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Full Length Article

Does information communication promote financial development? Empirical evidence from China

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Abstract

Sound information communication is an important guarantee of financial development. In this study, the impact of information communication on financial development is analyzed using panel data on Chinese cities. The instrumental variable method is adopted to deal with endogeneity between information communication and financial development, and a quasi-natural experiment is conducted to further alleviate endogeneity. Finally, we consider the heterogeneity of the impact of information communicated on financial development. The results show that information communication facilities, information communication levels, and information communication penetration rates can promote urban financial development. Financial development improves significantly in the pilot cities under the implementation of "Broadband China" strategy. And the impact of information communicated on financial development is more obvious in cities in the Northeast Economic Circle, the Pan-Pearl River Delta Economic Circle, the Southwest Economic Circle in China, and cities with a low level of foreign investment.

JEL classification: C58; G00

Keywords: Financial development; Information communication; Quasi-natural experiment; PSM-DID analysis

1. Introduction

The information communication, represented by information technology and communication networks, has developed rapidly in recent years. China has issued a series of policies, such as "Broadband China" for constructing communication infrastructure. On August 17, 2013, the State Council of China issued the "Broadband China" strategy, which proposed technical routes, development schedules and supporting measures to speed up the construction of broadband network. On February 25, 2022, the China Internet Network Information Center (CNNIC) released China's 49th statistical report on the development status of the internet. According to this report, at the end of 2021, the number of cell towers in China totaled 9.96 million, and the cumulative number of 5G cell towers totaled 1.425 million, showing a generally upward trend in the number of communication services. In addition, the number of users with access to internet broadband totaled 536 million, the number of people with mobile internet exceeded 200 million, and the internet penetration rate reached 73.0 percent at the end of 2021.

In this paper, information communication emphasizes the development of digital information and communication industry, including the construction of network infrastructure, the number of internet users, network coverage, and so on. The advancement in information communication provides a constant impetus for socioeconomic development. On the one hand, information communication gradually eases the dilemmas of higher costs and lower efficiency in the financial sector. On the other hand, the financial system, supported by

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information communication, helps enterprises to obtain more funding and promotes development of the real economy. The 2022 National People's Congress (NPC) and National Committee of the Chinese People's Political Consultative Conference (CPPCC) stressed that information technology should continue to be integrated into the real economy and play a pivotal role in financial development.

Information communication has a network effect, providing convenient channels for financial activity. Specifically, information communication increases the breadth and depth of financial services. First, it can expand the breadth of financial development. The widespread use of information communication is a critical driving force in developing the rural financial system (Chatterjee, 2020). Information technology, represented by mobile base stations and mobile banking, can meet the financial needs of more customers and provide the hardware for the effective supply of financial services. With the support of information technology, a large amount of data on financial transactions has been effectively integrated, helping financial institutions to provide financial support to the real economy more efficiently. Second, information communication enhances the depth of financial services. The continuous spread of information communication drives development of the internet, helps financial institutions to provide diversified financial services, makes people more willing to accept fintech (financial technology), and promotes the continuous optimization of financial services. The constant improvement of information technology enables it to be continuously applied in finance, accelerating the innovation of financial products and services. However, a digital divide still exists. The application of information technology varies significantly across different regions in a country. Therefore, comprehensively studying the influence of information communication on financial development has practical significance.

Most of the research in China on the influence of information communication on financial development strongly focuses on provincial regions. Because the resources in each province are usually concentrated in the province's capital, the literature does not adequately explain the role of information communication in financial development. Moreover, the *China City Statistical Yearbook* contains limited statistics on information communication, such as the number of post and telecommunications offices and fixed-line telephones. In terms of the methods of analysis, most literature uses theoretical analysis and case studies to explore the application of information communication in finance. However, these studies do not make causal inferences, and the research conclusions need further confirmation.

This paper makes the following main contributions to the literature, in an effort to address these shortcomings. First, we abandon the traditional research perspective from the provincial level and adopt the research perspective of combining the city level and the provincial level. City-level and province-level panel data are used to study the impact of information communication on financial development in terms of three dimensions: information communication facilities, information communication levels, and information communication penetration rates. Second, we have fully considered the endogeneity between information communication and financial development, which is neglected in the existing literature. We use the instrumental variable method to deal with the endogeneity, which is not entirely considered in the existing literature. For further supplementing the existing literature, we use the "Broadband China" strategy as a shock event to conduct a quasi-natural experiment. Third, we conduct an analysis of the heterogeneity from the perspective of regions and foreign investment levels, which are hardly seen in the existing literature. In summary, our findings offer new perspectives and empirical evidence on the role of information communication in supporting financial development.

The remainder of the paper is structured as follows. Section 2 reviews the literature on the impact of information communication on financial development. Section 3 presents the study design. The empirical analysis and the robustness test are discussed in Sections 4 and 5, respectively. Next, Section 6 explains further tests of endogeneity and heterogeneity. Finally, the conclusions are laid out in Section 7.

2. Literature review

Information communication is characterized by high permeability and extensive coverage, which can provide more inclusiveness for market participants and help them improve financial opportunities (Asongu et al., 2017; Lin et al., 2020). The high level and penetration of information communication has a positive impact on financial development (Sassi & Goaied, 2013) and are indispensable conditions for promoting financial development (Yang & Zhang, 2020). The role of information communication in promoting financial development is mainly reflected in decreasing financial transaction costs, reducing information asymmetry in financial markets, and expanding the scale of financial transactions.

First, information communication plays a significant role in decreasing financial transaction costs. On the one hand, information communication promotes the spread of fixed and mobile phones and facilitates the development of financial services. Banks can communicate with their customers remotely in time based on real-time information. It reduces operational costs in the banking business and the time costs for banking customers and drives banks to provide more innovative services (Lapukeni, 2015). On the other hand, perfect information communication induces automation of financial transactions. For example, electronic trading systems increase the speed of information transmission between different market participants, enhance the liquidity of market information, and improve the risk-sharing mechanism (Hendershott et al., 2011). In addition, information technology boosts the development of online banking and enables financial institutions to develop targeted financial products by collecting and processing user information (Wang, 2015).

