Research on the Impact of Financial Deepening on Digital Economy Development : An Empirical Analysis from China

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Article

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Abstract: In resent years, China's digital economy has achieved significant global recognition for its instrumental role in supporting sustainable economic and social development. Based on the panel data from China's provinces between 2013–2021, this paper investigates the impact and transmission mechanism of financial deepening on digital economy development. The study finds that financial deepening significantly improves digital economy development. Heterogeneity analysis indicates that financial deepening offers greater support to digital economy development in central and western regions than in the east. Further analysis shows that financial deepening improves technological innovation, which in turn promotes the digital economy development. After applying a test of robustness, the results proved significant.

Keywords: financial deepening; digital economy; technological innovation; mediation effect

1. Introduction

The world is currently experiencing unprecedented changes, and the COVID-19 pandemic of the 21st century has had far-reaching impacts, impeding the global economic recovery. In this context, the digital economy has emerged as a key force in restructuring global factor resources, reshaping the global economic structure, and transforming the global competitive landscape. Since the 18th Party Congress, the government has attached significant importance to digital economy development, elevating it to a more critical strategic position. It can be seen that the digital economy has become a powerful driving force for economic development and a key to economic recovery. In 2022, China's digital economy made a new breakthrough, with the digital economy size reaching 50.2 trillion, representing a nominal year-on-year growth rate of 10.3%. The proportion of the digital economy to GDP was as high as 41.5%, indicating that the digital economy has become increasingly important in the national economy. Therefore, the support of finance is indispensable. In October 2022, the 20th Communist Party Congress pointed out the importance of improving the function of the capital market and promoting healthy capital development. Financial deepening can further guide financial institutions to optimize the credit structure and provide sufficient financial support to better meet the needs of the digital economy development. As the digital economy is a significant component of national development, the financial industry must grasp the trends and patterns of the digital economy development, prioritize financial resources into the frontier areas, critical links, and important industries to drive sustainable development of China's economy. Regions or countries with a high degree of financial deepening can better mobilize resources, lower risks, and allocate funds more efficiently to support innovation projects with higher risks. Therefore, it's essential to examine whether financial deepening can further promote the digital economy development, and whether financial deepening can drive the digital economy development through technological innovation.

The contribution of this paper lies in the following aspects. Firstly, according to the existing researches on the digital economy development, this paper establishes a comprehensive index, which

can reflect the degree of digital economy development. Secondly, this paper investigates the relationship between financial deepening and digital economy development, and explores their heterogeneity in terms of region. Thirdly, when considering how financial deepening affects digital economy development, this paper adopts a mediating effects model to further evaluate the transmission effect of technological innovation on financial deepening affecting digital economy development, further deepening the existing literature. In addition, this paper changes the model to increase the robustness of the main conclusions.

The rest of this paper is organized as follows. Section 2 provides relevant literature and the development of hypotheses. Section 3 presents the data and methodology used in the study. Section 4 discusses the empirical results. Section 5 presents a discussion. Section 6 summarizes the study and provides policy implications.

