creating a good financial service environment for innovative financing of enterprises within the Yangtze River Delta urban agglomeration; The continuous development of the depth of financial use and the increasing types of financial products and financial services provide more choices for innovative financing of enterprises in the Yangtze River Delta urban agglomeration. The availability of innovative financing for enterprises in this region has been greatly improved; the degree of financial digitization continues to develop., so that the advantages of digital finance facilitation, high efficiency and low cost are fully demonstrated in the innovative financing of enterprises in the Yangtze River Delta urban agglomeration, especially the small and medium-sized enterprises in the region can quickly obtain innovative financing at a lower cost [6].

In order to test the robustness of the benchmark regression results, licensing and authorize were used as replacement criteria for testing, possible outliers were eliminated, and all continuous variables were trimmed by 1% up and down. The test results are generally consistent with the benchmark regression results, proving that digital finance can promote the improvement of regional innovation capabilities, so hypothesis H1 has been verified. Due to limited space, the robustness test results are no longer reported.

In order to verify the intermediary role of credit resource allocation, infrastructure construction and residents' consumption level between digital finance and regional innovation capability, this paper uses the GMM method to test models (2), (3) and (4), and the results are as follows: shown in Table 3.

Table3 of digital finance on regional innovation capabilities

variable name	credit resource allocation	infrastructure	Resident consumption level
digital	1.465*** (0.214)	1.095*** (0.264)	0.605*** (0.173)
(digital × constraints)	-0.081** (0.037)		
(digital × urbanization)		-0.124** (0.124)	
(digital × consumption)			-0.418** (0.142)
L. invention	0.642*** (0.046)	0.658*** (0.046)	0.638*** (0.043)
L2.invention	0.197*** (0.048)	0.214*** (0.046)	0.198*** (0.045)
Constant term	-1.834*** (0.356)	-0.862*** (0.395)	-1.919*** (0.408)
control variable	control	control	control
year fixed effects	control	control	control
Obs	1938	1938	1938
N	276	276	276
Hansen test	0.00	0.00	0.00
HR(1)	0.464	0.576	0.429
HR(2)	0.406	0.267	0.903

Note: The values in brackets are robust standard errors, the same below. Due to limited space, the parameter estimation results of the control variables are no longer reported, and are available upon request.

First, from the digital coefficient in the second column of Table 3, it can be seen that the digital coefficient of credit resource allocation in the Yangtze River Delta urban agglomeration is 1.465 at the level of 1%, and the coefficient of interaction term digital×constraints is -0.081 at the level of 5%. This result is consistent with the inferred results in this paper. The reason for this result may be that digital finance can optimize the allocation of financial resources, increase the supply of credit resources, break the innovative financing constraints of regional small and micro enterprises to a certain extent, and then promote the improvement of regional innovation capabilities. Therefore, in regions with poor credit resource allocation capabilities, the promotion effect of digital finance on regional innovation capabilities is more significant. In other words, digital finance can promote the improvement of regional innovation capabilities by optimizing the allocation of credit resources, assuming that H2 can be verified.

Second, from the digital coefficient in the third column of Table 3, it can be seen that the digital coefficient of the infrastructure construction of the Yangtze River Delta urban agglomeration is 1.095 at the level of 1%, and the digital × urbanization coefficient of the interaction term is -0.124 at the level of 5%., this conclusion is basically consistent with the inference of the article. The reason is that digital finance may promote the development of infrastructure construction through financial technology and financial support. In terms of financial technology, digital finance can be fully applied through artificial intelligence, big data, 5G, cloud computing and other intelligent financial technologies to promote the rapid development of regional infrastructure construction. In terms of financial support, digital finance can provide construction funds for regional infrastructure construction and provide financial guarantees for regional infrastructure construction. The development of infrastructure construction can provide convenient conditions for regional innovation-related activities and promote the improvement of regional innovation capabilities. From this point of view, in areas with poor infrastructure construction, the role of digital finance in promoting regional innovation capabilities is more obvious. In other words, digital finance can drive the improvement of regional innovation capabilities by promoting infrastructure construction, assuming that H3 can be verified.

Third, from the digital coefficient in the fourth column of Table 3, it can be seen that the digital coefficient of the residents' consumption level in the Yangtze River Delta urban agglomeration is 0.605 at the level of 1%, and the interaction term digital × consumption coefficient is -0.418 at the level of 5%. This result is consistent with the inferred results of the article. The reason for this result may be that digital finance can flow a large amount of funds into low-income people in the form of credit, thereby driving the improvement of the overall consumption level of the society. Based on Marx's political and economic theory, a strong level of residents' consumption can greatly stimulate social reproduction, drive regional enterprises to innovate products, and enhance their core competitiveness [7]. Therefore, in areas where the per capita disposable income of urban residents is low, the driving effect of digital finance on regional innovation capability is more significant. In other words, digital finance can promote the improvement of regional innovation capabilities by improving the level of residents' consumption, assuming that H4 can be verified.

4   Conclusions

Based on the sample data of 26 cities in the Yangtze River Delta urban agglomeration from 2017 to 2019, this paper empirically analyzes the impact of digital finance on regional innovation capabilities, and draws the following conclusions: First, digital finance can significantly promote regional innovation capabilities. Whether it is digital finance, or the three digital finance sub-dimensions of digital finance coverage, depth of use, and financial digitization, they all play a significant role in promoting regional innovation capabilities. Among them, the breadth of digital financial coverage has the most significant role in promoting regional innovation capabilities, followed by the depth of use, and finally the degree of financial digitization. Second, digital finance can significantly boost regional innovation capabilities by optimizing the allocation of credit resources, promoting infrastructure construction, and improving residents' consumption levels. First, digital finance can break the innovative financing constraints of regional small and micro enterprises to a certain extent, support regional real economic innovation, and promote regional innovation capabilities. Second, digital finance can empower infrastructure construction through financial technology and capital, and then drive the improvement of regional innovation capabilities. Finally, digital finance can provide credit funds for social low-income groups, drive the improvement of residents' consumption level, and further stimulate the rapid improvement of regional innovation capabilities. As an exploratory study, the study still has certain limitations: First, in order to directly verify the relationship between digital finance and regional innovation capabilities, this paper selects the Yangtze River Delta urban agglomeration, which is at the forefront of China's digital finance development level, as a sample to explore the regional scope. It is small and cannot represent the current situation in most parts of the country. Therefore, in the follow-up research, the scope of the study area can be further expanded, and the influence of the other regions in the east and the central and western regions can be properly explored. Second, for the consideration of data availability and accuracy, the article only explores the impact of digital finance in the Yangtze River Delta urban agglomeration on regional innovation capabilities from 2017 to 2019, and the research period is short. Therefore, it is necessary to expand the time range of sample data collection in the future, and further conduct in-depth research on the long-term impact of the two.

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