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Digital Financial Inclusion, Digital Threshold, and Urban-Rural Income Gap

Submission ID	244115438
Article Type	Research Article
Keywords	digital financial; income gap; digital thresholds ; Employment effects; human capital
Authors	Hu Huang, xiangmin Li

Digital Financial Inclusion, Digital Threshold, and Urban-Rural Income Gap

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Abstract: This paper examines how digital financial inclusion affects the income gap between urban and rural residents, based on panel data from 30 Chinese provinces from 2011 to 2022. The study finds that digital financial inclusion significantly narrows the income gap between urban and rural areas. This reduction is mainly due to the extensive coverage and depth of usage of digital financial services. However, the overall process of digitalization has also led to increased income disparities. Mechanistic analysis shows that digital financial inclusion reduces the income gap by boosting employment, expanding non-farm job opportunities, and improving human capital in rural areas. Heterogeneity analysis identifies a "digital divide," with digital financial inclusion benefiting economically advanced Eastern regions more than the less developed Central and Western regions. To address this divide, the study introduces a digital threshold variable and finds that exceeding this threshold significantly enhances the effectiveness of digital financial inclusion in narrowing the urban-rural income gap. Therefore, it is crucial to boost investment in digital financial inclusion, ease financial regulations in less developed regions, promote innovation in financial products, and improve financial literacy among rural residents to fully realize the benefits of digital financial inclusion.

Keywords: digital financial; income gap; digital thresholds； Employment effects; human capital

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1. Introduction

As the world's largest developing country and home to the most impoverished, China faces significant challenges in addressing poverty, particularly in rural areas, which severely hampers balanced economic and social development. Since the reform and opening-up period, the Chinese government has made significant efforts in poverty alleviation, yielding remarkable results. In 2020, China announced that it had lifted all rural poor out of poverty according to the current standards. Over the past forty years, China has lifted nearly 800 million people out of poverty, representing about 75% of the global poverty reduction during this period. China's experience in poverty alleviation provides valuable lessons for other countries in their poverty reduction efforts. While absolute poverty has been eradicated, relative poverty remains a concern. In 2022, the per capita disposable income was 49283 yuan for urban residents and 20133 yuan for rural residents, resulting in an urban-rural income ratio of 2.45. Although this ratio has narrowed from 2.50 in 2021, a significant gap persists, underscoring the ongoing issue of urban-rural income inequality. Continuous advancements in technology, including big data, cloud computing, and artificial intelligence, have led to the emergence of digital inclusive finance. Compared to traditional finance, digital inclusive finance effectively reduces financial exclusion, improves financial resource allocation efficiency, and enhances access to financial services, providing crucial funding support for rural development. At this new stage of development, whether digital inclusive finance can narrow the urban-rural income gap, and how it can do so, remains a question that requires further investigation.

Digital inclusive finance, as a new form of financial service, is fundamentally a part of financial development. Thus, its impact on the income gap between urban and rural residents should be understood within the broader context of the relationship between financial development and income distribution. Current academic research explores this relationship from three main perspectives. The first focuses on the link between traditional financial development and income distribution. Some scholars argue that financial development reduces income inequality, with its positive impact growing as the economy develops (Xu and Wang, 2023). Conversely, others suggest

that financial development can worsen income inequality, as disadvantaged groups often have limited access to financial services (Akpa et al., 2024). Another view proposes that financial development follows an inverted U-shaped trajectory in its impact on income inequality (Vo et al., 2023). Initially, the income gap widens as disadvantaged groups face challenges related to family background and personal skills. However, as financial development progresses, improvements in contracts, markets, and intermediaries enhance inclusivity, which eventually reduces income inequality. The second perspective examines the relationship between inclusive finance and income distribution. Inclusive finance, formally introduced at the 2005 International Microfinance Conference, is a financial system that effectively and comprehensively provides services to all social strata, particularly low-income and impoverished groups. The relationship between inclusive finance and income distribution remains debated. Some researchers claim that inclusive finance enhances financial stability (Khan et al., 2022), which in turn reduces income inequality (Simon and Isabelle, 2018; Luo and Li, 2022; Chinoda and Mashamba,2021), with more significant effects observed in developing countries (Omar and Inaba, 2020). On the other hand, some scholars argue that institutional factors lead to a positive correlation between inclusive finance and income inequality (Wong et al., 2023). Additionally, others contend that the relationship between inclusive finance and income inequality is an inverted U-shape (Fitriatinnisa and Khoirunurrofik, 2021; Sun and Tu, 2023), with inequality initially widening but eventually narrowing over time (Huang and Zhang, 2019). The third perspective explores the relationship between digital inclusive finance and income distribution. Digital inclusive finance, introduced at the 2016 G20 Summit in Hangzhou, refers to promoting inclusive finance through digital financial services. This includes using digital technology to provide formal financial services to groups that lack access to or are underserved by traditional financial systems. Given its relatively recent emergence, research on the impact of digital inclusive finance on income disparity is still limited. Some scholars suggest that digital inclusive finance can reduce the income gap between urban and rural residents (Li et al., 2020), primarily by easing credit constraints, supporting rural entrepreneurship (Tao et al., 2023), and fostering agricultural