2. Literature Review and Research Hypothesis

2.1. Literature Review

Schumpeter [1] emphasizes the importance of finance in economic development theoretically. Goldsmith [2] finds that economic growth and financial support are coordinated through a financial structure perspective. Shaw [3] argues that liberalization of financial markets and systems helps countries develop. Mckinnon [4] argues that developing countries are hindered by backward financial institutions and economic inefficiencies. Robert et al. [5] find that financial intermediary enhances capital formation, total factor productivity growth, and long-term economic growth. Marco et al. [6] argue that banks may act as catalysts for industrialization provided they are sufficiently large to mobilize a critical mass of firms and that they possess sufficient market power to make profits from coordination. Nader [7] finds that deregulation and a more developed banking sector prompt firms to increase the capital intensity of production, fostering more rapid growth [7]. Graff et al. [8] find that countries gain less from financial activity, if the latter fails to keep up with or exceeds what would follow from a balanced expansion path. Osuka et al. [9] find that financial deepening improves human capital in Nigeria, indicating a long-term relationship between financial deepening and economic development. Sugiyanto et al. [10] find that financial deepening has a positive effect on economic growth. Xu et al. [11] find that series of financial liberalization policies/measures, at both the macro and micro levels, significantly enhanced the productivity of the manufacturing sector. Wang [12] distinguishes financial deepening from financial liberalization by defining the former as a catalyst that promotes savings, investment, and improves the efficiency of the financial sector, ultimately boosting the national economy. Yang et al. [13] argue that insufficient financial development in the central region and weakened financial performance, impacting the region's economic growth. Based on the endogenous development of finance and economic growth, Shen et al. [14] argue that improving financial intermediary efficiency as a means to smooth the transmission mechanism between financial deepening and economic growth, achieving the dual goals of financial liberalization and economic growth. Zhan [15] emphasizes that for sustainable financial deepening reforms in developing countries, domestic macroeconomic stability must be prioritized through rationalization and regularization of government revenue structures. Xiong et al. [16] argue that capital accumulation is the most critical transmission channel of financial deepening to China's economic growth. Tian et al. [17] identify private capital as an essential factor for rural economic development, facilitated by microfinance companies as a carrier for financial deepening. Hu [18] finds that financial deepening in Gansu Province has a significant promoting effect on poverty reduction.

Yang et al. [19] argue that financial deepening and optimizing the allocation of financial resources can promote technological progress and high-quality economic development. Zhang et al. [20] find that financial scale, financial deepening and financial efficiency significantly enhance regional innovation quality. Xu et al. [21] find that "bank-led" financial deepening hinders technological progress in middle-high income countries and regions. Li et al. [22] find that financial deepening significantly promotes technological innovation, and technological innovation plays a vital mediating role in realizing financial support for industrial upgrading. Liu et al. [23] find that financial deep-

ening policies enhance "capital allocation" and "technological progress," promoting economic efficiency through enhanced output efficiency of social labor. Yuan [24] finds that financial deepening positively impacts enterprise motivation in input efforts.

Chen et al. [25] find that fintech facilitates technological innovation and weakens financial decentralization in local governments, promoting the development of the digital economy in China. Yuan et al. [26] find that a stable, long-term relationship between the determinants of technological innovation including digital economy, bank financing for R&D expenditures, GDP, and financial risk. Wu et al. [27] find that fintech accelerates data accumulation, enhances total factor productivity, and drives growth in the digital economy by promoting industry innovation. Xue et al. [28] argue that fintech can optimize resource allocation, improve information collection and transmission efficiency, and promote risk management in the financial industry to facilitate high-quality real economic development and the construction of digital industrial infrastructure, supporting China's economic transformation. Liu et al. [29] find that science and technology finance can facilitate the development of high-tech industries, leading to industrial restructuring and upgrading. Li et al. [30] discover that the scientific and technological development has a region-wide promotion effect on the digital transformation of enterprises in China. Qi [31] emphasizes the importance of actively exploring new paths in scenario finance to enable digital transformation in China's fast-growing digital economy.

In summary, there are few existing studies on the relationship between financial deepening and digital economy development, few studies have integrated financial deepening, technological innovation, and digital economy into a single theoretical framework. Therefore, this paper attempts to construct an index system for digital economy development based on the connotations of digital economy development, and further examine whether financial deepening promotes digital economy development and if it can promote digital economy development through technological innovation and thus accelerate China's digital economy development.

