

Digital finance, regional innovation and economic development linkage--Analysis of PVAR dynamic model based on panel data of Guangdong province

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Abstract. This paper takes 21 prefecture-level cities in Guangdong Province as the research object, and divides them into three regions: Pearl River Delta region, Northwest Guangdong region and Guangdong Province. The results of the study found that: digital finance, regional innovation and economic development have a mutual promotion relationship, but the promotion effect is not significant; there is regional heterogeneity in the linkage between digital finance and economic development, regional innovation and economic development; digital finance development should be more comprehensive and diversified, and different strategies for digital financial services should be formulated in response to the differences in the development of different regions, so as to attract more talents and promote regional innovation. The development of digital financial services should be more comprehensive and diversified in response to the differences in the development of different regions, formulate differentiated digital financial services strategies, increase the efforts to attract talents, promote regional innovation, and drive the high-quality development of regional economy.

Keywords. Digital finance, regional innovation, economic development, PVAR.

In recent years, with the development of digital technology and big data analysis technology, technological innovation has continued to advance to a wider scope, higher level and deeper degree, and the innovation power is highly integrated into economic and social development, which plays an important role in promoting the conversion of old kinetic energy into new kinetic energy as well as upgrading the regional economic structure, increasing employment opportunities and enhancing social livelihood, achieving the provision of fair opportunities and vertical development of society, and the innovation vitality also provides China's economic development.

However, if we want to rapidly improve the efficiency of innovation, we can't do without the development of financial services. With the promotion of digital finance, it solves the problem of difficult and expensive financing for enterprises, solves the information asymmetry troubles of small and medium-sized enterprises in the process of entrepreneurship, and provides a strong support for innovation and entrepreneurship. The promotion of digital finance has brought together more professional investment platforms and high-end technology talents as well as outstanding entrepreneurs. For regions with better resources, a new situation of "troika" led by science and technology, talents and capital is gradually formed.

At present, China continues to strengthen financial support for market players and use digital technology to enhance regional innovation capacity by creating a healthy financial environment, which leads to the conclusion that how to use digital financial tools to promote regional innovation has become an issue worth discussing in today's socio-economic development, and whether and to what extent the current level of digital financial development, regional innovation and economic development affect each other. It is also worth analyzing whether and to what extent the current level of digital finance development, regional innovation and economic development interact. Therefore, in this context, it is necessary to conduct an empirical analysis on the relationship between the current digital finance development, regional innovation level and economic development, to analyze the degree of influence of digital finance in the cultivation of regional innovation capacity and its contribution to economic development, and to propose feasible suggestions for the results and their problems.

1. Review of the literature

The development of digital finance stimulates regional innovation. Cui Ran et al. (2022) analyzed the impact of digital finance on regional innovation, and suggested that digital finance can significantly stimulate regional innovation development, and its incentive effect shows positive marginal effect increasing nonlinear characteristics. Lang et al. (2022) analyzed the impact of digital finance on innovation of SMEs by taking the New Third Board enterprises as the target, and studied that digital finance can promote innovation of SMEs and enhance the innovation level of enterprises. Currently, there are many studies on digital finance and economic development, and many scholars have analyzed the relationship between digital finance and economic development through different spatial econometric models. Chu, Cui-Cui et al. (2021) studied the relationship between digital finance and economic development by constructing a spatial econometric model, and found that digital finance promotes the economic development of the region, but the spatial spillover effect on its neighboring regions is negative. Qian et al. (2020) found that digital finance promotes technological innovation and entrepreneurship more strongly in regions with low urbanization rate and high material capital, which in turn promotes economic development.

2. Empirical model construction

2.1. PVAR Model Construction

The PVAR model is a combination of a panel data model and a vector autoregressive model, which has the characteristics of a VAR model that does not require a causal relationship between variables, but also allows the variables to be treated as endogenous variables, so as to study the influence of each variable and its lagged variables on other variables in the model. At the same time, the PVAR model can take into account both time and individual effects, effectively controlling for cross-sectional and individual differences, and providing an effective empirical test method for analyzing digital finance, regional innovation and economic development.

