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Can digital finance drive urban–rural integration?

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ABSTRACT

Financial services are an essential source of capital and play a crucial and significant role in urban–rural integration. We analyse empirically the effect of digital finance on urban–rural integration and its mechanism using provincial panel data in China for 2011–2020. The results indicate that digital finance contributes to urban–rural integration. Moreover, for every 1 standard deviation increase in digital finance development, the degree of urban–rural integration increases by 7.7% on average, and it is more evident in China's eastern regions, with regional heterogeneity. The level of entrepreneurship can be a vital channel for digital finance to facilitate urban–rural integration. The mechanism of action of digital finance to facilitate urban–rural integration by improving entrepreneurship levels is primarily revealed in the group with lower levels of human capital, which exhibits certain inclusive characteristics. This study is conducive to developing a policy for promoting the free flow of resources between urban and rural areas and advancing urban–rural integration.

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1. Introduction

China is globally ranked as the second-largest economy and a major agricultural country (Zhang & Zhou, 2022; Zhu & Zhang, 2022). China's economic development is therefore of global significance. China has achieved increasing progress in reducing the urban–rural divide, and in economic development, social infrastructure, resource management, and environmental protection, whereas the process of urban–rural integration still faces difficulties (e.g. urban–rural development gap, low equalisation in basic public services, and poor flow of urban–rural resources). As a result, urban–rural integration is difficult to achieve. Development is a difficult and a painful challenge that needs to be addressed.

Finance, the core of economic development, plays a vital role in facilitating economic development and urban–rural integration. There are disparities in resource endowment, economic development, and location advantages between urban and rural areas; consequently, conventional financial institutions incur higher costs when

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offering financial services to rural areas. Since financial services have a profit-seeking aspect, financial institutions are more willing to provide financial services to urban residents and as a result increase outlets in urban areas for profit maximisation, thus leading to an uneven distribution of financial resources between urban and rural areas (Berger, 2003; Kempson & Whyley, 1999). In addition, access to financial services requires collateral, whereas rural residents are often excluded by financial institutions due to their lack of collateral (Beck et al., 2007; He & Miao, 2016; Sarma & Pais, 2011). Digital finance has made significant advances by virtue of big data, cloud computing, artificial intelligence, blockchain, and other innovative technologies. As a result, the conventional financial service model has been significantly revolutionised, which has alleviated information asymmetry between urban and rural areas, reduced transaction costs, and has given more people convenient access to financial services. Moreover, digital finance has been effective in extending the boundaries of financial services. Social groups excluded by conventional financial institutions now have greater access to financial services, and the problem of insufficient financial services in remote and rural areas has been resolved to a certain extent. Digital finance also helps to improve residents' budget constraints, boosts entrepreneurship, and narrows the urban–rural income gap.

Existing research has suggested that the development of digital finance can alleviate information asymmetry and reduce transaction costs. It can also improve household income, narrow the urban–rural income gap, and boost economic growth. However, the effect of digital financial on urban–rural integration and the mechanism through which the development of digital finance advances urban–rural integration is rarely investigated. Research on the effect of digital financial development on urban–rural integration and its transmission mechanism, that is, the main objective of this study, is of great theoretical and practical significance. This study investigates the correlation between digital financial development and urban–rural integration and its transmission mechanism using the provincial panel data of China between 2011 and 2020.

This study makes three main contributions. First, to the best of our knowledge, this study is the first to build a theoretical framework for the effect of digital financial development on urban–rural integration. Second, the correlation between digital financial development and urban–rural integration is discussed in detail, and the results suggest that entrepreneurship is a vital channel through which digital financial development boosts urban–rural integration. Last, this study explores how the transmission mechanism of digital financial development to urban–rural integration may change at different levels of human capital.

The rest of this study is organised as follows. [Section 2](#) presents the literature review. [Section 3](#) builds the theoretical analysis framework. [Section 4](#) introduces the research design. [Section 5](#) presents the econometric results. The transmission mechanism is analysed in [Section 6](#). The conclusions and policy implications of this study are summarised in [Section 7](#).