2.2. Research Hypothesis

2.2.1. Financial Deepening and Digital Economy Development

Financial deepening refers to the multidimensional approach of developing a multi-level, market-oriented financial system to enhance economic growth. This approach includes opening and developing financial markets, creating innovative financial products and services, initiating reforms in financial institutions, and strengthening financial supervision. Nowadays, the digital economy is no longer limited to the electronics, communication and information industries, but is achieving deep integration with the traditional economy. The digital economy is no longer merely a part of the economy, but it represents the economy as a whole. Given its high growth potential and profitability, the digital economy and its associated industries require substantial financial support. Financial deepening can increase the reserve of liquid assets and expand the scale of financing [32], guiding the flow of capital into highly competitive, high-yield digital industries and thereby promoting their rapid development. Furthermore, regional financial deepening can improve the access of financial intermediaries, such as banks and venture capitalists, to real enterprise information and alleviate the financing constraints that enterprises face [33], thus broadening enterprise financing channels, reducing financing costs, and providing more options for digital economy enterprises. Financial deepening can improve the efficiency of resource allocation within the digital economy through the integration of modern technologies such as big data. The effective investment of funds in key aspects of the digital economy can be facilitated by financial deepening, thereby promoting its development. As the digital economy continues to develop rapidly, it is imperative to manage the associated financial risks. Financial deepening can address these risks by enhancing the financial market system and regulatory environment, among other measures, and ensure healthy and sustainable growth of the digital economy. Moreover, financial deepening can drive innovation in digital payment systems, digital currency, financial technology, and other related areas, thereby providing more efficient and convenient financial services to support the growth of the digital economy. Overall, financial deepening plays a crucial role in supporting the healthy and sustainable development of the digital economy by

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easing financing constraints, enhancing resource allocation efficiency, managing financial risks, and providing crucial financial support and services where necessary.

Therefore, based on the above analysis, this paper proposes the following hypotheses:

Hypothesis 1 (H1): *Financial deepening can promote the digital economy development.*

2.2.2. Financial Deepening, Technological Innovation and Digital Economy Development

Technological innovation exhibits characteristics of long cycles, high returns, and high risks. Financial institutions are often hesitant to offer financial support to innovation projects with lengthy cycles and high risks, setting a capital constraint on technological innovation for enterprises. Financial deepening can mitigate this challenge by expanding the scale of savings, increasing the availability of loanable funds, easing competition for enterprise funds [34]. Secondly, financial deepening promotes a wide range of financial instruments that reduce the investor's investment risks and fosters their willingness to invest. With the advancement of financial deepening, financial institutions can enhance their ability to collect information on corporate innovation, alleviating the challenge of information asymmetry. Financial deepening can improve the efficiency of savings and investment conversion, reduce innovation funding costs, mitigate investment risks, alleviate information asymmetry, and thereby increase investment in innovative projects that drive technological innovation. Technological innovation is the fundamental source of productivity and a critical driver of digital economy development. Achieving technological innovation in traditional industries, reduce energy consumption and accelerate the digitalization process to help promote sustainable economic development [35]. It facilitates the digital transformation of traditional industries and promotes digital economy development.

Through the above analysis, it is obvious that financial deepening can promote technological innovation. Technological innovation lays the foundation for achieving digital economy development .

Therefore, based on the above analysis, this paper proposes the following hypotheses:

Hypothesis 2 (H2): *Technological innovation has a mediating effect between financial deepening and the digital economy development.*

3. Methodoloy and Data

3.1. Models

3.1.1. Basic Model

This paper constructs a fixed-effects model controlling time and region as a way to investigate the study of the impact of financial deepening on the digital economy development to test Hypothesis 1:

$$De_{it} = \alpha_0 + \alpha_1 Fd_{it} + \alpha_2 Controls_{it} + \varepsilon_{it} \quad (1)$$

Where *De* stands for digital economy development index, *Fd* stands for financial deepening, *Controls* stands for control variables, i stands for province, t stands for time, α stands for coefficient, and ε stands for residual term.

3.1.2. Mediating Effect Model

To investigate whether there is a mediating effect of technological innovation between financial deepening and digital economy development, in accordance with the study of Wen et al. [36], this paper constructs a mediating effect model as a way to test Hypothesis 2:

$$De_{it} = \alpha_0 + \alpha_1 Fd_{it} + \alpha_2 Controls_{it} + \varepsilon_{it} \quad (1)$$

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$$In_{it} = \beta_0 + \beta_1 Fd_{it} + \beta_2 Controls_{it} + \eta_{it} \quad (2)$$

$$De_{it} = \gamma_0 + \gamma_1 Fd_{it} + \gamma_2 In_{it} + \gamma_3 Controls_{it} + \zeta_{it} \quad (3)$$

Where *In* represents the technology innovation index, β and γ represent the coefficients, η and ζ represent the the residual terms, and the rest of the letters represent the same meaning as above. In addition, in the mediating effect model, α_1 represents the total effect, γ_1 represents the direct effect, and the result of multiplying β_1 and γ_2 represents the mediating effect.