A PVAR model is constructed to study the relationship between digital finance diffusion, regional innovation and economic relationship between development, corresponding to each municipality i . The standard model is as follows:

$$Y_{it} = \partial_t + \rho_1 Y_{i,t-1} + \rho_2 Y_{i,t-2} + \dots + \rho_p Y_{i,t-p} + \varepsilon_{i,t} \quad (1)$$

where, $Y_{it} = [DF, IE, ED]^T$ is a column vector including 3 variables; DF denotes the level of digital financial development; IE denotes regional innovation; ED denotes economic development level; $\varepsilon_{i,t}$ denotes the random disturbance term, using the forward mean difference mentioned by Arellano et al. (1995) The heterogeneity effect of individual shareholder effect is removed by using the forward mean difference mentioned by Arellano et al.

2.2. Data sources

In this paper, the panel data of 21 prefecture-level cities in Guangdong Province from 2011 to 2020 are selected by Python crawling related information almanac. The level of digital finance development is expressed by the "Peking University Digital Inclusive Finance Index". The regional innovation level is expressed by the "China Regional Innovation and Entrepreneurship Index" released by the Guanghua School of Management of Peking University, which combines entrepreneurs, capital and technology to reflect the innovation vitality and development level of each region in China in five aspects: the number of new enterprises, attracting foreign investment and venture capital, the number of regional patents granted and the number of trademark registrations. The index is chosen because it can better reflect the regional innovation capacity according to Long (2018), who suggested that the growth of regional innovation capacity is determined by the exogenous path (foreign investment, import/export trade) and the endogenous path (technological innovation, human capital) to a certain extent and the synergistic effect. The economic development level is expressed by "GDP per capita", and the model is set and tested by Stata.

2.3. Variable Setting

In order to reduce the influence of heteroskedasticity and excessive data fluctuation, the three variables of digital finance development level, regional innovation and entrepreneurship development level and economic development are logarithmized, and the three variables are first-order differenced in order to make all variables of the model smooth. Meanwhile, this paper draws on the approach of R. Xie et al. (2022) to divide the 21 prefecture-level cities in Guangdong Province into Guangdong Province, the Pearl River Delta region (hereinafter referred to as the "PRD region"), and the northwest of Guangdong Province, the remaining 12 prefectures are divided into the northwest and east regions of Guangdong, with the above three regions as representatives, and the overall and local regional differences are analyzed.

Table 1. Descriptive statistics for variables

Area	Variate	Sample No.	Evarage	standard deviation	MIN	MAX
Guangdong	lnDF	210	5.130	0.467	3.729	5.765
	lnIE	210	4.037	0.588	1.698	4.605
	lnED	210	10.813	0.612	9.689	12.223
Pearl River Delta	lnDF	90	5.236	0.422	3.956	5.766
	lnIE	90	4.475	0.187	3.344	4.605
	lnED	90	11.384	0.449	10.299	12.223
North Guangdong	lnDF	120	5.051	0.484	3.729	5.599
	lnIE	120	3.708	0.573	1.698	4.525
	lnED	120	10.384	0.275	9.689	10.884

In order to reduce the effects of heteroskedasticity and excessive data fluctuations, this paper logarithmizes the three variables of digital financial development level, regional innovation, and economic development. In addition, in order to make all variables of the model are smooth, this paper conducts first-order difference treatment on the three variables.

3. Empirical Analysis

3.1. Unit root test

In order to avoid the problem of pseudo-regression, we need to conduct unit root tests. In this paper, the LLC test, PP test and ADF-Fisher test are used to test the unit root. The results of unit root test are shown in Table 2.