2. Literature review

With the continuous use of advanced technologies (e.g. big data, cloud computing, artificial intelligence, and blockchain) in the field of financial services, digital financial

services have ushered in a shift in payment methods, thus reducing information search costs and transaction costs and breaking through time and regional restrictions (Wang & Chen, 2022; Zeng & Reinartz, 2003). The development of digital finance also brings challenges and opportunities to conventional financial institutions by fostering competition in the banking industry, expediting the transformation and upgrading of business in the banking industry, and increasing the efficiency of financial services (Cortina Lorente & Schmukler, 2018; Luo, 2022).

The development of digital financial services has significantly enriched the coverage and breadth of financial services. It can effectively reduce liquidity constraints, allow groups that were excluded by financial institutions to enjoy financial services, foster consumption through access to financial instruments, and increase consumer demand (Campbell & Mankiw, 1991). Digital financial services can also help farmers to increase their income by offering loans and savings services, convenient payment methods, and so forth (Pierrakis & Collins, 2013). Moreover, digital financial development can reduce information asymmetry, enhance households' ability to use financial services, and satisfy their growing demand for funds; moreover, the financial system's networks also increase efficiency in financial resource allocation and reduce information asymmetry (Shen & Huang, 2016). When residents have access to financial services and the ability to use them, household consumption increases (Banerjee et al., 2015; Burgess et al., 2005), and they invest more in education, accumulate assets, and are more effective in managing risk, and thus income levels increase (Bruhn & Love, 2014; Dupas & Robinson, 2013). Furthermore, digital financial services can boost entrepreneurship (Su et al., 2022; Xie et al., 2018; Xie et al., 2020) and facilitate labour mobility by creating more employment opportunities and increasing expected income (Deng & Liu, 2022; Ma & Hu, 2022).

Digital financial development reduces the availability of conventional private borrowing by households and increases the likelihood of borrowing constraints, such that conventional borrowing by households becomes more difficult (Wu et al., 2020). Digital financial development reduces the potential demand for rural productive funds while increasing the potential demand for rural consumer credit, and thus has a multidimensional effect on rural consumption (Fu & Huang, 2018). As a result, the effectiveness and diversity of household financial asset portfolios can be enhanced, the likelihood of extreme household investment risks can be elevated, and the efficiency of household asset allocation can be increased (Wu et al., 2021). The development of digital finance leads to a significant increase in household income and consumption, promotes structural transformation in employment, and helps to bridge the digital divide (Zhang et al., 2021). He and Song (2020) found that digital financial services contribute to an increase in urban residents' consumption in the short term, which is facilitated by the convenience of digital payments and an acceleration in residents' consumption decisions. It also reduces household uncertainty, unleashes consumer demand, and boosts consumption. Savings and subsidies to residents can also stimulate an increase in basic household consumption (Grossman & Tarazi, 2014). Digital financial development therefore significantly boosts consumption while reducing consumption inequality, especially the consumption gap between high-income households and low- and middle-income households. The effect of promoting

Table 1. Urban–rural integration assessment index.

Dimensionality indicators	Specific indicators	Calculation method	Unit	Properties
Urban and rural economic integration	Ratio of output value of secondary and tertiary industries to primary industries	Secondary and tertiary industry output value/Primary industry output value	/	–
	Binary structure factor	(Share of output value of secondary and tertiary industries/Share of employment in secondary and tertiary industries)/(Share of output value of primary industries/Share of employment in primary industries)	/	–
	Ratio of urban to rural per capita income	Per capita disposable income of urban residents/Per capita disposable income of rural residents	/	–
	Ratio of urban and rural per capita consumption expenditure	Per capita consumption expenditure of urban residents/Per capita consumption expenditure of rural residents	/	–
	Ratio of urban to rural Engel coefficient	Engel's coefficient of urban households/Engel's coefficient of rural households	/	+
	Ratio of urban and rural fixed asset investment	Urban fixed asset investment/rural fixed asset investment	/	–
	Percentage of financial support to agriculture	Financial expenditure on agriculture/total financial expenditure*100%	/	+
Urban and rural population integration	Ratio of urban to rural population	Urban population/Rural population	/	–
	Ratio of urban and rural population with college and above	(Population with college education or above in urban areas/total population in urban areas)/(Population with college education or above in rural areas/total population in rural areas)	/	–
	Ratio of total urban–rural dependency ratio	Total urban dependency ratio/Total rural dependency ratio	/	+
	Ratio of employment in secondary and tertiary industries to employment in primary industries	Number of employees in the secondary and tertiary industries/Number of employees in primary industries	/	+
	Ratio of average household size in urban and rural areas	Average urban household size/average rural household size	/	–
Urban and rural social integration	Ratio of urban and rural expenditure on culture, education and entertainment	Per capita expenditure on culture, education and entertainment on urban residents/Per capita expenditure on culture, education and entertainment on rural residents	/	–
	Ratio of urban and rural health care expenditures	Urban per capita healthcare expenditure/Rural per capita healthcare expenditure	/	–

(continued)

Table 1. Continued.