Second, information communication reduces information asymmetry in financial markets. By strengthening information flow, information technology reduces market failure caused by information asymmetry and provides a prerequisite for the

effective operation of the financial market (Lechman & Marszk, 2015). The diffusion of information communication can improve the process of information acquisition and collection of financial institutions, reduce market friction, and expand the coverage of financial services. More market participants acquire financial knowledge and participate in financial transactions, thus increasing the availability and accuracy of information (Akerman et al., 2022). In the information age, credit scoring technology increases the supply of finance, makes credit available to groups with opaque information, enables capital providers and demanders to timely and accurately match their needs, and constantly promotes efficiency in transactions (Meijers, 2014). Therefore, the rapid development of information communication enhances the degree of matching in the supply and demand for financing, provides development space for financial services, and promotes inclusive growth in the financial industry (Zhang et al., 2019).

Third, information communication is conducive to expanding the scale of financial transactions. Due to the reduction of transaction costs, households and business sectors adopt more mobile money services, increasing the proportion of savings and deposits (Munyegera & Matsumoto, 2018). And information communication can enrich the types of financial transactions by increasing the supply of funds. In particular, the integration of financial services and information communication is an essential force for innovation and reform in the modern financial industry (Suryono et al., 2020). As a large component of financial inclusion, information communication promotes a financial revolution, especially in providing more financial services to industrial and commercial enterprises (Wellalage et al., 2021). Information communication helps financial institutions to quickly and comprehensively grasp the information on the demand for credit and ultimately improve the efficiency of the supply of funds and allocation of capital (Li & Zhao, 2014; Xie et al., 2015). Furthermore, information communication also increases the scale of the supply of funds and promotes economic growth, especially in low-income countries.

Despite these advantages in promoting financial development, some scholars believe that information communication has some disadvantages. The increasing penetration rates of information communication caused sharp fluctuations in asset prices, making financial markets more volatile and sensitive (Ilyina & Samaniego, 2011). Market participants without timely access to information are easily excluded from financial transactions, exacerbating the imbalance in financial development (Pozzi et al., 2013). The impact of information communication on financial development is likely to vary across financial markets. For example, a stronger influencing relationship between information communication and financial development is found in the Mexican ETF (Exchange Traded Fund) market, but not in the Brazil ETF market (Lechman & Marszk, 2015). In addition, the impact of information communication on financial development also varies across income groups. For example, mobile phones are found to have a negative effect in high-income groups and a positive effect in middle- and low-income groups (Chien et al., 2020). The existing research on the impact of information communication on financial development remains controversial based on the advantages and disadvantages mentioned above. This paper further explores this impact from the perspective of information communication facilities, levels, and penetration rates.

3. Study design

3.1. Model

This paper uses panel data on 287 cities in China from 2000 to 2019 for empirical research. The core explanatory variable, information communication, comes from the *China Urban Statistical Yearbook*. The variables for financial development (loan balances, deposit balances, and social financing scale) and other macro variables (urban gross domestic product [GDP], population of permanent residents, population density, investment in fixed assets, built-up area) come from China's Guotai'an database. The transportation infrastructure variables (railway mileage in operation, highway mileage, and passenger-carrying capacity) come from China's economic prediction system (EPS) database. The robustness test uses panel data on 31 provinces (including provinces, autonomous regions, and municipalities directly under the central government) from 2000 to 2020, and the data come from the *China Statistical Yearbook*. The panel fixed effects model is constructed as follows.

$$\ln\text{loan}_{it} = \alpha_{it} + \beta_{it} lnpost_{it} + \gamma_{it} X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

$$\ln\text{loan}_{it} = \alpha_{it} + \beta_{it} lnts_{it} + \gamma_{it} X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (2)$$

$$\ln\text{loan}_{it} = \alpha_{it} + \beta_{it} lniba_{it} + \gamma_{it} X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (3)$$

In Equations (1)–(3), i is the city, and t is the year. All explained variables, explanatory variables, and control variables are further explained in Table 1. Time fixed effects (δ_t) and individual fixed effects (μ_i) are added to the models, and ε_{it} is random error.

In Table 1, the explained variable is financial development, which is the process of supplementing and improving financial operations. Following the literature (Shan & Wang, 2017), we use the logarithm of loan balances in domestic and foreign currencies at financial institutions (lnloan and lnloan-p) to measure financial development. In the robustness test, the explained variable is replaced by the logarithm of deposit balances in domestic and foreign currencies at financial institutions (lndeposit) and the logarithm of the increase in the social financing scale (lnsfs).

As the explanatory variable, information communication can be further discussed in terms of the information communication facilities, levels, and penetration rates. First, the post and telecommunications offices and mobile telephone exchange capacity are important parts of communication infrastructure, providing the basic conditions for transmitting information (Shi & Shi, 2014). Therefore, we use the logarithm of the number of post and telecommunications offices (lnpost) and the logarithm of mobile telephone exchange capacity (lnmtc-p) to measure information communication facilities.

Table 1
Definition of variables.

	Variable labels	Definition
Urban data		
Explained variables	lnloan	The logarithm of loan balances in domestic and foreign currencies at financial institutions
	lndeposit	The logarithm of deposit balances in domestic and foreign currencies at financial institution
	lnsfs	The logarithm of the increase in the social financing scale (The social financing scale refers to the total amount of funds obtained by the real economy from the financial system.)
Explanatory variables	lnpost	The logarithm of the number of post and telecommunications offices
	lnts	The logarithm of the number of telecommunications services
	lniba	The logarithm of the number of users with access to internet broadband
Control variables	dlngdp	The difference in the logarithm of urban GDP
	lnpop	The logarithm of population of permanent residents
	lndpop	The logarithm of population density
	lnfix	The logarithm of investment in fixed assets
	lnarea	The logarithm of built-up area
	lnrailway	The logarithm of railway mileage in operation
	lnhighway	The logarithm of highway mileage
	lnvol	The logarithm of passenger-carrying capacity
Province-level data		
Explained variable	lnloan-p	The logarithm of loan balances in domestic and foreign currencies at financial institutions
Explanatory variables	lnmtc-p	The logarithm of mobile telephone exchange capacity (The exchange capacity indicates the total data exchange capacity of the switch.)
	lnts-p	The logarithm of the number of telecommunications services
	lniap-p	The logarithm of the number of internet broadband access ports (Users can access the internet by these ports.)
Control variables	lnpgdp-p	The logarithm of GDP per capita
	lndpop-p	The logarithm of population density
	lnfix-p	The logarithm of investment in fixed assets
	lncarea-p	The logarithm of built-up area
	lnreal-p	The logarithm of real estate investment
	lnpbe-p	The logarithm of general public budgetary expenditure

Second, the logarithm of the number of telecommunications services (lnts and lnts-p) is used to measure information communication levels. Third, the number of users with access to internet broadband and ports (lniba and lniap-p) reflects the public acceptance of modern information technology and the popularity of information technology (Liang, 2020). The availability of internet broadband raises the penetration rate of information networks rapidly. Thus we use the logarithm of the number of users with access to internet broadband and ports to measure the rate of information communication penetration.