Table 2. Results of p-value of unit root test of variables

Area	Variate	LLC test	ADF-Fisher test	PP test	results
Guangdong	lnDF	0.0000	0.0000	0.0000	stable
	lnIE	0.0000	0.0000	0.0000	stable
	lnED	0.0523	0.9588	0.9585	unstable
	dlnDF	0.0000	0.0000	0.0000	stable
	dlnIE	0.0000	0.0000	0.0000	stable
	dlnED	0.0030	0.0428	0.0000	stable
Pearl River Delta	lnDF	0.0000	0.0000	0.0000	stable
	lnIE	0.0055	0.0000	0.0000	stable
	lnED	0.0069	0.4607	0.3978	unstable
	dlnDF	0.0000	0.0000	0.0000	stable
	dlnIE	0.0033	0.0000	0.0000	stable
	dlnED	0.0005	0.0000	0.0000	stable
North Guangdong	lnDF	0.0000	0.0000	0.0000	stable
	lnIE	0.0000	0.2963	0.0000	unstable
	lnED	0.0000	0.1636	0.6688	unstable
	dlnDF	0.0000	0.0000	0.0000	stable
	dlnIE	0.0000	0.0304	0.0000	stable
	dlnED	0.0000	0.0000	0.0314	stable

As can be seen from Table 2, in the whole sample of Guangdong Province, lnED fails to reject the original hypothesis of the variable in ADF-Fisher test and PP test, in the PRD region, lnDF fails to reject the original hypothesis of the variable in ADF-Fisher test and PP test, in the northwest of Guangdong Province, lnED fails to reject the original hypothesis of the variable in ADF-Fisher test and PP test, and lnIE in ADF-Fisher test failed to reject the original hypothesis of the variables. Therefore, the p-values of lnED, lnDF, and lnIE are all less than 0.05 after first-order differencing, which also indicates that the p-values obtained from the three-unit root tests significantly reject the original hypothesis, and therefore digital finance, regional innovation, and economic development are all stable after first-order differencing.

3.2. Determining the optimal lag order

Before determining the PVAR model, we need to determine the optimal lag order by using the AIC, BIC and HQIC statistics to prevent the decrease of degrees of freedom caused by the large autocorrelation lag order of the error term due to the small lag order. According to the minimization information criterion, the minimum values of AIC, BIC and HQIC appear in order 1, which is the optimal lag order, so the optimal order of PVAR model is order 1.

Table 3. Optimum lag order test results

Area	LAG	BIC	AIC	HQIC
Guangdong	1	-23.54486	0.3407855	-9.338148
Pearl River Delta	1	-25.04179	-8.781827	-14.84338
North Guangdong	1	-26.52736	-7.678261	-15.05118

3.3. PVAR model stability test

If all the characteristic roots fall within the unit circle (whether they are less than 1), this indicates that the constructed model is stable and can be used for impulse response and variance decomposition. After the test, all the characteristic roots of the model fall within the circle, so the constructed panel vector autoregressive model with a lag of 1 period has some stability.

3.4. Granger causality test

The Granger causality test is applied to analyze the relationship between digital finance, regional innovation and economic development in Guangdong Province. Table 4 shows that only digital finance is the Granger cause of economic development in Guangdong Province and the Pearl River Delta region, while all indicators in the northwest and east of Guangdong accept the original hypothesis.

Table 4. Results of Granger causality test

Area	explained variable	explaining variable	chi-square value	P value	Result
Guangdong	dlnED	dlnDF	5.113	0.024	Rejection
Pearl River Delta	dlnED	dlnDF	7.694	0.006	Rejection

However, it is worth noting that due to factors such as the length of data selection and the lag of mutual influence, the Granger causality test only judges that the variables have a mutual influence relationship, which does not fully represent the actual economic activities, so the direction of mutual influence between variables and the weight of influence need to be further analyzed by impulse response and variance decomposition.

3.5. Impulse Response Analysis

In this section, the impulse response results of each region are obtained by 200 simulations with 95% confidence interval for 10 periods.