Dimensionality indicators	Specific indicators	Calculation method	Unit	Properties
Urban and rural ecological integration	Road network density	Road mileage/Land area	km/100 km ²	+
	Railroad network density	Railroad operating miles/Land area	km/100 km ²	+
	Passenger turnover	Number of passengers*Distance travelled	Billion passenger kms	+
	Cargo turnover	Cargo volume*Delivery distance	Billion tons per km	+
	The ratio of urban and rural residents' minimum living standards	Minimum living standard of urban residents/Minimum living standard of rural residents	/	-
	Ratio of retail sales on consumer goods between urban and rural areas	Retail sales on urban consumer goods/Retail sales on rural consumer goods	/	-
	Agricultural mechanisation level	Total power of agricultural machinery/Area of cultivated land in the region	kW/ha	+
	Ratio of per capita consumption expenditure on urban and rural domestic tourism	Per capita consumption expenditure of urban residents on domestic tourism/Per capita consumption expenditure of rural residents on domestic tourism	/	+
	Ratio of urban and rural water penetration rate	Urban water penetration rate/Rural water penetration rate	/	-
	Ratio of road area per capita in urban and rural areas	Urban road area per capita/Village roads area per capita	/	-

Source: All data in the table are from the China Statistical Yearbook, China Social Statistical Yearbook, China Population and Employment Statistical Yearbook, China Environmental Statistical Yearbook, China Rural Statistical Yearbook, and provincial statistical yearbooks and statistics bureaux.

household consumption is more significant in China's middle and western regions, rural areas, and low-income households. Digital financial development fosters consumption by facilitating payments and alleviating liquidity constraints (Li et al., 2020).

Digital financial development enhances household consumption and facilitates economic growth (Kapoor, 2013; Zhang et al., 2020), as well as enhances financial market competition and the efficiency of financial services to the real economy, and advances regional economic growth (Bauer, 2018). It is also capable of stimulating economic growth through technological innovation and regional entrepreneurship, which can serve as a channel for digital finance to expedite economic growth (Qian et al., 2020) and contribute to the reduction of the urban–rural income gap. The role of digital financial development is more significant in the lower quartile (Su et al., 2023). Digital financial development has a catalytic effect on county economic growth, with the government playing a moderating role (Wang & Bei, 2022). It develops faster in backward regions, and contributes significantly to raising the household income of low-income households in rural areas. The above findings reveal that digital finance development contributes to inclusive growth (Zhang et al., 2019), and there is a marginal effect of this contribution, which is primarily demonstrated via the wealth channel and innovation channel (Fu et al., 2021; Meng & Xiao, 2022). Digital finance promotes regional innovation and openness by alleviating financing

constraints, making digital financial services more inclusive. It also helps to coordinate regional development so that all households can benefit from the fruits of economic growth; it also facilitates high-quality development (Ozili, 2018; Teng & Ma, 2020).

Our review of the literature highlights several research implications. First, most studies focused on the role of digital finance on banking competition, innovation and entrepreneurship, and urban–rural income levels, while fewer studies focused on the effect of digital finance on urban–rural integration. A key node of urban–rural integration lies in rural economic development, which is inseparable from financial services. Second, digital finance can alleviate information asymmetry between urban and rural areas through the continuous integration of digital technology and financial services. It effectively enhances resource allocation, improves the effectiveness of households' financial asset portfolio, and facilitates rural economic development, which suggests that digital finance development is important in expediting urban–rural integration. Third, digital financial development helps farmers to increase their income and alleviates the urban–rural income gap, although there is no theoretical framework to analyse the theoretical relationship between the two. Few studies have constructed a theoretical analysis framework for digital financial development's impact on urban–rural integration. This study therefore constructs a theoretical analysis framework for digital financial development's effect on urban–rural integration, and explores the relationship between the two at a theoretical level.