technological innovation (Zhang et al., 2024). Taking a micro-level perspective, others find an inverted U-shape relationship between digital inclusive finance and household income inequality (Hu et al., 2023), with the turning point occurring earlier in economically advanced regions. Furthermore, some researchers argue that differences in financial literacy, driven by varying education levels, create a digital divide. This divide hampers the positive effects of digital inclusive finance on rural residents' welfare, ultimately exacerbating the urban-rural income gap (Yao and Ma, 2022).

While existing literature provides a solid foundation for understanding the relationship between digital financial inclusion and the urban-rural income gap, certain gaps remain. First, many studies rely on overall indices for regression analysis, without considering the heterogeneity across different dimensions of these indices. Second, few studies include rural human capital accumulation in their analytical frameworks, missing the opportunity to closely examine its impact on the effectiveness of digital financial inclusion. Third, research has yet to fully explore how the digital divide influences the income distribution effects of digital financial inclusion.

This paper offers several potential contributions to the current body of research. First, it approaches the topic from a comprehensive and a detailed perspective, providing new insights into existing studies. Second, it investigates how digital financial inclusion can reduce income disparities between urban and rural areas, focusing on employment effects and rural human capital. This analysis includes both theoretical and empirical components. Finally, it introduces a digital threshold variable to assess how the digital divide influences the income convergence effects of digital financial inclusion.

The rest of the study is organized as follows: Section 2 outlines the theoretical framework and research hypotheses. Section 3 details the research design. Section 4 presents the results of the empirical analysis. Section 5 provides further discussion. Section 6 concludes with a summary of the results and provides relevant policy recommendations.

2. Theoretical analysis and research hypotheses

2.1 Direct effect channels

Digital financial inclusion can substantially reduce credit barriers and enhance access to financial services in rural areas (De Moraes et al., 2023). Traditional lending often requires rural residents to provide significant collateral, excluding many potential borrowers (Aiyar et al., 2015). By utilizing digital technologies such as big data, financial institutions can consolidate users' credit information, thereby reducing information asymmetries between lenders and borrowers (Cheng et al., 2024). This approach not only lowers credit barriers for rural populations but also facilitates the flow of capital into these areas, expanding the reach of financial services (Gutiérrez-Romero and Ahamed, 2021). Moreover, digital financial inclusion transcends traditional financial services' time and location constraints, thereby reducing transaction costs for rural residents. With mobile devices, users can access financial services online, streamline credit approval processes, minimize the need for physical branch visits, and lower the overall cost of financial services. Finally, digital financial inclusion drives financial innovation and increases the adoption of financial products among rural residents (Gong et al., 2023). Technologies such as the internet, cloud computing, and blockchain are advancing tools for investment, credit, and insurance, broadening the spectrum of available financial products. These innovations, tailored to the unique needs of rural areas, offer low-threshold, low-risk, and cost-effective financial solutions, thereby boosting the use of these products among rural populations.

H1: Digital financial inclusion can promote the convergence of income gaps between urban and rural residents.

2.2 Indirect effect channels

Digital financial inclusion reduces income disparities between urban and rural areas by increasing employment and expanding non-agricultural job opportunities. It eases financial constraints for businesses, promotes technological innovation, and facilitates production scaling (Chen and Guo,2023), thereby generating additional employment opportunities. Small and micro enterprises, essential for job creation, frequently face significant financing challenges due to insufficient collateral and difficulties in credit assessment (Zhang et al., 2023), which hinder their long-term growth. Digital financial inclusion expands financing options for these enterprises and

disadvantaged groups by providing access to formal financial services. This alleviates financial difficulties, fosters development and innovation (Li and Pang, 2023), enhances production efficiency (Abbasi et al., 2021), and creates more job opportunities. Additionally, digital financial inclusion promotes rural entrepreneurship (Tao et al., 2022; Yang et al.,2022) and supports the transformation of rural industries. China's dual economic structure has led to a significant imbalance in financial resources between urban and rural areas, resulting in inadequate funding for rural development. Digital financial inclusion addresses this imbalance by providing affordable, inclusive financial services, and ensuring sufficient resources for rural development. It fosters rural entrepreneurship, supports industry specialization, and generates non-agricultural jobs locally (Ren et al., 2023). Finally, digital financial inclusion facilitates smoother labor mobility between urban and rural areas, thereby improving non-agricultural employment. Rural workers migrating to cities often face frictional unemployment during job searches, which incurs costs for communication, transportation, and accommodation. Digital financial inclusion can provide short-term, interest-free working capital to help rural migrants overcome initial financial barriers, thereby increasing their likelihood of securing employment in urban areas. Considering these observations, Hypothesis 2 is proposed.