The selection of control variables considers the factors that affect financial development as well as information communication. Urban GDP reflects the level of urban economic growth, which is related to the ability of financial institutions to support entity enterprises (Ye et al., 2019). The structure of population and age affects the level of human capital in cities (Liu & Li, 2019), and population activity and agglomeration relate to the supply and service levels of financial institutions (Su & Fang, 2016). Improvement in transportation infrastructure supports the supply-side structural reform of finance and provides a foundation for financial development (Wang et al., 2021). The real estate market plays an important role in a country's economic and financial development (Lim, 2018). Government expenditure contributes significantly to financial development (Ajayi & Musyimi, 2022). Therefore, the control variables include the difference in the logarithm of urban GDP (dlngdp), the logarithm of the population of permanent residents (lnpop),

Table 2
Descriptive statistics of the variables.

Variables	Obs.	Mean	Std.	Min.	Max.
Urban data					
lnloan	4633	15.85	1.335	6.370	20.42
lndeposit	4637	16.30	1.244	9.682	21.22
lnsfs	4629	15.74	1.127	6.267	19.74
lnpost	4815	5.012	0.728	0.000	9.152
lnts	2516	12.48	0.958	8.686	16.45
lniba	2515	4.142	0.939	0.000	7.198
dlngdp	5338	0.126	0.231	−1.772	7.784
lnpop	5229	5.837	0.787	−3.912	8.136
lndpop	4530	5.722	0.902	1.548	9.356
lnfix	5103	15.10	1.411	10.82	18.97
lnarea	5716	9.338	0.859	2.565	12.92
lnrailway	3702	5.582	1.361	0.000	10.25
lnhighway	5229	8.395	0.987	0.000	12.57
lnvol	4423	8.540	0.965	0.693	12.57
Provincial data					
lnloan-p	557	9.397	1.221	5.411	11.71
lnmtc-p	627	7.903	1.224	4.337	10.00
lnts-p	649	6.015	1.282	2.513	8.929
lniap-p	466	6.593	1.332	2.754	8.885
lnpgdp-p	651	10.12	0.843	8.404	11.82
lnpop-p	651	8.086	0.859	5.653	9.349
lnfix-p	560	8.310	1.332	5.060	10.74
lncarea-p	650	6.881	0.888	4.357	8.636
lnreal-p	527	7.056	1.412	1.636	9.759
lnpbe-p	651	7.417	1.166	4.539	9.459

population density (lndpop and lndpop-p), investment in fixed assets (lnfix and lnfix-p), built-up area (lnarea and lncarea-p), railway mileage in operation (lnrailway), highway mileage (lnhighway), passenger-carrying capacity (lnvol), GDP per capita (lnpgdp-p), real estate investment (lnreal-p), and general public budgetary expenditure (lnpbe-p).

3.2. Descriptive statistics of the variables

The descriptive statistics in Table 2 show that cities vary in their level of financial development.

In the urban data, the standard deviations of lnloan, lndeposit, and lnsfs are 1.335, 1.244, and 1.127, respectively, with a large gap between the maximum and minimum values for these three variables. The standard deviation of lnpost, lnts, and lniba is 0.728, 0.958, and 0.939, respectively. It shows that the level of the construction of information communication facilities between cities significantly differs. In the provincial data, the standard deviation of lnloan-p is 1.221, and the difference between the maximum and minimum is smaller than in the urban data. The standard deviation of lnmtc-p, lnts-p, and lniap-p is 1.224, 1.282, and 1.332 respectively. This indicates that the level of construction of information communication facilities between provinces differs very little.

4. Empirical analysis

4.1. Unit-root test

To ensure the validity of the estimated results, a data stationarity analysis is required before the regression of the model. We conduct a Fisher-adjusted Dickey-Fuller (ADF) test to determine the stationarity of the panel data, and the results are in Table 3. The p-values of all the variables are less than 0.01. The null hypothesis that a unit root exists is rejected at the 1 percent significance level, indicating that the variable is stable.

4.2. Benchmark regression

The results of the benchmark regression are shown in Table 4, where information communication facilities, levels, and penetration rates all have positive effects on financial development.

After control variables and fixed effects are added, an increase of 1 percent in the number of post and telecommunications offices raises the level of financial development by 0.038 percent at a 1 percent level of significance, indicating that information communication facilities have a positive effect on financial development. And an increase of 1 percent in the number of telecommunications services boosts the level of financial development by 0.015 percent. In addition, an increase in the number of users with access to internet broadband by 1 percent raises the level of financial development by 0.033 percent. The continuous rise of communication services drives innovation in electronic trading systems and improves efficiency in financial transactions.

Information communication infrastructure, which provides technical support for network financial services, can alleviate financial exclusion caused by geographic factors and promote financial development. For all kinds of financial institutions, efficient information channels can be used to screen borrowers more effectively and identify borrowers who meet the loan conditions. Therefore, information communication can directly reduce information asymmetry between financial institutions and borrowers and promote efficient operations of funds. In addition, information communication can accelerate the innovation and supply of financial products, drive financial institutions to reduce transaction costs and improve risk control capabilities, and finally increase the service coverage and loan scale of financial institutions.

Table 3
The results of the unit-root test of urban data.