3.2. Description of the Data

3.2.1. Dependent Variables

Tapscott [37] first proposes the concept of digital economy, arguing that the digital revolution of information technology has made the digital economy a new economy based on human intelligence networking. Margherio [38] argues that the digital economy includes the infrastructure of the Internet, e-commerce, digital transaction payments for goods and services, and retail tangible goods. Mesenbourg [39] regards the digital economy as consisting of the infrastructure of electronic business, e-commerce, and electronic commerce. Kim [40] includes digital infrastructure into the concept of the digital economy, presenting a new driving force for digital economic growth. Tae [41] points out that the digital economy is a new way of economic development. Particularly with the rapid development of information technology, the rapid development of the digital economy is profoundly impacting the world economy. Xie [42] believes that the digital economy promotes "dematerialization" of production and life, reducing energy and resource consumption. Liu et al. [43] argue that the digital economy is a new economic form which utilizes the core element of digital information and is supported by the development of informatization and the internet. In July 2022, the "China Digital Economy Development White Paper (2022)," released by the China Academy of Information and Communications Technology, defines the digital economy as "a new form of economy that uses digitized knowledge and information as the key production elements, digital technology as the core driving force, and modern information networks as important carriers. By deeply integrating the digital economy with the real economy, it continuously enhances the level of digital, networked, and intelligent economic and social development, and accelerates the reconstruction of the economic development and governance models." This paper draws on relevant research , referring to the "Classification of the digital economy and its core industries (2021)" and considering the principles of scientificity, systematicity, comprehensiveness, and comparability in selecting indicators, finally categorizes the digital economy development level into four dimensions: digital economy infrastructure, digital industrialization, industrial digitization, and digital services. Each dimension includes various sub-indicators that have been carefully selected to construct a comprehensive measurement system to determine the level of digital economic development at the provincial level. The specific indicators are detailed in Table 1, where + represents the positive indicators, and the data of each indicator are from the CSMAR database.

Table 1. Index system of digital economy development.

First-level indicators	Second-level indicators	Third-level indicators	Properties
Digital economy development level	Digital Infrastructure	Length of fiber optic cable line	+
		Number of Mobile phone base stations	+
		Mobile Phone Penetration Rate	+
		Number of Internet broadband access ports	+
		Number of Internet domain names	+

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		Number of ipv4 addresses	+
	Digital Industrialization	Total Amount of Telecommunications Services	+
		Software industry revenue	+
		Number of Employees in Information Services Industry	+
		Output Value of Information Technology Industry	+
	Industry Digitization	E-commerce Sales Revenue	+
		Proportion of Enterprises with E-commerce Transactions	+
		Number of Websites per Hundred Enterprises	+
	Digital Services	Digital Inclusive Finance	+

To enhance objectivity and reduce subjectivity, this paper adopts the entropy value method to determine the indicator weights and obtain the comprehensive digital economy development index by province. To avoid the influence of extreme values, the data need to be standardized first, and the weights of each indicator are measured as shown in Table 2.

Table 2. Indicator weights (Unit:%).

Indicators	Weights	Indicators	Weights
Length of fiber optic cable line	4.571%	Software industry revenue	14.600%
Number of Mobile phone base stations	4.273%	Number of Employees in Information Services Industry	9.261%
Mobile Phone Penetration Rate	2.242%	Output Value of Information Technology Industry	15.006%
Number of Internet broadband access ports	4.495%	E-commerce Sales Revenue	10.526%
Number of Internet domain names	10.038%	Proportion of Enterprises with E-commerce Transactions	2.215%
Number of ipv4 addresses	10.994%	Number of Websites per Hundred Enterprises	0.733%
Total Amount of Telecommunications Services	8.830%	Digital Inclusive Finance	2.225%

3.2.2. Independent Variable

The measurement of financial deepening is commonly expressed through the scale and structure of the financial system. Presently, China's financial system is largely reliant on indirect financing, and bank loans are the main source of financing for digital economy enterprises. Financial deepening is reflected in the deepening penetration of credit in the banking sector and the investment bias of loans from banks or other financial institutions [44]. This paper decides to use the logarithm of loan balances of financial institutions to measure the actual situation of financial deepening.