H2: Digital financial inclusion reduces income disparities between urban and rural residents by boosting overall employment and expanding non-farm job opportunities.

Digital financial inclusion reduces the income gap between urban and rural residents by enhancing the development of human capital in rural areas. It promotes increased investment in education among rural residents. Improving access to financial services such as savings, credit, and investments, expands income opportunities and facilitates greater investment in children's education. For instance, loans can be used by rural residents to support higher education and vocational training, thereby enhancing their skills and knowledge. Moreover, digital financial inclusion results in increased healthcare spending in rural areas. Since health is a crucial component of human capital, expanded financial inclusion raises health awareness and encourages greater investment in healthcare. Digital financial services offer rural residents access to health

insurance, medical advice, and healthcare services, improving overall health and strengthening human capital within these communities. Based on these findings, Hypothesis 3 is proposed.

H3: Digital financial inclusion reduces the income gap between urban and rural residents by improving human capital in rural areas.

3. Research design

3.1 Sample Selection

Given the availability of digital data, this study utilizes annual data from 30 provinces in China (excluding Tibet) for the period from 2011 to 2022. The data is sourced from the National Bureau of Statistics, provincial statistical bureaus, the China Statistical Yearbook, and the Digital Finance Research Center at Peking University.

3.2 Variable Definition

3.2.1 Dependent variable

The dependent variable in this study is income inequality, primarily focused on the disparity between urban and rural residents. Existing literature employs three indicators to measure urban-rural income inequality: the ratio of urban to rural per capita disposable income, the Gini coefficient, and the Theil index. The ratio of disposable income per capita, as a static measure, overlooks the population distribution in urban and rural areas, failing to account for population mobility and income dynamics. The Gini coefficient gauges overall income distribution inequality but is more sensitive to changes in middle-class incomes, making it less effective in capturing urban-rural income disparities. The Theil index, however, is more responsive to changes in high and low-income groups, aligning better with the research objectives of this paper. Therefore, the Theil index is selected as the core indicator for measuring income inequality. Referring to (Casilda and Casilda,2013), the calculation formula is as follows:

$$Theil_{i,t} = \sum_{J=1}^{2} \left[\frac{P_{ij,t}}{P_{i,t}}\right] ln\left[\frac{P_{ij,t}}{P_{i,t}} \Big/ \frac{Z_{ij,t}}{Z_{i,t}}\right] \quad (1)$$

Where j=1,2 denotes urban and rural areas respectively, $Z_{i,t}$ represents the total population of region i in year t, $Z_{ij,t}$ indicates the urban or rural population, $P_{i,t}$

represents the total disposable income of the region, $P_{ij,t}$ presents the total disposable income of the urban or rural residents. The region's total income is calculated by multiplying the population of the region by the per capita disposable income.

3.2.2 Independent variable

The Digital Financial Inclusion Index (Dfi) released by the Digital Finance Research Center of Peking University is chosen as the explanatory variable of this paper (Guo et al.,2020), which mainly includes three dimensions, breadth of coverage, depth of use, and degree of digitization. The breadth of digital financial inclusion measures the coverage of digital financial services, the more people have access to digital financial inclusion, the higher the breadth of coverage; the depth of digital financial inclusion measures the degree of use of digital financial services by residents, the higher the amount of use, the greater the intensity of use, the deeper the depth of development; the degree of digitization measures the degree of convenience brought by digital financial inclusion, the lower the cost and the more convenient the digitalization, the higher the degree of convenience brought by digital financial inclusion.

3.2.3 Mechanism variable

This paper investigates the impact mechanisms through two key areas: employment effects and rural human capital development. Employment effects are evaluated by overall employment and non-farm employment. Overall employment is determined by the number of urban jobs at year-end in each region. In contrast, non-farm employment is measured by the ratio of jobs in the secondary and tertiary sectors to total employment. Rural human capital development is assessed by combining per capita expenditures on healthcare and education among rural residents.

3.2.4 Control variable

This study considers five control variables relevant to the income disparity between urban and rural residents: regional per capita GDP (Pgdp), urbanization level (Urban), fiscal expenditure (Fe), regional education level (Edu), and the extent of openness to foreign trade (Open). Specific definitions of these variables can be found in Table A. 1.

3.3 Model Construction

$$Theil_{i,t} = \alpha_0 + \alpha_1 Dfi_{i,t} + \alpha_2 Control_{i,t} + + \beta_i + \gamma_t + \varepsilon_{i,t} \quad (2)$$

where i is the province, t is the year, and $Theil_{i,t}$ represents the urban-rural income gap, $Dfi_{i,t}$ is the digital financial inclusion index, and $Control_{i,t}$ represents the control variables, and β_i represents province fixed effects, and γ_t represents year fixed effects, $\varepsilon_{i,t}$ represents the random interference term.