3.5.1. Analysis of impulse response results for Guangdong Province

Digital finance promotes regional innovation enhancement in periods 0~2, and its effect changes from negative to positive direction; digital finance is positive for economic development, but the strength of the promotion effect gradually decreases in periods 5~10. The effect of regional innovation on the development of digital finance is positive in period 0~3, but its long-term effect is not obvious; the effect of regional innovation enhancement on economic development is positive in period 0~3. Economic development has a positive effect on the development of digital finance and regional innovation, and the positive promotion effect is larger in the short term, and the impact influence strength gradually disappears as time goes by.

3.5.2. Analysis of the impulse response results in the PRD region

The interaction between digital finance, regional innovation and economic development is positively promoted in the period 0-3, but the effect is not significant. With the extension of time from period 5 to period 10, the mutual promotion effect of the three is significantly enhanced.

3.5.3. Analysis of the impulse response results in the northwest and east of Guangdong

The effect of digital finance on regional innovation is changed from negative to positive in period 0-3; digital finance has a positive effect on economic development in period 0-3. Regional innovation has a positive promotion effect on digital finance in period 0~3, with a downward and then upward trend as the number of periods increases, and the promotion effect decreases in period 5~10; regional innovation has a positive promotion effect on economic development in period 0~3, and its impact effect changes from negative to positive. The effect of economic development on digital finance is obvious in period 0~2, and its obvious effect is weakened in period 5~10; the effect of economic development on regional innovation is positive in period 0~2, but its effect is significantly weakened with the increase of period number.

Table 5. Results of variance decomposition of each index

Variate	Period	Guangdong			Pearl River Delta			North Guangdong		
		dlnDF	dlnIE	dlnED	dlnDF	dlnIE	dlnED	dlnDF	dlnIE	dlnED
DlnDF	1	1	0	0	1	0	0	1	0	0
	5	0.969	0.003	0.025	0.784	0.015	0.202	0.977	0.010	0.014
	10	0.965	0.003	0.033	0.323	0.038	0.639	0.976	0.010	0.014
DlnIE	1	0.037	0.963	0	0.017	0.983	0	0.051	0.949	0
	5	0.029	0.946	0.025	0.053	0.828	0.120	0.042	0.913	0.045
	10	0.030	0.945	0.025	0.223	0.195	0.582	0.042	0.912	0.046
DlnED	1	0.054	0.059	0.887	0.131	0.068	0.800	0.001	0.017	0.982
	5	0.105	0.037	0.858	0.254	0.041	0.705	0.009	0.017	0.974
	10	0.109	0.037	0.854	0.264	0.040	0.700	0.009	0.017	0.974

3.6. Variance Decomposition

In order to analyze the long-term influence of digital finance, regional innovation and economic development among regions, this paper performs variance decomposition of the model to determine the contribution of each indicator, as shown in Table 5, the variance decomposition results of each indicator in the 1st, 5th and 10th periods. According to the analysis of the variance decomposition results of Guangdong Province, Northwest Guangdong and Pearl

River Delta, from Guangdong Province, digital finance is mainly influenced by its own contribution, which is 96.5% until the 10th period, followed by economic development and regional innovation respectively. Regional innovation is mainly influenced by its own contribution, which is 95.5% in the 10th period, followed by digital finance and economic development respectively. Economic development is mainly influenced by its own contribution, 85.4% in period 10, followed by the contribution of digital finance and regional innovation, respectively.

From the PRD region, digital finance is mainly influenced by the contribution of economic development up to period 10 at 63.9%, followed by its own and regional innovation contributions, respectively. Regional innovation is mainly influenced by the contribution of economic development up to period 10, at 58.2%, followed by digital finance and itself, respectively. Economic development is mainly influenced by its own contribution with 70% in the 10th period, followed by the influencing factors of digital finance and regional innovation respectively. From the north-eastern and western regions of Guangdong, digital finance, regional innovation and economic development are mainly influenced by their own contribution, with 97.6%, 91.2% and 97.4% respectively in period 10.