Variables and Results			
lnloan	670.630*** (0.000)	lnpop	1430.177*** (0.000)
lndeposit	786.421*** (0.000)	lndpop	8269.833*** (0.000)
lnsfs	783.726*** (0.000)	lnfix	1052.707*** (0.000)
lnpost	1298.437*** (0.000)	lnarea	3416.505*** (0.000)
lnts	1409.142*** (0.000)	lnrailway	756.206*** (0.000)
lniba	1136.547*** (0.000)	lnhighway	651.169** (0.019)
dlngdp	1285.021*** (0.000)	lnvol	622.532* (0.097)

Notes: ***, **, and * significant at 1%, 5%, and 10%, respectively.

5. Robustness test

5.1. Substituting explained variables

In the benchmark regression, the logarithm of loan balances in domestic and foreign currency for financial institutions is the explained variable. In Table 5, the explained variable is lndeposit in Columns (1)–(3) and lnsfs in Columns (4)–(6).

As shown in Columns (1) and (4) of Table 5, the increase in the number of post and telecommunications offices (lnpost) significantly raises the level of financial development.

The post and telecommunications offices represent urban infrastructure to a certain extent. A well-developed communication infrastructure provides convenient conditions for enterprises and households to increase their deposits and savings and helps financial institutions make loans more efficiently. Therefore, the increase in the number of post and telecommunications offices (lnpost) has a positive effect on the loan balances of financial institutions (lnloan) in Table 4, the deposit balances of financial institutions (lndeposit), and the increase in the social financing scale (lnsfs) in Table 5.

The results in Columns (2) and (5) of Table 5 show that the increase in the number of telecommunications services (lnts) does not affect the deposit balances (lndeposit) and the increase in the social financing scale (lnsfs). Telephone services account for the vast majority of telecommunications services as a whole. Before the rise of mobile banking, enterprises and households were more likely to make deposits directly at bank counters rather than through telephones. However, telephones to some extent enable financial institutions to understand the actual conditions for borrowers, which helps to reduce information asymmetry. Therefore, the increase in the number of telecommunications services (lnts)

Table 4
The results of benchmark regression.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Explained variable: lnloan					
lnpost	0.013	0.038**				
	(0.025)	(0.019)				
lnts			0.025	0.015*		
			(0.015)	(0.008)		
lniba					0.113***	0.033***
					(0.019)	(0.012)
dlngdp		−0.041		−0.018		−0.013
		(0.030)		(0.028)		(0.030)
lnpop		0.151***		−0.003		−0.002
		(0.028)		(0.008)		(0.007)
lndpop		0.004		−0.120		−0.098
		(0.016)		(0.110)		(0.110)
lnfix		0.065**		0.065***		0.061***
		(0.028)		(0.023)		(0.023)
lnarea		0.093**		−0.008		−0.007
		(0.047)		(0.008)		(0.008)
lnrailway		0.030**		0.014		0.016
		(0.014)		(0.012)		(0.011)
lnhighway		−0.071		0.078		0.081
		(0.062)		(0.050)		(0.051)
lnvol		0.094		−0.074		−0.078
		(0.068)		(0.061)		(0.062)
Constant	14.692***	11.657***	15.571***	15.470***	15.468***	15.438***
	(0.128)	(0.598)	(0.188)	(0.790)	(0.069)	(0.794)
Control	N	Y	N	Y	N	Y
Year fixed	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y
Obs.	3728	2482	2516	855	2515	855
R^2	0.938	0.938	0.847	0.903	0.852	0.903

Notes: The table shows the results of six regressions. The results in Columns (1), (3), and (5) are derived from the regression models without adding the control variables. The control variables are added to the regression models, with the results in columns (2), (4), and (6). ***, ** and * significant at 1%, 5%, and 10%, respectively.

does not change the deposit balances (lndeposit) and the increase in the social financing scale (lnsfs).

Furthermore, lniba is not significant for lndeposit but is significant for lnsfs in Columns (3) and (6) of Table 5. In the banking-dominated financial system in China, enterprises and households are still more likely to make deposits directly at bank counters, but the internet is often more used for financial investment activities. As the internet makes the dissemination of financial information more convenient and efficient, enterprises and households often use the internet to perform various financing activities. Through the interne, capital providers and demanders can search and match transaction information on network platforms and directly complete financial transactions. Therefore, the increase in the number of users with access to internet broadband (lniba) has a positive effect on the increase in the social financing scale (lnsfs).

5.2. Regression analysis based on provincial data

Due to the limitations on data disclosure, few disclosure indicators for information communication are available at the city level. But many indicators for information communication are disclosed at the provincial level. Therefore, for further testing we use panel data on 31 provinces (including provinces, autonomous regions, and municipalities directly under the central government) from 2000 to 2020.

Before performing empirical analysis, we describe the selection of variables as follows. First, explanatory variables mainly include the logarithm of mobile telephone exchange capacity at the provincial level (lnmtc-p), the logarithm of the number of telecommunications services at the provincial level (lnts-p), and the logarithm of the number of internet broadband access ports at the provincial level (lniap-p). These three explanatory variables measure information communication facilities, levels, and penetration rates separately. Second, the control variables are mainly derived from the provincial data, including GDP per capita (lnpgdp-p), population density (lndpop-p), built-up area (lncarea-p), investment in fixed assets (lnfix-p), real estate investment (lnreal-p), and general public budgetary expenditure (lnpbe-p). In addition, the data on the control variables require logarithmic processing. The Fisher-ADF test is used to conduct a unit-root test of panel data stationarity. The results of the unit-root test of provincial data are shown in Table 6, which shows that all the variables are stationary.