3. A theoretical analysis framework

There is a significant gap between urban and rural areas in terms of information asymmetry, economic development, and access to basic public services. While alleviating information asymmetry, digital financial development can also enhance urban and rural households' ability to increase their income, improve their property income, expedite urban–rural economic development, lay a financial foundation for economic development in rural areas, and stimulate urban–rural integration. Referring to the study conducted by Gennaioli et al. (2013), we reconstruct their production function and construct a theoretical analysis framework to analyse the effect of digital finance development on urban–rural integration.

3.1. Basic assumptions

We assume that a competitive economy includes two regions, urban U and rural R . The total factor productivity of U is \bar{A}_U , and the total factor productivity of R is \bar{A}_R . U has a higher total factor productivity than R , that is, $\bar{A}_U > \bar{A}_R$. Let $i = R, U$; according to Gennaioli et al. (2013) utility function can be set as:

$$u(c, a) = c^{1-\theta} a^\theta \quad (1)$$

where c and a represent consumption and housing, respectively; θ denotes the share of housing, a represents one unit of housing; L expresses units of labour; K represents units of physical capital and B units of financial capital. The labour force can choose

to be either entrepreneurs or workers. The entrepreneur invests physical capital $K_{i,\varphi}$, financial capital $B_{i,\varphi}$, and labour $L_{i,\varphi}$ to produce output $y_{i,\varphi}$. The production function can be written as:

$$y_{i,\varphi} = A_i \varphi_i^{1-\alpha-\beta-\delta} K_{i,\varphi}^\alpha L_{i,\varphi}^\beta B_{i,\varphi}^\delta, \quad \alpha + \beta + \delta < 1 \quad (2)$$

In accordance with Lucas (1978) research concept, regional total factor productivity and financial capital are assumed to satisfy:

$$A_i = \bar{A}_i (\varphi_i^\psi B_i)^\gamma, \quad \gamma > 0, \psi \geq 1 \quad (3)$$

Eq. (3) suggests that total factor productivity is dependent on region-specific \bar{A}_i factors, such as geographic location, locational advantages, policy, economic, and other factors. φ_i represents the level of regional digital financial development, and L_i expresses the amount of labour input, ψ denotes the importance of digital financial development on total factor productivity, γ represents the role of externalities, $\gamma > 0$ denotes the existence of regional effects, A_i is endogenously determined by the region in which the labour force is located. Households provide labour and capital to firms, and they may also rent out houses to entrepreneurs. In region i , households rent out physical capital and houses to firms for rental income from physical capital $\rho_i K$ and rental income from housing η_i . Housing is immobile, while physical capital can flow between urban and rural areas. Labourers with some financial capital can earn profits as entrepreneurs $\pi_i(\varphi)$ or wages as workers $w_i(\varphi)$, and households receive the same interest income $r_i B$ whether they deposit money in a bank or invest it in a business, assuming the interest rate on loans or deposits remains the same.

At $t = 0$, workers maximise their choice between urban or rural areas, as well as between entrepreneurial or formal work, and housing can be fully rented out to local entrepreneurs or allocated to the local labour force without constraints. At $t = 1$, the entrepreneur hires labour, rents physical capital, and invests financial capital for production. Production requires the payment of wages, rent for physical capital, rent for housing, and loan fees. When the equilibrium (K_i, L_i, B_i^E, B_i^W) is reached, the entrepreneur hires labour, rents physical capital, and invests financial capital to maximise profit. Workers select the optimal location, occupation, and proportion of income to spend on consumption and housing. The markets for physical capital, financial capital, labour, and housing are cleared and have a unique rent rate ρ since physical capital is perfectly mobile, whereas housing is not mobile, and rents η_i are dependent on productivity and population differences. For simplicity, consumer prices are normalised to 1. Regional differences in housing rents affect the welfare of workers in different regions. Firms maximise their profits by selecting $K_{i,\varphi}$, $B_{i,\varphi}$ and $L_{i,\varphi}$ as follows:

$$\max_{K_{i,\varphi}, B_{i,\varphi}, L_{i,\varphi}} A_i \varphi_i^{1-\alpha-\beta-\delta} K_{i,\varphi}^\alpha L_{i,\varphi}^\beta B_{i,\varphi}^\delta - w_i L_{i,\varphi} - \rho K_{i,\varphi} - r_i B_{i,\varphi} \quad (4)$$