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3.2.3. Mediating Variable

Patent data is more objective and transparent compared to R&D expenditure data. Following the approach of Xiong et al. [45], this paper decides to use the logarithm of the number of patents granted per ten thousand people to measure the level of technological innovation.

3.2.4. Control Variables

This paper aims to study the impact of financial deepening on the digital economy development. Therefore, other important control variables should be taken into account to control for the effects on the independent variables. This paper sets the following control variables based on the existing researches by Wang et al. [46] and Zhu et al. [47]: government support (Gov), measured as the ratio of regional fiscal expenditure to GDP ; foreign investment (FDI), measured as the ratio of foreign direct investment to GDP in each province; openness (Open), measured as the ratio of total imports and exports to GDP in each province; transportation level (Transport), measured as the logarithm of the number of grade kilometers ; and human capital (Edu), measured as the ratio of regional education expenditures to regional fiscal expenditures.

3.3. Data Source

Due to the unavailability of data from the Tibetan province, this paper finally takes panel data from 30 provincial administrative units (excluding Hong Kong, Macao and Taiwan) in China from 2013-2021. Among them, Digital Inclusive Finance is from the Digital Inclusive Finance Index released by Peking University, and other data are from the National Bureau of Statistics, the China Financial Yearbook, statistical yearbooks of each province, and the CSMAR database. The variable descriptions are shown in Table 3.

Table 3. Descriptive Statistical Results of Main Variables.

Variables	Symbols	Mean	Standard deviation	Min	Max
Digital Economy	De	0.3704	0.4143	0.0254	2.5897
Financial Deepening	Fd	10.3072	0.8083	8.1647	12.3115
Technology Innovation	In	2.1724	0.9971	-0.1288	4.5087
Government Support	Gov	0.2522	0.1023	0.1066	0.6430
Foreign Investment	FDI	0.0188	0.0170	0.0001	0.1210
Openness	Open	0.2529	0.2643	0.0076	1.3418
Transportation Level	Transport	11.6327	0.8258	9.4441	12.8607
Human Capital	Edu	0.1613	0.0257	0.0989	0.2099

3.4. Correlation Matrix

Preliminary to the regression analysis, this study conducts correlation analysis for each variable, and the results of correlation coefficients are shown in Table 4. The results reveal that financial deepening is significant and positive correlation with both digital economy and technological innovation. Additionally, digital economy is significant and positive correlation with technological innovation.

The correlation analysis conducted provides a solid basis for this paper to proceed with regression analysis and further argue the hypothesis.

Table 4. Correlation matrix.

	De	Fd	In	Gov	FDI	Open	Transport	Edu
De	1.000							
Fd	0.7679***	1.0000						
In	0.7416***	0.7870***	1.0000					
Gov	-0.4615***	-0.7373***	-0.5271***	1.0000				
FDI	0.0966	0.1727***	0.2813***	-0.3808***	1.0000			
Open	0.6599***	0.5560***	0.6722***	-0.4027***	0.3538***	1.0000		
Transport	-0.0687	0.2384***	-0.2122***	-0.1866***	-0.3509***	-0.5255***	1.0000	
Edu	0.2130***	0.3960***	0.1257**	-0.4705***	-0.0079	0.0426	0.4062***	1.0000

Note: *, ** and *** represent significance at the level of 10%, 5% and 1%.

4. Empirical Results and Analysis

4.1. Regression Results

4.1.1. Benchmark Regression Results

This paper regresses the relationship between financial deepening and digital economy development controlling region and time. The regression results are shown in Table 5. According to Table 5, after controlling for the effects of other factors, the financial deepening is positively correlated to digital economy development and is significant at the 1% level, indicating that financial deepening can significantly improve the level of digital economy development , proving the validity of Hypothesis 1. Financial deepening facilitates the allocation of funds to digital economy industries through credit and financing channels, thus encouraging the growth of digital industries and ultimately promoting the development of the digital economy. Additionally, financial deepening introduces innovative financial products and services, such as online banking and third-party payments, which contribute to overall improvements in the efficiency and effectiveness of financing for enterprises engaged in the digital economy. Among the control variables, the human capital level is positively correlated to digital economy development, human capital is a crucial force driving digital economy development. In contrast, openness is negatively correlated to digital economy development, which could potentially be attributed to external factors such as the trade war between China and the U.S., resulting in a declining trend of China's total import and export and potentially weakening the driving force for the digital economy. Furthermore, the transportation level is negatively correlated to digital economy development, possibly because communication technology and the Internet have reduced spatial barriers and provided convenience for digital economy development.