The results in Column (1) of Table 7 show that an increase of 1 percent in the mobile telephone exchange capacity (lnmtc-p) raises the level of financial development by 0.340 percent, indicating that information communication facilities have a

Table 5
Substitution of the explained variables.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Explained variable: lndeposit			Explained variable: lnsfs		
lnpost	0.037**			0.032*		
	(0.015)			(0.016)		
lnts		0.007			0.007	
		(0.007)			(0.007)	
lniba			0.009			0.022*
			(0.008)			(0.013)
dlngdp	−0.014	0.000	0.002	−0.023	−0.023	−0.021
	(0.019)	(0.019)	(0.019)	(0.022)	(0.025)	(0.024)
lnpop	0.060***	−0.010*	−0.010	0.105**	0.043	0.044
	(0.018)	(0.006)	(0.006)	(0.041)	(0.049)	(0.049)
lndpop	0.002	0.064	0.073	−0.005	−0.802	−0.790
	(0.010)	(0.078)	(0.079)	(0.012)	(0.663)	(0.659)
lnfix	0.079***	0.079***	0.078***	0.055***	0.058***	0.056***
	(0.019)	(0.020)	(0.020)	(0.017)	(0.016)	(0.016)
lnarea	0.075	0.006	0.006	0.156	0.038	0.038
	(0.051)	(0.006)	(0.006)	(0.104)	(0.047)	(0.048)
lnrailway	0.016	0.005	0.006	0.014*	0.003	0.004
	(0.010)	(0.008)	(0.008)	(0.008)	(0.006)	(0.007)
lnhighway	−0.053	0.059***	0.060***	−0.046	0.127***	0.129***
	(0.043)	(0.022)	(0.023)	(0.036)	(0.022)	(0.023)
lnvol	0.076*	−0.050*	−0.052*	0.063	−0.137***	−0.139***
Constant	12.594***	14.661***	14.668***	11.606***	18.985***	18.948***
	(0.555)	(0.549)	(0.559)	(1.028)	(3.299)	(3.288)
Control	Y	Y	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y
Obs.	2482	855	855	2481	855	855
R^2	0.975	0.938	0.938	0.959	0.799	0.800

Notes: ***, ** and * significant at 1%, 5%, and 10%, respectively.

Table 6
The results of the unit-root test of provincial data.

Variables and Results			
lnloan-p	85.1234** (0.027)	lndpop-p	169.710*** (0.000)
lnmtc-p	101.424*** (0.001)	lnfix-p	81.287* (0.000)
lnts-p	102.058*** (0.001)	lncarea-p	111.930*** (0.000)
lniap-p	113.820*** (0.000)	lnreal-p	149.795*** (0.000)
lnpgdp-p	86.617** (0.021)	lnpbe-p	82.623** (0.041)

Notes: ***, ** and * significant at 1%, 5%, and 10%, respectively.

significantly positive effect on the level of financial development. As an important network device, the mobile telephone switching system can expand a network and provide more connection ports. An increase in the mobile telephone exchange capacity (lnmtc-p) enables more mobile terminals to be connected, provides better conditions for the dissemination of network information, and improves efficiency in financial transactions. The results in Column (2) of Table 7 show that information communication, represented by the number of telecommunications services (lnts-p), is conducive to increases in financial development. Information communication is the technical basis for financial institutions to provide diversified financial services. It improves the coverage breadth and depth of financial services by continuously expanding the business of financial institutions. In addition, a similar result is obtained in Column (3) of Table 7. An increase of 1 percent in the number of internet broadband access ports (lniap-p) can boost the level of financial development by 0.158 percent. Because of the network effect of the internet, a transparent market environment provides convenience for the development of enterprises and is conducive to reducing their information collection costs and promoting financial development.

In the regression results of urban data, we use the logarithm of the number of post and telecommunications offices (lnpost), the logarithm of the number of telecommunications services (lnts), and the logarithm of the number of users with access to internet broadband (lniba) measure information communication facilities, levels, and penetration rates. The coefficients of lnpost, lnts, and lniba for lnloan are 0.038, 0.015, and 0.033 in Table 4, respectively.

In the regression results of the provincial data, we use the logarithm of mobile telephone exchange capacity (lnmtc-p), the logarithm of the number of telecommunications services (lnts-p), and the logarithm of the number of internet broadband access ports (lniap-p) to measure information communication facilities, levels, and penetration rates. In Table 7, the coefficients of lnmtc-p, lnts-p, and lniap-p for lnloan-p are 0.340, 0.166, and 0.158, respectively.

The regression coefficient of the provincial data is significantly larger than that of the urban data because provincial platforms can mobilize more financial resources to improve information communication infrastructure. Because a provincial

Table 7
Regression results of the provincial data.

Variables	(1) Explained variable: lnloan-p	(2)	(3)
lnmtc-p	0.340***		
	(0.081)		
lnts-p		0.166**	
		(0.063)	
lniap-p			0.158**
			(0.061)
lnpgdp-p	−0.088	−0.177	−0.197
	(0.099)	(0.142)	(0.168)
lndpop-p	−0.015	0.005	0.103
	(0.025)	(0.029)	(0.096)
lncarea-p	0.472***	0.481***	0.553*
	(0.136)	(0.172)	(0.295)
lnfix-p	0.062	0.126**	0.102
	(0.062)	(0.059)	(0.069)
lnreal-p	−0.020	0.007	0.012
	(0.041)	(0.034)	(0.027)
lnpbe-p	0.269***	0.425***	0.512**
	(0.094)	(0.133)	(0.189)
Constant	1.738	2.209*	0.963
	(1.053)	(1.196)	(2.501)
Control	Y	Y	Y
Year fixed	Y	Y	Y
City fixed	Y	Y	Y
Obs.	435	435	374
R^2	0.983	0.976	0.970

Notes: The table describes the regression results of the provincial data. The results are shown in Columns (1), (2), and (3), when the explanatory variable is lnmtc-p, lnts-p, and lniap-p, respectively. ***, **, and * significant at 1%, 5%, and 10%, respectively.

region often includes many cities, it can have more fiscal revenue, deposit and loan balances, social financing scales, infrastructure construction, transportation facilities, investment in fixed assets, and so on. As a province can obtain more resources, it can have more social funds and better infrastructure construction. In a provincial region, information communication can play a greater role in promoting financial development.

6. Further tests for endogeneity and heterogeneity

6.1. Instrumental variable regression

Before the rise of the internet, fixed-line (landline) phones and mobile phones were the leading media for communication. The distribution of post and telecommunications offices was also affected by the coverage of landlines to a certain extent. The number of landline phones as an instrumental variable (IV) met the requirement of correlation with explanatory variables. Moreover, landline phones have little impact on current financial development. Therefore, historical landline phones meet the requirement of exogeneity.

Following the literature (Nunn & Qian, 2014), the number of landlines per 100 people historically is used as an IV. Because this paper uses a panel data sample, the number of landline phones in a particular year cannot be included in the fixed effect model as a cross-section of data on a city.