Whether in urban or rural areas, firms have the same employment ratio (K_i, L_i, B_i^E, B_i^W) , and firm j invests a portion of its start-up capital φ_j/B_j^E , then the other input factors can be expressed as

$$K_{i,j} = \frac{\Phi_j}{B_i^E} K_i, \quad L_{i,j} = \frac{\Phi_j}{B_i^E} L_i, \quad B_{i,j} = \frac{\Phi_j}{B_i^E} \quad (5)$$

Total output in urban or rural areas can be expressed as

$$Y_i = A_i (B_i^E)^{1-\alpha-\beta-\delta} K_i^\alpha L_i^\beta (B_i^W)^\delta \quad (6)$$

where $B_i = B_i^E + B_i^W$, B_i^E denotes the entrepreneurial financial capital, and B_i^W represents workers' financial capital.

3.2. Equilibrium analysis

Based on Eq. (6), the regional factor supply functions of wages, profits, physical capital lease rate, and loan interest rate can be determined by marginal product pricing, which can be expressed as follow:

$$\rho = \frac{\partial Y_i}{\partial K_i} = \alpha A_i \left(\frac{B_i^E}{K_i} \right)^{1-\alpha-\beta-\delta} \left(\frac{L_i}{K_i} \right)^\beta \left(\frac{B_i^W}{K_i} \right)^\delta \quad (7)$$

$$\pi_i = r_i^E = \frac{\partial Y_i}{\partial B_i^E} = (1 - \alpha - \beta - \delta) A_i \left(\frac{K_i}{B_i^E} \right)^\alpha \left(\frac{L_i}{B_i^E} \right)^\beta \left(\frac{B_i^W}{B_i^E} \right)^\delta \quad (8)$$

$$w_i = \frac{\partial Y_i}{\partial L_i} = \beta A_i \left(\frac{B_i^E}{L_i} \right)^{1-\alpha-\beta-\delta} \left(\frac{K_i}{L_i} \right)^\alpha \left(\frac{B_i^W}{L_i} \right)^\delta \quad (9)$$

$$r_i^W = \frac{\partial Y_i}{\partial B_i^W} = \delta A_i \left(\frac{B_i^E}{B_i^W} \right)^{1-\alpha-\beta-\delta} \left(\frac{K_i}{B_i^W} \right)^\alpha \left(\frac{L_i}{B_i^W} \right)^\beta \quad (10)$$

In accordance with Eqs. (7) (9) and (10), it yields:

$$K_i = \frac{\alpha r_i^W}{\delta \rho} B_i^W, \quad L_i = \frac{\beta r_i^W}{\delta w_i} B_i^W \quad (11)$$

Thus, profit $\pi_i(\varphi)$ can be expressed as the product of π_i and the digital financial development of the entrepreneur φ , that is, $\pi_i(\varphi) = \pi_i \varphi$. Marginal product pricing shows that profit $\pi_i(\varphi)$ in region i is equal to the φ multiple of the regional entrepreneurial financial capital return $\partial Y_i / \partial B_i^E$. The same person can earn a profit equal to the φ multiple of the return on wages $\partial Y_i / \partial L_i$ in the region. The worker chooses to become an entrepreneur when and only when $(\partial Y_i / \partial B_i^E) \varphi_j > (\partial Y_i / \partial L_i) \varphi_j$. The worker chooses to be a worker when and only when $(\partial Y_i / \partial B_i^E) \varphi_j < (\partial Y_i / \partial L_i) \varphi_j$, and to bank or invest the surplus. In equilibrium, there is no difference between workers choosing to be entrepreneurs and workers, satisfying

$$B_i^E = \frac{(1 - \alpha - \beta - \delta)r_i^W}{\delta w_i + (1 - \alpha - \beta - \delta)r_i^W} B_i \quad (12)$$

$$B_i^W = \frac{\delta w_i}{\delta w_i + (1 - \alpha - \beta - \delta)r_i^W} B_i \quad (13)$$