Table 5. Regression results

Variables	Coefficient
	De
Fd	0.5327***
	(4.88)
Gov	-0.5976
	(-1.61)
FDI	-0.4554

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	(-0.64)
Open	-1.3771***
	(-9.93)
Transport	-0.8053***
	(-7.11)
Edu	1.8827**
	(1.98)
Cons	4.4564***
	(2.99)
N	270
R^2	0.7133
Province	YES
Year	YES

Note: *, ** and *** represent significance at the level of 10%, 5% and 1%. respectively, and the values in brackets are T-values.

4.1.2. Robust Regression Results

To ensure the reliability of the results, this paper conducts Robust tests, and the test results are shown in Table 6.

(1) Substituting the core explanatory variable. In column (1) of Table 6, the regression outcomes are displayed using the financial depth (Depth) released by Peking University to represent the level of financial deepening. The results are consistent with the benchmark regression, indicating robust results.

(2) Excluding the sample of centrally governed municipalities. The data from four municipalities governed by the central government, Beijing, Shanghai, Tianjin, and Chongqing, are not included in the sample. Instead, the regression results for the remaining 26 provinces are shown in column (2) of Table 6, the regression coefficients of the core explanatory variable is significantly positive, and the results are reliable.

(3) referring to Hu et al. [48], concerning possible causality issues between financial deepening and the digital economy development , this paper lags the explanatory variable and control variables by one period. The regression results are shown in column (3) of Table 6. Financial deepening with a one-period lagged continues to have a significant positive effect on the digital economy development.

Table 6. Robust regression results.

Variables	**(1)** **De**	**(2)** **De**	**(3)** **De**
Fd		0.7119***	0.3575***
		(8.31)	(2.82)
Depth	0.4727***		
	(7.33)		
Gov	-0.3423	-0.3525	-1.0407***
	(-0.97)	(-1.19)	(-2.73)
FDI	0.5627	-2.1270***	0.1055
	(0.86)	(-2.87)	(0.15)
Open	-1.0843***	-1.3750***	-1.2803***
	(-8.62)	(-8.79)	(-9.66)

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Transport	-0.3962***	-0.6851***	-0.7700***
	(-3.57)	(-7.16)	(-6.30)
Edu	1.0860	-0.1615	0.9034
	(1.19)	(-0.20)	(0.96)
Cons	4.1334***	1.7104	6.0617***
	(3.11)	(1.33)	(3.75)
N	270	234	240
R^2	0.7439	0.7598	0.7217
Province	YES	YES	YES
Year	YES	YES	YES

Note: *, ** and *** represent significance at the level of 10%, 5% and 1%. respectively, and the values in brackets are T-values.

4.2. Heterogeneity Results

To test whether there is heterogeneity in Financial deepening for the digital economy development, this paper conducts heterogeneity test from regions, and the test results are shown in Table 7. The regional differences of financial resources distribution across China have resulted in varying impacts of financial deepening on the country's digital economy. This research has categorized the 30 provincial administrative units into eastern, central, and western regions for analysis. The results indicate that the impact of financial deepening on the digital economy development is more significant in the central and western regions compared to the eastern region. The economic composition of the central and western regions is mainly concentrated in industries such as construction, energy, and manufacturing, while financial development is relatively lagging behind. By increasing financial support in the central and western regions, financial deepening can better prioritize the allocation of financial resources to the digital economy sector and accelerate the digital transformation of these traditional industries. Hence, it has a greater marginal effect on promoting the digital economy development in the central and western regions, thereby emerging as a driving force in promoting the digital economy development in these regions.

Table 7. Heterogeneity test results.