4.1 Descriptive statistics

In the empirical analysis, to ensure the stability of the model, logarithmic transformations were applied to the Digital Financial Inclusion Index (Dfi), coverage breadth (Coverage), usage depth (Depth), digitization level (Digitization), regional per capita GDP (Pgdp), regional total employment (Employ), rural human capital expenditure (Humanexp), and the instrumental variable (Distancedfi). After a rigorous selection process, we obtained 360 valid research samples and identified 15 key variables. The descriptive statistics for the main variables are presented in Table 1.

Table 1 Descriptive statistics

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	Mean	Sd	Min	Max
Theil	360	0.0845	0.0384	0.0145	0.202
Dfi	360	5.338	0.666	2.910	6.130
Coverage	360	5.216	0.813	0.670	6.120
Depth	360	5.312	0.645	1.910	6.240
Digitization	360	5.599	0.667	2.030	6.150
Urban	360	0.601	0.121	0.350	0.900
Pgdp	360	10.87	0.461	9.680	12.15
Edu	360	9.415	1.023	7.510	12.68
Fe	360	0.259	0.111	0.105	0.758
Open	360	0.110	0.158	0.0001	0.944
Employ	360	6.091	0.769	4.100	7.650
Nonemp	360	0.695	0.149	0.330	0.980
Humanexp	360	7.567	0.507	6.060	8.400
Digthr	360	1.026	0.244	0.519	1.878
Distancedfi	360	8.263	1.668	0	9.848

4.2 Benchmark regression

Table 2 presents the baseline regression results. Column (1) displays the results of the Digital Financial Inclusion Index. After accounting for individual and time effects, it is found that advancements in digital financial inclusion significantly narrow the

income gap between urban and rural residents, with results statistically significant at the 1% level. Specifically, a 1% increase in digital financial inclusion is associated with a 0.00007-unit reduction in the income gap, validating Hypothesis 1. Columns (2) through (4) show the regression results for coverage breadth, usage depth, and digitization level. Coverage breadth and usage depth are both significantly effective in reducing the income gap between urban and rural residents. Conversely, a higher level of digitization seems to exacerbate the income gap. This may be due to the increased complexity of financial services with more digitization. Rural residents, who generally have lower financial literacy, tend to use digital financial services less frequently than their urban counterparts, leading to a counterintuitive widening of the income gap.

Table 2 Benchmark regression

	(1)	(2)	(3)	(4)
VARIABLES	Theil	Theil	Theil	Theil
Dfi	-0.007***			
	(0.003)			
Coverage		-0.004***		
		(0.001)		
Depth			-0.008***	
			(0.002)	
Digitization				0.008***
				(0.001)
Urban	-0.227***	-0.223***	-0.230***	-0.222***
	(0.019)	(0.019)	(0.018)	(0.018)
Pgdp	-0.008	-0.006	-0.012**	-0.012**
	(0.005)	(0.005)	(0.005)	(0.005)
Edu	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Fe	0.063***	0.063***	0.057***	0.063***
	(0.011)	(0.011)	(0.011)	(0.010)
Open	-0.018***	-0.018***	-0.017***	-0.016**
	(0.007)	(0.007)	(0.007)	(0.006)
Constant	0.330***	0.295***	0.379***	0.315***
	(0.050)	(0.049)	(0.050)	(0.048)
Observations	360	360	360	360
R-squared	0.942	0.944	0.945	0.946
Number of provinces	30	30	30	30
Province FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: ***, **, and * denote that the coefficient is statistically significant at the 1%, 5%, and 10% levels, respectively, and standard errors are in parentheses.

4.3 Endogeneity test

In addition to the control variables selected for this study, there are numerous other variables affecting the income gap between urban and rural residents that are not included in the analysis framework, leading to the issue of omitted variables. Digital financial inclusion can influence the income gap, while an expanding income gap may also exacerbate the digital divide, affecting the development of digital financial inclusion. This suggests a potential bidirectional causality, which could introduce endogeneity issues and weaken the robustness of the study's conclusions.

To address the endogeneity issue, this study employs the instrumental variable (IV) approach. The spherical distance from each provincial capital city to Hangzhou is chosen as the instrument. Alibaba, a leading company in China's digital financial inclusion sector, is based in Hangzhou, and the digital financial inclusion index used in this study is derived from Alipay data. Research indicates that the extent of digital financial inclusion is related to the distance from Hangzhou, thus the distance to Hangzhou affects the development of digital financial inclusion, satisfying the relevance condition for the instrument. Additionally, the distance from each provincial capital to Hangzhou does not change with economic or social fluctuations. By multiplying the spherical distance data with the annual provincial-level digital financial inclusion index average, the overall national level of digital financial inclusion influences provincial development. Thus, the product of these two variables is used as an instrumental variable for digital financial inclusion.