4. Conclusion

4.1. Findings

It is found that: (1) there is a mutual promotion relationship among digital finance, regional innovation and economic development, but the promotion effect is less significant; (2) there is geographical heterogeneity in the degree of mutual promotion among digital finance, regional innovation and economic development, from Guangdong Province, the synergistic effect of mutual promotion among the three is greater in the developed Pearl River Delta region, and the synergistic effect of promotion among the three is less in the less developed Guangdong East and Northwest regions. less. Economic development has a greater impact on digital finance and regional innovation, but digital finance and regional innovation have a smaller impact on economic development respectively.

4.2. Suggestions

From the conclusion of the above empirical model analysis, the linkage between digital finance, regional innovation and economic development in Guangdong Province as a whole, from which the following issues can be summarized: (1) digital finance has a certain influence on economic development, but the geographical threshold feature is demanding; (2) regional innovation has a strong geographical threshold for economic development efficiency enhancement; (3) how to use the digital finance platform to enhance regional innovation and How to attract talents for innovative employment, effectively attract talents to less developed regions, enhance innovation vitality, and improve the province's economic development efficiency has become an issue of concern.

In response to the above conclusions, this paper puts forward several suggestions: first, accelerate the development of digital finance, increase the popularity of digital financial products and ways of application, comprehensively meet the economic and financial needs of each region, promote the degree of digitization, strengthen the construction of digital infrastructure, and enhance the efficiency of urban economic development; second, implement differentiated digital financial development promotion programs, develop differentiated digital financial service strategies according to the characteristics of the region, and promote regional economic development without blindly following the trend; third, vigorously accelerate the pace of integrating digital finance into regional innovation, and provide service foundation support for regional innovation.

References

- [1] Liu C.H., Xu J.C., Zhang C.C. Science and technology innovation, industrial structure upgrading and carbon emission efficiency efficiency: PVAR analysis based on provincial panel data[J]. *Journal of Natural Resources*, 2022(2). 508-520.
- [2] Digital finance, population mobility and economic development: a study based on panel data of 16 prefecture-level cities in Anhui Province. A study based on panel data of 16 cities in Anhui Province[J]. *Journal of Shenyang University (Social Science Edition)*, 2022(6):261-269.
- [3] Cui Ran, Gao Yuqiang, Lu Yuchen. Digital inclusive finance, financing constraints and regional innovation[J]. *Journal of Xinjiang University of Finance and Economics*, 2022(2):36-46.
- [4] Lang, Xiangxiang, Zhang, Misty, Wang, Jia-Ning. Digital Inclusive Finance, Financing Constraints and SME Innovation: A study based on data of New Third Board enterprises, 2021(11):13-25.
- [5] Chu Cui-Cui, Tong Meng-Hua, Li Yang, et al. Digital inclusive finance and provincial economic development in China[J]. *Exploration of Economic Issues*, 2021(6):179-190.
- [6] Qian H. Zhang, Tao Y. Qing, Cao S. Wei. China's digital financial development and economic development: theory and empirical evidence[J]. *Quantitative and technical economic research*, 2020(6):26-46.
- [7] Xie Ruzong, Yang Minwan, Bai Fuchen. Digital Inclusive Finance, Resident Consumption and Industrial Structure upgrading: A dynamic analysis of PVAR based on prefecture-level panel data in Guangdong Province[J]. *Research World World*, 2020(2):59-70.
- [8] Long Jianhui. An empirical study on the growth path of regional innovation capacity and its symbiotic mechanism in China[J]. *Soft Science*, 2018(3):67-71.
- [9] Arellano M, Bover O. Another Look at the Instrumental Variable Estimation of Error-components Models[J]. *Journal of Econometrics*. 1995, 68(1):29-51.