Variables	**Eastern Region**	**Central and Western Regions**
	De	De
Fd	0.3367	0.3235***
	(1.42)	(5.46)
Gov	-1.6639	-0.9222***
	(-1.58)	(-5.34)
FDI	1.5259	-3.0301***
	(1.44)	(-3.68)
Open	-1.1580***	0.2209
	(-5.19)	(1.44)
Transport	-1.0944***	-0.0869
	(-4.06)	(-1.39)
Edu	5.655***	-1.8109***
	(2.91)	(-3.39)
Cons	8.9299**	-1.3915*
	(2.29)	(-1.96)

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N	90	180
R^2	0.8496	0.8217
Province	YES	YES
Year	YES	YES

Note: *, ** and *** represent significance at the level of 10%, 5% and 1%. respectively, and the values in brackets are T-values.

4.3. Mechanism Results

4.3.1. Mediating Effect Results

This paper uses Sobel to test whether there is a mediating effect of technological innovation between financial deepening and digital economy development, and the test results are shown in Table 8. According to Table 8, financial deepening and digital economy development are positively correlated at the 1% significance level, implying that financial deepening has a significant impact on the the digital economy development, which is consistent with prior research. The financial deepening can improve technological innovation, thereby optimizing capital allocation, reducing enterprise financing costs, and eliminating information asymmetry. Thus increasing investors' investment in innovation projects to promote technological innovation. At the same time, technological innovation is the source of productivity and the most important driving force of economic growth. Technological innovation can bring about upgrading of production processes, efficiency improvement and promote the digital transformation of traditional industries, which in turn promotes the development of digital economy. According to Table 8, the Sobel intermediary effect test is significant at the 1% level, and every 1% increase in the degree of financial deepening increases the degree of digital economy development by 0.4139%, of which the direct effect accounts for 0.3226% and the indirect effect accounts for 0.0913%. Consequently, there is a partial intermediary effect of technological innovation between financial deepening and digital economy development, and financial deepening can promote the the digital economy development through the channels of technological innovation.

Table 8. Mediation effect test results.

Variables	**(1)** **De**	**(2)** **In**	**(3)** **De**
Fd	0.4139***	1.3581***	0.3226***
	(11.32)	(18.96)	(5.77)
In			0.0672**
			(2.15)
Gov	0.6701***	0.8968*	0.6098***
	(2.87)	(1.96)	(2.61)
FDI	-2.8917***	0.1550	-2.9021***
	(-2.86)	(0.08)	(-2.89)
Open	0.3685***	-0.6949***	0.4152***
	(3.35)	(-3.23)	(3.73)
Transport	-0.0795**	-0.6482***	-0.0359
	(-2.43)	(-10.13)	(-0.94)
Edu	0.3935	-1.5896	0.5004
	(0.59)	(-1.22)	(0.76)
Cons	-3.2431***	-4.0827***	-2.9685***
	(-8.28)	(-5.32)	(-7.25)

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R^2	0.7036	0.7992	0.7088
Sobel		0.0913**	
Indirect effect		0.0913**	
Direct effect		0.3226***	
Total effect		0.4139***	

Note: *, **, *** represent significant at the 10%, 5%, and 1% levels, respectively, and t-values are in parentheses.

4.3.2. Robust Regression Results

To ensure the accuracy of the results, this paper uses a bootstrap self-sampling method for testing, and the test results are shown in Table 9. According to Table 9, the direct effect of financial deepening on digital economy development is 0.3226, which is significantly positive at the 1% level; the indirect effect is 0.0913, which shows that there is a mediating effect of technological innovation between financial deepening and digital economy development, and financial deepening can stimulate digital economy development through the intermediary effect of technological innovation.

Table 9. Robustness test results.