Table 3 displays the results of the instrumental variable regressions. Column (1) shows the results for the Digital Financial Inclusion Index, where the LM statistic is 29.901, rejecting the identification test, and the Cragg-Donald Wald F statistic is 31.186, indicating the instrument is effective according to the weak instrument test. The coefficient for the impact of digital financial inclusion on the income gap between urban and rural residents is -0.022, statistically significant at the 5% level. Columns (2) through (4) present the instrumental variable regression results for coverage breadth,

usage depth, and digitization level. The sign of the coefficients remains consistent with the baseline regression results, suggesting the robustness of the study's conclusions. Compared to the baseline regression, the coefficients in the instrumental variable regressions are higher, indicating that endogeneity issues led to an underestimation of the impact of digital financial inclusion on the income gap. This implies that bidirectional causality and measurement errors are major contributors to endogeneity.

Table 3 Endogeneity test

	IV			
VARIABLES	(1)	(2)	(3)	(4)
	Theil	Theil	Theil	Theil
Dfi	-0.022**			
	(0.009)			
Coverage		-0.013**		
		(0.005)		
Depth			-0.019**	
			(0.008)	
Digitization				0.015***
				(0.006)
Urban	-0.210***	-0.197***	-0.223***	-0.211***
	(0.022)	(0.026)	(0.020)	(0.020)
Pgdp	-0.005	0.001	-0.016***	-0.015***
	(0.005)	(0.007)	(0.006)	(0.005)
Edu	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Fe	0.063***	0.063***	0.047***	0.062***
	(0.011)	(0.012)	(0.013)	(0.011)
Open	-0.004	-0.004	-0.006	-0.008
	(0.010)	(0.011)	(0.010)	(0.009)
Observations	360	360	360	360
R-squared	0.936	0.930	0.936	0.942
Number of provinces	30	30	30	30
Province FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: ***, **, and * denote that the coefficient is statistically significant at the 1%, 5%, and 10% levels, respectively, and standard errors are in parentheses.

4.4 Mechanism testing

Table 4 presents the regression results of the mechanism tests. This study explores the impact of digital inclusive finance through two key dimensions: employment effects and rural human capital accumulation. The analysis of employment effects, which includes both total employment and non-agricultural employment, is provided in columns (1) and (2). The impact of digital inclusive finance on the urban-rural income gap consistently indicates a reduction in disparity. However, the positive regression coefficients for the interaction between total employment, non-agricultural employment, and digital inclusive finance suggest a more significant effect in regions with lower employment levels and a smaller share of non-agricultural jobs. This implies that digital inclusive finance more effectively reduces the income gap in areas with lower overall employment and fewer non-agricultural jobs, thereby enhancing its role in promoting employment and increasing non-agricultural opportunities. Column (3) presents the findings related to rural human capital accumulation. Similarly, the influence of digital inclusive finance is stronger in regions with lower levels of rural human capital. Consequently, the pathways through which digital inclusive finance enhances employment, increases non-agricultural job opportunities, and promotes rural human capital accumulation are validated, confirming Hypotheses 2 and 3.

Table 4 Mechanism testing

	(1)	(2)	(3)
VARIABLES	Theil	Theil	Theil
Dfi	-0.015***	-0.010***	-0.050***
	(0.003)	(0.002)	(0.008)
Employ	-0.015***		
	(0.004)		
Dfi×employ	0.002***		
	(0.000)		
Nonemp		-0.198***	
		(0.020)	
Dfi×nonemp		0.033***	
		(0.004)	
Humanexp			-0.043***
			(0.007)
Dfi×humanexp			0.008***
			(0.001)
Urban	-0.233***	-0.186***	-0.205***

	(0.019)	(0.018)	(0.019)
Pgdp	-0.009*	0.000	-0.005
	(0.005)	(0.004)	(0.005)
Edu	-0.001	-0.001*	-0.001
	(0.001)	(0.001)	(0.001)
Fe	0.047***	0.070***	0.059***
	(0.011)	(0.009)	(0.010)
Open	-0.016**	0.003	-0.019***
	(0.007)	(0.006)	(0.007)
Constant	0.417***	0.282***	0.538***
	(0.053)	(0.044)	(0.061)
Observations	360	360	360
R-squared	0.946	0.956	0.948
Number of provinces	30	30	30
province FE	YES	YES	YES
Year FE	YES	YES	YES

Note: ***, **, and * denote that the coefficient is statistically significant at the 1%, 5%, and 10% levels, respectively, and standard errors are in parentheses.