Table 8
The results of instrumental variable regression.

Variables	(1) Explained variable: lnloan	(2)	(3)
lnpost	3.929***		
	(1.305)		
lnts		1.074***	
		(0.092)	
lniba			1.276***
			(0.096)
dlngdp	−0.972**	−0.808*	−0.250
	(0.439)	(0.446)	(0.181)
lnpop	−0.424	0.027	0.041
	(0.409)	(0.084)	(0.088)
lndpop	−1.225***	−0.482***	−0.549***
	(0.426)	(0.088)	(0.084)
lnfix	0.448***	0.426***	0.239***
	(0.150)	(0.057)	(0.070)
lnarea	−2.242***	−0.467***	−0.472***
	(0.685)	(0.089)	(0.090)
lnrailway	0.020	0.022	−0.036*
	(0.059)	(0.025)	(0.022)
lnhighway	0.054	−0.030	−0.576***
	(0.434)	(0.146)	(0.153)
lnvol	−0.397	0.084	0.722***
	(0.601)	(0.170)	(0.168)
Constant	23.198***	2.470***	13.573***
	(6.922)	(0.883)	(1.252)
Control	Y	Y	Y
Year fixed	Y	Y	Y
City fixed	Y	Y	Y
Obs.	606	606	606
R^2	0.784	0.843	0.837
First-stage regression			
Variables	lnpost	lnts	lniba
pphone	0.012***	0.044 ***	0.037***
	(0.004)	(0.000)	(0.000)
F-value	143.60	256.51	336.89

Notes: ***, ** and * significant at 1%, 5%, and 10%, respectively.

Therefore, the interaction term (expressed in Table 8 as pphone) between the number of landline phones per 100 people in 1996 and the revenue by the software and information service industry in the previous year is selected as the IV to mitigate endogenity problems.

6.2. Quasi-natural experiment

We use Propensity Score Matching and Difference-in-Difference (PSM-DID) analysis to ensure the robustness of the results and further mitigate endogeneity problems. On August 17, 2013, China's State Council announced the implementation of “Broadband China” strategy, including a comprehensive speed-up stage (at the end of 2013), a popularization stage (2014–2015) and an optimization stage (2016–2020). In the comprehensive speed-up stage, the government focuses on strengthening the construction of optical fiber networks and 3G networks, increasing the access rate of broadband networks, and improving and enhancing users' online experience. In the popularization stage, the government

focuses on expanding the coverage and scale of broadband networks and deepening their application and popularization. In the optimization stage, the government focuses on broadband network optimization and technology upgrading. To explore the impact of information communication on financial development, we use the implementation of "Broadband China" strategy as a shock event to conduct a quasi-natural experiment and consider the cities selected in batches during three consecutive years from 2014 to 2016 as the event period. Compared to the statistical indicators on information communication in all cities, it is relatively more exogenous to study the impact of information communication on financial development in pilot cities under the "Broadband China" strategy. After being selected as pilot cities, these cities have a greater ability to provide financial products and services through increasing the scale of infrastructure and the number of users with access to internet broadband.

We set treated-v as the treatment variable. Cities that are selected as pilot cities are assigned a value of 1; otherwise, 0. Then, we set time-v as the time variable. The value of time-v is 1 when the sample interval is in the full event period and the following year; otherwise, 0. In the PSM-DID analysis, the explanatory variable is treated-v, and the matched variable is the control variable that affects treated-v. The matched variables include urban GDP, population of permanent residents, population density, investment in fixed assets, built-up area, railway mileage in operation, highway mileage, and passenger-carrying capacity. The nearest-neighbor matching method is used in the PSM matching, and 1:1 backmatching is performed between the two groups with a radius of 0.05. Then, the matched samples are used for regression analysis.

Table 9
The results of PSM-DID regression.

Variables	(1)	(2)	(3)	(4)
	Explained variable: lnloan			
tr-ti	0.206***	0.178***	0.221***	0.229***
	(0.025)	(0.025)	(0.038)	(0.039)
dlngdp	−0.360***	−0.268***	−0.389***	−0.299**
	(0.120)	(0.095)	(0.136)	(0.116)
lnpop	0.132***	0.028	0.095*	−0.022
	(0.044)	(0.033)	(0.055)	(0.047)
lndpop	0.035	0.010	−0.019	−0.027
	(0.028)	(0.024)	(0.033)	(0.028)
lnfix	0.632***	0.538***	0.663***	0.593***
	(0.015)	(0.019)	(0.019)	(0.024)
lnarea	0.126***	0.136***	0.187**	0.271***
	(0.039)	(0.037)	(0.079)	(0.092)
lnrailway	0.070***	0.064***	0.038	0.032
	(0.020)	(0.019)	(0.028)	(0.026)
lnhighway	−0.090	0.069	−0.177	−0.030
	(0.117)	(0.089)	(0.166)	(0.137)
lnvol	0.151	−0.015	0.237	0.092
	(0.130)	(0.102)	(0.184)	(0.153)
Constant	2.822***	−46.944***	2.479***	−35.515***
	(0.400)	(6.167)	(0.595)	(7.728)
Control	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y
City fixed	Y	Y	Y	Y
Prov_Trend	N	Y	N	Y
PSM	N	N	Y	Y
Obs.	2485	2485	1096	1096
R^2	0.859	0.889	0.882	0.902

Notes: tr-ti is the interaction term of the treatment variable and the time variable. ***, ** and * significant at 1%, 5%, and 10%, respectively.

Columns (1) and (2) of Table 9 show the DID regression results for unmatched samples. The interaction term coefficients (0.206 and 0.178) are positive at the 1 percent significance level. In Columns (2) and (4) of Table 9, we add a time trend to control for the influence of unobservable factors at the province level. Columns (3) and (4) of Table 9 display the results of DID regression after PSM. The estimated coefficients (0.221 and 0.229) are still positive at the 1 percent significance level. Therefore, after the cities were selected as pilot cities for the "Broadband China" strategy, financial development significantly increased in these cities.