Eqs. (12) and (13) describe the allocation of financial resources in the same region. According to the utility function in Eq. (1), workers spend a proportion of their income on housing θ and a proportion on consumption $1 - \theta$. The total income of workers in region i is equal to $w_i L_i$, and housing demand in the region is $\theta w_i L_i / \eta_i$; the housing rent for a single unit is $\eta_i = \theta w_i L_i$, and the utility function of workers in region i is

$$u_{w_i}(c, a) = \frac{w_i \varphi_i}{\eta_i^\theta} = \frac{w_i^{1-\theta}}{\theta^\theta} \frac{\varphi_i}{L_i^\theta} \quad (14)$$

Eq. (14) suggests that utility increases with an increase in wages, decreases with an increase in the labour force, and increases with the development of digital finance. Based on Eqs. (3) (9) (11) (12), and (13), the ratio between urban and rural payment of wages can be written as:

$$\frac{w_U}{w_R} = \left(\frac{\bar{A}_U}{\bar{A}_R} \right)^{\frac{1}{1-\alpha-\delta}} \left(\frac{\varphi_U}{\varphi_R} \right)^{\frac{\psi\gamma}{1-\alpha-\delta}} \left(\frac{B_U}{B_R} \right)^{\frac{\gamma}{1-\alpha-\delta}} \quad (15)$$

Labour moves freely between urban and rural areas. Eq. (14) suggests that if $[w_U^{1-\theta}(\varphi_U - \phi)/L_U^\theta] \geq w_R^{1-\theta}\varphi_R/L_R^\theta$, labour can migrate from rural to urban areas, where ϕ denotes the cost of migration. If $[w_U^{1-\theta}(\varphi_U - \phi)/L_U^\theta] < w_R^{1-\theta}\varphi_R/L_R^\theta$, labour can migrate from urban to rural areas. When equilibrium is reached, the equation can be written as:

$$\phi = \varphi_U - \left(\frac{w_R}{w_U} \right)^{1-\theta} \left(\frac{L_U}{L_R} \right)^\theta \varphi_R \quad (16)$$

According to Eqs. (11) (15) and (16), it yields:

$$\phi = \varphi_U - \left(\frac{\bar{A}_U}{\bar{A}_R} \right)^{\frac{1}{1-\alpha-\delta}} \left(\frac{\varphi_U}{\varphi_R} \right)^{\frac{\psi\gamma}{1-\alpha-\delta}} \left(\frac{B_U}{B_R} \right)^{\frac{\gamma}{1-\alpha-\delta}} \left(\frac{B_U^W}{B_R^W} \right)^\theta \varphi_R \quad (17)$$

To determine the equilibrium, we assume that financial capital is allocated between urban and rural areas in a fixed proportion. This constraint can be expressed as:

$$\frac{\varphi_U}{\varphi_R} = \frac{B_U}{B_R} = \frac{B_U^W}{B_R^W} = \frac{B_U^E}{B_R^E} \quad (18)$$

Eq. (17) can be simplified as:

$$\phi = \varphi_U - \left(\frac{\bar{A}_U}{\bar{A}_R}\right)^{\frac{1}{1-\alpha-\delta}} \left(\frac{\varphi_U}{\varphi_R}\right)^{\frac{\psi\gamma}{1-\alpha-\delta}} \left(\frac{B_U}{B_R}\right)^{\frac{\gamma}{1-\alpha-\delta}+\theta} \varphi_R \quad (19)$$

If the degree of urban–rural integration is assumed as $\Lambda = u_{w_R}(c, a)/u_{w_U}(c, a)$, the larger the value Λ or the closer to 1, the higher the urban–rural integration will be and vice versa. Next, the function of the degree of urban–rural integration can be expressed as:

$$\Lambda = \frac{u_{w_R}(c, a)}{u_{w_U}(c, a)} = \left(\frac{w_R}{w_U}\right)^{1-\theta} \left(\frac{L_U}{L_R}\right)^{\theta} \left(\frac{\varphi_R}{\varphi_U}\right) \quad (20)$$

According to Eq. (16), Eq. (20) can be simplified as:

$$\Lambda = \frac{u_{w_R}(c, a)}{u_{w_U}(c, a)} = \frac{\varphi_U - \phi}{\varphi_R} \left(\frac{\varphi_R}{\varphi_U}\right) \quad (21)$$