4.5 Regional heterogeneity

Table 5 shows the results of the regional heterogeneity analysis, which divides the 30 provinces into three geographic regions: Eastern, Central, and Western. In the Eastern region, digital inclusive finance significantly narrows the income gap between urban and rural residents. Conversely, in the Central region, digital inclusive finance has exacerbated the income gap. This may result from the rapid expansion of digital finance combined with notable disparities in education and financial literacy between urban and rural areas. The greater benefits for more advantaged groups, coupled with limited impact on disadvantaged rural residents, have contributed to increased polarization and income inequality. In the Western region, although the impact of digital inclusive finance on the urban-rural income gap is not statistically significant, it remains negative. The comparison reveals that the impact of digital inclusive finance on the urban-rural income gap varies significantly across regions, illustrating a digital divide. The effect is most pronounced in the more developed Eastern region.

Table 5 Regional heterogeneity regression

	(1)	(2)	(3)
VARIABLES	Theil	Theil	Theil

	East	Mid	West
Dfi	-0.009*	0.019***	-0.007
	(0.005)	(0.007)	(0.004)
Urban	-0.198***	-0.250***	-0.046
	(0.018)	(0.037)	(0.044)
Pgdp	-0.010	-0.001	-0.035***
	(0.006)	(0.007)	(0.009)
Edu	0.000	-0.003	0.003
	(0.001)	(0.002)	(0.002)
Fe	0.004	-0.004	0.007
	(0.016)	(0.025)	(0.016)
Open	-0.006	-0.145***	0.020
	(0.006)	(0.030)	(0.023)
Constant	0.341***	0.193**	0.518***
	(0.069)	(0.079)	(0.091)
Observations	132	96	132
R-squared	0.946	0.979	0.973
Number of provinces	11	8	11
province FE	YES	YES	YES
Year FE	YES	YES	YES

Note: ***, **, and * denote that the coefficient is statistically significant at the 1%, 5%, and 10% levels, respectively, and standard errors are in parentheses.

4.6 Robustness testing

This study utilizes data trimming, the Generalized Method of Moments (GMM), and Limited Information Maximum Likelihood (LIML) methods for the robustness check. Table 6 displays the results of these robustness checks, with Columns (1) through (3) showing the regression outcomes from data trimming, GMM, and LIML, respectively. The results confirm that digital inclusive finance consistently reduces the income gap between urban and rural residents, thereby reinforcing the robustness of the study's conclusions.

Table 6 Robustness testing

VARIABLES	(1) Winsor Theil	(2) Gmm Theil	(3) Liml Theil
Dfi	-0.007**	-0.004**	-0.022***
	(0.003)	(0.002)	(0.008)
Urban	-0.236***	-0.205***	-0.210***
	(0.019)	(0.020)	(0.021)

Pgdp	-0.006	0.011**	-0.005
	(0.005)	(0.005)	(0.005)
Edu	-0.001	-0.002**	-0.001
	(0.001)	(0.001)	(0.001)
Fe	0.070***	0.088***	0.063***
	(0.011)	(0.009)	(0.011)
Open	-0.019***	-0.053***	-0.004
	(0.007)	(0.009)	(0.010)
Constant	0.315***	0.128***	0.356***
	(0.052)	(0.045)	(0.052)
Observations	360	360	360
Number of provinces	30	30	30
province FE	YES	YES	YES
Year FE	YES	YES	YES

Note: ***, **, and * denote that the coefficient is statistically significant at the 1%, 5%, and 10% levels, respectively, and standard errors are in parentheses.

4.7 Extended analysis: the digital threshold effect

The regional heterogeneity analysis shows that digital inclusive finance more effectively narrows the income gap between urban and rural residents in the Eastern region, highlighting a digital divide between developed and less developed areas. This digital divide may establish a threshold that limits the effectiveness of digital inclusive finance in addressing the misallocation of financial resources between urban and rural areas, thus diminishing its impact on reducing the income gap. Consequently, a panel threshold model is developed to examine the effect of this digital threshold on the impact of digital inclusive finance on the urban-rural income gap.

The panel threshold model is as follows:

$$Theil_{i,t} = \alpha_0 + \alpha_1 Dfi_{i,t} I(q_{i,t} < h) + \alpha_2 Dfi_{i,t} I(q_{i,t} \gg h) + \alpha_3 Control_{i,t} + \beta_i + \gamma_t + \varepsilon_{i,t} \quad (3)$$

Where I denotes the indicator function, h represents the threshold, and the definitions of the other variables are consistent with those used in the benchmark regression.

Table 7 shows the results of the digital threshold test, where the mobile phone ownership rate is used as the threshold variable to evaluate its impact on the convergence effect of digital inclusive finance. The analysis also includes regressions of secondary dimension indices for digital inclusive finance. The findings indicate that

the mobile phone ownership rate influences the convergence effect of digital inclusive finance on the urban-rural income gap, with a significant threshold identified at a rate of 1.0484. The mobile phone ownership rate also shows a single threshold effect for various dimensions of digital inclusive finance. Specifically, the threshold values are 1.0484 for coverage and digitalization extent, and 1.0425 for usage depth.