6.3. Heterogeneity analysis

6.3.1. Heterogeneity analysis of regions

China has considerable regional differences in the construction of information communication infrastructure and financial development, with unequal spatial distribution. Following the literature (Zhang & Qiao, 2016), we divide the 31 provinces into eight economic circles in Table 10, to conduct a heterogeneity analysis of regions.

In Table 11, lniba is chosen as the explanatory variable to study the impact of information communication on financial development in different economic circles, for two reasons. First, to avoid too miscellaneous empirical results of the eight economic circles after using three explanatory variables (lnpost, lnts and lniba), we choose only lniba to study the impact of information communication on financial development. Second, people frequently use the internet to complete financial operations, such as business applications and approvals, fund transfers and liquidation, and financial risk management, instead of post and telecommunications offices and telecommunications services. Therefore, this paper analyzes the influence of lniba on financial development in different economic circles using group regressions.

Table 10
Regional economic circles in China.

Acronym	Economic circle	Provinces in each economic circle
NwEC	Northwest Economic Circle	Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang
NeEC	Northeast Economic Circle	Liaoning, Jilin, and Heilongjiang
PRDEC	Pan-Pearl River Delta Economic Circle	Shanghai, Jiangsu, and Zhejiang
ECEC	East China Economic Circle	Anhui, Fujian, and Jiangxi
SEC	Southwest Economic Circle	Chongqing, Sichuan, Guizhou, Yunnan, and Tibet
CEC	Central Economic Circle	Henan, Hubei, Hunan, and Shandong
YRDEC	Pan-Yangtze River Delta Economic Circle	Guangdong, Guangxi, and Hainan
BHEC	Bohai Economic Circle	Beijing, Tianjin, Hebei, Shanxi, and Inner Mongolia

Table 11
The results of regional heterogeneity analysis.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Explained variable: lnloan							
	NwEC	NeEC	PRDEC	ECEC	SEC	CEC	YRDEC	BHEC
lniba	−0.105	0.046*	0.066*	0.006	0.041*	−0.001	0.027	0.013
	(0.094)	(0.023)	(0.034)	(0.019)	(0.020)	(0.068)	(0.035)	(0.036)
dlngdp	0.569	0.439*	−0.499*	−0.261	0.391*	0.341	−0.030	−0.270
	(0.368)	(0.231)	(0.290)	(0.225)	(0.196)	(0.335)	(0.047)	(0.368)
lnpop	1.875	−5.138*	−0.669	0.000	−4.838***	3.243	−1.403	−0.274**
	(2.537)	(2.751)	(1.346)	(0.009)	(0.776)	(2.008)	(1.484)	(0.130)
lndpop	−1.092**	2.741	−0.178	−0.642	4.504***	−1.197	−0.429	0.591
	(0.489)	(2.562)	(0.721)	(0.413)	(0.672)	(0.903)	(0.464)	(0.679)
lnfix	−0.008	0.082	0.021	0.349***	0.059	0.354*	0.061	0.005
	(0.047)	(0.084)	(0.031)	(0.093)	(0.076)	(0.174)	(0.049)	(0.099)
lnarea	−4.601	12.456***	−0.475	−0.530	4.388***	−1.100	−0.000	0.525
	(3.295)	(3.855)	(0.894)	(0.441)	(1.098)	(0.903)	(0.007)	(0.723)
lnrailway	0.222***	−0.011	−0.020	−0.002	0.019**	−0.080	0.022	−0.003
	(0.063)	(0.021)	(0.016)	(0.024)	(0.009)	(0.058)	(0.091)	(0.024)
lnhighway	0.248	−0.157	−0.081	0.211***	−0.011	0.159	−0.259	−0.012
	(0.213)	(0.388)	(0.151)	(0.069)	(0.086)	(0.189)	(0.330)	(0.056)
lnvol	−0.224	0.210	0.093	−0.196**	0.049	−0.189	0.251	0.075
	(0.220)	(0.418)	(0.168)	(0.076)	(0.102)	(0.219)	(0.378)	(0.076)
Constant	54.359	−88.539**	24.546***	19.177***	−24.384**	9.548	24.370**	9.149
	(35.254)	(39.103)	(6.418)	(6.803)	(11.434)	(9.470)	(9.967)	(10.332)
Control	Y	Y	Y	Y	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y	Y	Y
Obs.	52	98	118	154	133	90	129	81
R^2	0.915	0.953	0.895	0.961	0.952	0.936	0.921	0.951

Notes: The table shows the results of heterogeneity analysis of different economic circles: the Northwest Economic Circle (NwEC), the Northeast Economic Circle (NeEC), the Pan-Pearl River Delta Economic Circle (PRDEC), the East China Economic Circle (ECEC), the Southwest Economic Circle (SEC), the Central Economic Circle (CEC), the Pan-Yangtze River Delta Economic Circle (YRDEC), and the Bohai Economic Circle (BHEC). ***, **, and * significant at 1%, 5%, and 10%, respectively.

In Table 11, the impact of lniba on lnloan is significantly positive in the Northeast Economic Circle, the Pan-Pearl River Delta Economic Circle, and the Southwest Economic Circle. First, Column (2) of Table 11 shows that information communication has a significant positive impact on financial development in the Northeast Economic Circle. As this region is far from the developed coastal cities, the information communication infrastructure in this economic circle is imperfect. Compared to the results of benchmark regression in Table 4, the role of information communication in promoting financial development is more obvious in the Northeast Economic Circle. Second, Column (3) of Table 11 shows that information communication plays a significant role in the financial development of the Pan-Pearl River Delta Economic Circle. For every 1 percent increase in the number of internet users, the level of financial development rises by 0.066 percent. The Pan-Pearl River Delta Economic Circle includes Shanghai, Jiangsu, and Zhejiang. Shanghai is China's technology and financial center, with relatively high software and hardware support for information communication. So, availability of the internet can improve the loan business of financial institutions. In addition, Zhejiang has highly developed e-commerce resources, and Jiangsu has the forefront resources of integration of industry and education due to the large number of universities and research institutions. These two provinces have many supportive conditions and resources for driving development of the internet. With continuous expansion in the network effect and radiation scope, the number of users with access to internet broadband can raise the level of financial development. Third, the results in Column (5) of Table 11 show that information communications also play a significant role in promoting financial development in the Southwest Economic Circle. The Southwest Economic Circle includes Chongqing, Sichuan, and Guizhou. Both Chongqing and Sichuan are in the Chengdu-Chongqing area, with the Tianfu Data Center Cluster and Chongqing Data Center Cluster, which have advantages in the collaborative layout of data storage, transmission, and computing resources. In addition, Guizhou has had remarkable achievements in the integration of information communication and financial development. As of February 2022, Guizhou had formed 401 benchmark projects and 4234 demonstration projects for the integration of big data and the real economy. The integration of the digital internet and financial industry has become an important part of Guizhou's economic transformation and development.