	Coefficient	**p-Value**
Indirect effect	0.0913	0.005
Direct effect	0.3226	0.000

5. Discussion

The international power structure has undergone significant adjustments, presenting new strategic opportunities for economic development in China.The digital economy has become a powerful driving force for sustainable economic development and a key force in the recovery of the Chinese economy. Nevertheless, digital industries and sectors frequently encounter challenges in obtaining the necessary financial support. To address this issue, this paper constructs a comprehensive evaluation system to for the digital economy development .In the research, we find that financial deepening exhibits a positive relationship with the digital economy development. Financial deepening encourages an increase in domestic savings, foreign capital inflows, and the overall amount of savings. This increased savings can bolster the pool of loanable funds, thus promoting investment in the digital economy. Moreover, intense market competition ensures efficient allocation of investment opportunities, with a focus on high-return projects, thereby supporting the development of new digital industries and promoting the growth of the digital economy. For a long time, China's central and western regions have experienced significant economic disparities, with relatively lower levels of financial development. In this context, financial deepening can optimize resource allocation and accelerate the development of the digital economy in these regions. The intermediary effect test also reveals that technological innovation plays a crucial role. By reducing the financing costs faced by innovative projects, financial deepening stimulates technological innovation. The resulting technological advancement can facilitate the implementation of new digital projects and industries, accelerate the digital transformation of traditional industries, gradually phasing out backward industries with high energy consumption and pollution , and promote the development of the digital economy.

In conclusion, from the above discussion, we can see that financial deepening can promote the digital economy development.

6. Conclusions and Policy Recommendations

This study presents a digital economy development index system based on a panel dataset of 30 provincial administrative units in China from 2013-2021. Through using a fixed-effects model, Sobel-mediated effects model and Bootstrap self-sampling method, we empirically examine the impact of

financial deepening on digital economy development. The results indicate that financial deepening plays a key role in promoting digital economy development, and this conclusion maintains its significance after a robustness test. Furthermore, we find that the impact of financial deepening on digital economy development varies significantly across regions, with the central and western regions of China experiencing greater impacts.In addition, our study finds that financial deepening is critical in fostering technological innovation, and technological innovation further mediates the relationship between financial deepening and digital economy development. Drawing on these results, we propose the following recommendations:

Firstly, it is crucial to pursue progressive reforms to the financial system, increasing the efficiency and quality of financial services and based on an effective regulatory framework. Enhancing the capacity of financial services for the real economy and guiding traditional financial institutions, including banks, in enhancing their service capabilities, can also ensure robust service delivery. Meanwhile, approval processes for digital economy enterprises should be simplified, and financing thresholds lowered, to facilitate swift development of this crucial sector.Innovation in financial products and services tailored to the digital economy is essential to driving further progress, including the introduction of e-commerce finance and blockchain-based solutions. Also, increasing direct financing by moderately opening up the capital market and raising its proportion can play a vital role in powering growth. Welcoming foreign investment and easing the access of foreign financial institutions can help channel additional financial resources and advanced technology into China, consequently fast-tracking the progress of the digital economy.

Secondly, the digital economy development can be impacted heterogeneously by financial deepening. Hence, it is imperative for the government to prioritize top-level design focused on regional coordinated development that factors in local specifics. The central and western regions of China have relatively weaker financial development and require improvement in the construction of relevant financial institutions. Furthermore, corresponding policies and measures should be promoted to create a conducive environment for digital economy development by enhancing financial support. Conversely, the eastern region has better financial business development, and should focus on improving the service capacity of financial institutions through the adept use of modern technologies such as artificial intelligence, big data to allocate and manage financial resources effectively to provide high-quality and convenient services to promote digital economy development.To advance coordinated development between the eastern region and central and western regions, strengthening regional exchanges and cooperative frameworks will be critical. Leveraging the financial resources of the eastern region to radiate and assist the central and western regions will facilitate regional synergy and integration, ultimately contributing to the overall progress and economic development of the digital economy.

Thirdly, to facilitate the implementation of digital projects and the digital transformation of enterprises, financial institutions should moderately enhance the availability of credit funds, reduce financing costs, and provide more financial support. Efforts should be made to increase the training of digital technology professionals, financial technology professionals and hybrid professionals to meet the accelerating pace of digitalization. The government should encourage the provision of reasonable support in financing, technology, and talent development for digital industries and enterprises. Led by the government, in-depth industry-research cooperation should be carried out, involving participation from enterprises, universities, and other relevant subjects, to enhance their innovation ability and enthusiasm, accelerate digital transformation, promote the high integration of technological innovation and the digital economy, actively cultivate new dynamic modes of the digital economy, and inject considerable momentum into the sustainable development of the Chinese economy.

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