Table 7 Digital threshold test

Variables	Threshold type	F-statistic	P-value	Threshold value	Lower	Upper
Dfi	Single Threshold	29.36*	0.077	1.0484	1.0420	1.0489
Coverage	Single Threshold	29.97*	0.073	1.0484	1.0420	1.0489
Depth	Single Threshold	27.08*	0.090	1.0425	1.0391	1.0427
Digitization	Single Threshold	23.80*	0.080	1.0484	1.0415	1.0489

Note: ***, **, and * denote that the threshold is statistically significant at the 1%, 5%, and 10% levels.

Table 8 shows how digital inclusive finance affects the urban-rural income gap before and after surpassing the threshold. Before crossing the threshold, the coefficient indicating its effect on the income gap was -0.009. After exceeding the threshold, this coefficient was -0.010. Both coefficients are statistically significant at the 1% level. This finding suggests that digital inclusive finance's ability to reduce the income gap improves after surpassing the threshold. Specifically, the dimensions of coverage breadth and usage depth have a greater impact on narrowing the income gap after crossing the threshold. While the effect of digitalization level on the income gap continues to be positive, its widening effect has diminished. This suggests that digital inclusive finance, when delivered through mobile phones, becomes more effective in bridging the digital divide as mobile phone ownership rises. This facilitates the dissemination of digital technology to remote rural areas, thereby supporting the growth of digital inclusive finance and improving its effectiveness in reducing the income gap.

Table 8 Digital threshold regression results

	(1)	(2)	(3)	(4)
VARIABLES	Theil	Theil	Theil	Theil
Dfi(I<1.0484)	-0.009***			
	(0.003)			
Dfi (I≥1.0484)	-0.010***			
	(0.003)			

Coverage (I<1.0484)		-0.004***		
		(0.001)		
Coverage (I≥1.0484)		-0.005***		
		(0.001)		
Depth(I<1.0425)			-0.008***	
			(0.002)	
Depth(I≥1.0425)			-0.009***	
			(0.002)	
Digitization(I<1.0484)				0.008***
				(0.001)
Digitization (I≥1.0484)				0.007***
				(0.001)
Urban	-0.204***	-0.201***	-0.208***	-0.206***
	(0.019)	(0.018)	(0.018)	(0.018)
Pgdp	-0.016***	-0.014***	-0.021***	-0.020***
	(0.005)	(0.005)	(0.005)	(0.005)
Edu	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Fe	0.053***	0.053***	0.047***	0.054***
	(0.011)	(0.010)	(0.010)	(0.010)
Open	-0.018***	-0.018***	-0.018***	-0.017***
	(0.007)	(0.006)	(0.006)	(0.006)
Constant	0.415***	0.376***	0.465***	0.387***
	(0.051)	(0.050)	(0.051)	(0.049)
Observations	360	360	360	360
Number of provinces	30	30	30	30
R-squared	0.947	0.948	0.949	0.950
province FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: ***, **, and * denote that the coefficient is statistically significant at the 1%, 5%, and 10% levels, respectively, and standard errors are in parentheses.

5. Further discussion

Financial resources are central to driving economic growth and shaping income distribution in modern societies. Traditional financial systems, which typically demand collateral and credit history, disadvantage rural residents in accessing credit, thereby worsening income inequality between urban and rural areas in China (Xu et al., 2022). The advancement of digital technology has provided traditional finance with new development opportunities, giving rise to digital inclusive finance. This emerging form of finance has broadened access to financial services (Yang et al., 2023), reduced

financial exclusion, and promoted inclusive growth (Shen et al., 2019; Demir et al., 2020). The rise of digital inclusive finance mitigates rural financial repression, raises rural income levels, and consequently narrows the income gap (Ozili, 2018; Shang, 2023; Liu and Guo, 2023). Digital inclusive finance reduces income inequality by encouraging household entrepreneurship (Hao and Zhang, 2024; Song et al., 2024), fostering industry integration (Wang et al., 2024; Yang et al., 2024), enhancing financial service efficiency (Adugna, 2024), and creating more employment opportunities for rural residents (Fu et al., 2024). Although previous studies have examined the relationship between digital inclusive finance and the urban-rural income gap, further in-depth analysis is required. This paper provides a comprehensive analysis of the aggregate effects of digital inclusive finance from both general and structural perspectives. It reveals that not all factors contribute to narrowing the urban-rural income gap. While broader coverage and deeper usage help reduce the gap, a higher degree of digitization can widen it. This occurs because increased digitization often complicates financial services, and rural residents, with generally lower financial literacy, use these services less frequently than urban residents. Since digitization also measures the cost of using digital inclusive finance, higher usage frequency results in lower costs. By integrating digital inclusive finance with employment effects, human capital accumulation, and the urban-rural income gap into a single analytical framework, this study identifies the mechanisms through which employment and human capital accumulation influence the convergent effects of digital inclusive finance. Contrary to some studies (Lai et al.,2020; Sodokin et al.,2023), this paper demonstrates that the effects of digital inclusive finance are more pronounced in more developed regions, underscoring the presence of a digital divide. Therefore, this study introduces a digital threshold variable to further examine its impact on the urban-rural income gap. The findings suggest that the effects of digital inclusive finance are further amplified once this digital threshold is surpassed.