6.3.2. Heterogeneity analysis of foreign investment levels

Foreign investment is essential for Chinese enterprises to raise funds and introduce technology (Zhuang et al., 2020).

Table 12
The results of heterogeneity analysis of foreign investment levels.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Explained variable: lnloan					
lnpost	0.041**			0.079***		
	(0.018)			(0.030)		
lnts		0.027**			0.025**	
		(0.010)			(0.010)	
lniba			0.027			0.026**
			(0.026)			(0.011)
dlngdp	0.033	−0.054***	−0.050***	−0.126***	−0.010	−0.002
	(0.073)	(0.017)	(0.016)	(0.047)	(0.035)	(0.040)
lnpop	0.072	0.919***	0.737***	0.150***	−0.004	−0.003
	(0.279)	(0.264)	(0.271)	(0.030)	(0.007)	(0.006)
lndpop	0.013	−0.628***	−0.507***	0.024	−0.123	−0.083
	(0.036)	(0.103)	(0.111)	(0.018)	(0.139)	(0.148)
lnfix	0.148**	0.027**	0.021*	0.093***	0.093***	0.095***
	(0.071)	(0.011)	(0.012)	(0.033)	(0.027)	(0.027)
lnarea	−0.003	−0.474***	−0.355**	0.059	−0.008	−0.008
	(0.326)	(0.124)	(0.136)	(0.049)	(0.006)	(0.006)
lnrailway	−0.000	0.026	0.023	0.020	−0.003	0.000
	(0.027)	(0.022)	(0.022)	(0.018)	(0.007)	(0.008)
lnhighway	0.112	0.144*	0.137*	−0.204*	0.026	0.031
	(0.131)	(0.079)	(0.083)	(0.117)	(0.054)	(0.055)
lnvol	−0.132	−0.156*	−0.152	0.242*	0.002	−0.003
	(0.155)	(0.093)	(0.098)	(0.128)	(0.060)	(0.062)
Constant	13.069***	18.712***	18.351***	11.002***	14.544***	14.474***
	(3.537)	(1.725)	(1.819)	(0.657)	(0.927)	(0.971)
Control	Y	Y	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y
Obs.	544	187	187	1938	668	668
R^2	0.934	0.928	0.926	0.943	0.913	0.913

Notes: The table can be divided between the first three columns and the last three columns. In columns (1), (2), and (3), the foreign investment level is higher than its mean value, and in columns (4), (5), and (6), the foreign investment level is lower than its mean value. ***, **, and * significant at 1%, 5%, and 10%, respectively.

When the foreign investment level is low, real enterprises can rely on fewer external capital sources. With the availability of foreign capital, foreign capital institutions compete with local financial institutions and effectively improve the market environment. Therefore, when foreign investment is low, information communication plays a more critical role in supporting the development of the real economy.

In our heterogeneity analysis of the foreign investment levels, the number of new contracts signed by foreign investors is used as a proxy for the foreign investment level, and its mean value is used for grouping regressions. The coefficients in Columns (4), (5), and (6) of Table 12 —0.079, 0.025, and 0.026, respectively—are higher than 0 at the 1 percent, 5 percent, and 5 percent significance levels, respectively. This indicates that the construction of perfect information communication infrastructure has a large marginal impact on financial development. Because of the continuous increase in foreign investment, enterprises can continuously expand related business and further promote financial development.

7. Conclusions

Based on panel data on 287 cities in China from 2000 to 2019, this paper discusses the impact of information communication on financial development on three dimensions: information communication facilities, levels, and penetration rates. Our conclusions are as follows.

First, information communication can significantly affect financial development. Specifically, the information communication facilities, represented by the number of post and telecommunications offices and the mobile telephone exchange capacity, reflect the underlying technical architecture and provide essential technical conditions for financial development. Moreover, information communication levels, represented by the number of telecommunications services, provide a basis for continuous innovation of financial products and services. The increase in the number of telecommunications services promotes further improvement in electronic trading systems and enhances the efficiency of financial transactions. Information communication penetration rates, represented by the number of users who have access to internet broadband and ports, provide various channels in which market participants to obtain information and financial services.

Second, after using the interaction term between the number of landlines per 100 people in 1996 and the revenue of the software and information service industry in the previous year as instrumental variables to alleviate endogeneity, information communication still significantly drives financial development.

Further, we use the "Broadband China" strategy as a shock to conduct a quasi-natural experiment. We show that the cities selected to pilot the "Broadband China" strategy can offer better financial products and services by increasing the scale of infrastructure and the number of users with access to internet broadband.

Third, the impact of information communication on financial development has heterogeneous characteristics, including regional heterogeneity and heterogeneity in foreign investment levels. With respect to regional heterogeneity, information communication has a significantly positive impact on financial development in the Northeast Economic Circle, the Pan-Pearl River Delta Economic Circle, and the Southwest Economic Circle. With regard to heterogeneity in foreign investment levels, the construction of perfect information communication infrastructure has a large marginal impact on financial development, especially in cities with low foreign investment.

Avenues for future research on the impact of information communication on financial development include the following. The first is a comparison of the spillover effect of information communication on financial development in different cities. Considering the differences in regional development in China, many cities have very different information communication facilities and technologies. The information communication level in a central city can easily have a siphon or diffusion effect on surrounding cities. Future research should further analyze these effects based on a spatial measurement model. The second research direction is the role of the external environment in the effect of information communication on financial development. Follow-up research should focus on whether stability in economic growth and the degree of policy uncertainty change the impact of information communication on financial development and discuss the possible influencing mechanism and transmission path of external uncertaint.

Declaration of competing interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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