This study recognizes certain limitations. First, this paper utilizes the Digital Inclusive Finance Index developed by Peking University to assess the growth of digital inclusive finance in China. However, this index primarily depends on data from Alipay,

a single digital financial platform among many others. Alipay's data mainly reflects demand-side trends across different regions and does not include information on large corporations or significant enterprises. As a result, the index may not be fully compatible with data from large companies and might not provide a complete picture of the overall development of digital inclusive finance. Second, limitations in macroeconomic data mean that current statistics do not adequately represent the development of rural areas. This shortcoming hampers evaluating how digital inclusive finance impacts income disparities in rural regions. Finally, the heterogeneity analysis in this paper examines regional variations in the influence of digital inclusive finance on the income gap between urban and rural residents. However, it does not consider whether these effects exhibit threshold behavior across different regions. Future research will explore this dimension.

6. Conclusions and recommendations

6.1 Main conclusions

The key findings are: First, digital inclusive finance reduces the urban-rural income gap. This conclusion holds even after various robustness checks. Second, the mechanism analysis indicates that digital inclusive finance reduces the income gap by boosting employment, increasing non-agricultural jobs, and fostering rural human capital development. Third, the analysis of regional differences highlights a digital divide in the effectiveness of digital inclusive finance. Fourth, a digital threshold variable, based on mobile phone ownership rates, was introduced to address the digital divide. The results indicate that when digital inclusive finance exceeds this threshold, its effectiveness in reducing the income gap is further enhanced.

6.2 Policy recommendations

The advancement of digital inclusive finance demands continuous and proactive efforts. The swift progression of digital technology has established the digital economy as an unstoppable trend, with future innovations poised to bring substantial breakthroughs. Identifying the convergence points between digital technology and inclusive finance, while accounting for their evolving nature, is essential. This strategy will deepen the integration of digital technology with inclusive finance, thereby

fulfilling the potential of digital inclusive finance by improving its accessibility and affordability.

Financial institutions should be incentivized to innovate and broaden the variety of financial products available in rural regions. Thorough research to understand the unique financial needs of rural residents is essential. Providing accessible and varied financial products that meet these specific needs is vital. In underdeveloped areas, efforts like reducing loan interest rates, simplifying approval processes, and innovating financial services to enhance credit efficiency and lower access barriers.

Appendix：

Table A. 1 Definitions of Variables

Nature of the variable	Level 1 indicators	Secondary indicators	Quantitative standard
Dependent variable	Income gap between urban and rural residents (Theil)		Obtained through data collection calculations
Independent variable	Level of development of digital financial inclusion (Dfi)	Breadth of coverage Depth of use Degree of digitization	Reference to the Digital Inclusive Finance Index System compiled by the Digital Finance Research Center of Peking University
Control variable	Gross national product per capita (Pgdp)		GDP at the end of the year/ resident population at the end of the year for each province and municipality
	Urbanization rate (Urban)		Proportion of regional urban population to the total regional population
	Fiscal expenditure (Fe)		Fiscal expenditure as a share of regional GDP
	Regional level of education (Edu)		Average number of years of schooling of the population aged 6 years and over Average number of years of schooling at age 6 and above = [number of people not attending school * 0 + number of elementary school * 6 + number of junior high schools * 9 + number of senior high schools * 12 + (colleges + universities + postgraduate students) * 16] / number of

		people aged 6 and above
	Degree of openness to the outside world (Open)	Total import and export of foreign-invested enterprises as a share of regional GDP
Mechanism variables	Total employment (Employ)	Total urban employment
	Structure of non-farm payrolls (Nonemp)	Nonfarm payrolls/total regional employment
	Rural human capital (Humanexp)	Expenditures on education and health
Threshold variables	Digital threshold (Digthr)	Number of mobile cellular subscribers/total regional population
Instrumental variable	Geographic distance (Dis)	Spherical distance from home city to Hangzhou

Acknowledgments

This work was supported by the Yunnan Provincial Department of Education Funding (2024Y505)

Author contributions

Hu Huang: Conceptualization, Writing-review & editing, Data curation, Formal analysis. Xiangmin Li: Writing-review & editing, Data curation, Formal analysis.

Data availability statement

The data that support the findings of this study are available from the corresponding author, [HuHuang], uponreasonable request.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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