Substituting Eq. (19) into Eq. (21), it yields:

$$\Lambda = \frac{u_{w_R}(c, a)}{u_{w_U}(c, a)} = \left(\frac{\bar{A}_U}{\bar{A}_R}\right)^{\frac{1}{1-\alpha-\delta}} \left(\frac{\varphi_U}{\varphi_R}\right)^{\frac{\psi\gamma+\gamma}{1-\alpha-\delta}-1+\theta} \quad (22)$$

From the first order condition of Eq. (22), we can see that

$$\frac{\partial \Lambda}{\partial(\varphi_U/\varphi_R)} = \left(\frac{\psi\gamma + \gamma - (1-\theta)(1-\alpha-\delta)}{1-\alpha-\delta}\right) \left(\frac{\bar{A}_U}{\bar{A}_R}\right)^{\frac{1}{1-\alpha-\delta}} \left(\frac{\varphi_U}{\varphi_R}\right)^{\frac{\psi\gamma+\gamma}{1-\alpha-\delta}-2+\theta} \quad (23)$$

When urban–rural integration is being boosted, the regional effect γ can converge to zero infinitely, that is, $\gamma \approx 0$. Eq. (23) indicates that $\psi\gamma + \gamma - (1-\theta)(1-\alpha-\delta) < 0$, thus suggesting that digital financial development alleviates urban–rural information asymmetry, and the availability of financial services in rural areas is increased relative to urban areas. It also becomes easier to satisfy the needs of production and life through access to financial services. On that basis, the relative reduction of φ_U/φ_R contributes to urban–rural integration, thus suggesting that financial availability benefits more from the development of digital finance in the case of rapid of digital financial development, which is conducive to boosting urban–rural integration. The above analysis leads to the research hypothesis that the digital financial development is beneficial to boosting urban–rural integration.

4. Research design

4.1. Data sources and variable selection

4.1.1. Digital financial development (*Indifi*)

The data are from the digital inclusive finance index of the digital finance research centre of Peking University; the specific index construction method and dimensions refer to the study of Guo et al. (2020). The digital financial inclusion index includes three dimensions: breadth of coverage (account coverage), depth of use (payment business, money fund business, credit business, insurance business, investment business, and credit business), and degree of digitalisation (mobile, affordable, credit, and convenience).

4.1.2. Urban–rural integration development (*Indur*)

Referring to Lv and Wang (2018), a comprehensive indicator system of urban–rural integration is constructed from four dimensions: urban–rural economic integration, population integration, social integration, and ecological integration. A total of 24 indicators are also included. The data were obtained from the *China Statistical Yearbook*, *China Social Statistical Yearbook*, *China Population and Employment Statistical Yearbook*, *China Environmental Statistical Yearbook*, *China Rural Statistical Yearbook*, and provincial statistical yearbooks and statistics bureaux. This study calculates a comprehensive index of urban–rural integration based on Euclidean distance by drawing on Liu et al. (2018). The average values for the two years before and after were used to replace missing data. The specific indicators and calculation methods are shown in Table 1.

4.2. Model design

To examine the effect of digital finance on urban–rural integration, the model constructed in this study can be depicted as follows.

$$\ln dur_{it} = \alpha_0 + \beta_1 \ln difi_{it} + \beta_2 \ln X_{it} + \varepsilon_{it} \quad (24)$$

where α_0 represents the constant term; β_1 and β_2 denote the corresponding regression coefficient; X_{it} expresses a vector of the control variables, including population density ($\ln pd$), government intervention ($\ln gov$; the share of government expenditure in GDP), urbanisation level ($\ln urb$; the share of urban population), openness level ($\ln open$; total imports and exports as a share of GDP), as well as the unemployment rate ($\ln rat$; urban registered unemployment rate). The relevant data are obtained from the *China Statistical Yearbook*, the *China Social Statistical Yearbook* and the statistical yearbooks of each province (city and autonomous region). ε_{it} is a random perturbation term. The construction of the digital inclusive finance index originated in 2011, and the latest data on urban–rural integration ends in 2020, as the data interval from 2011 to 2020. Table 2 presents the descriptive statistical analysis of the variables in detail.

Table 2. Descriptive statistical analysis.

Variable	Definition	Mean	SD	Min	Max	N
Indur	Urban–rural integration	−4.288	0.535	−4.933	−0.509	310
Indure	Urban and rural economic integration	−0.953	0.175	−1.661	−0.284	310
Indurp	Urban and rural population integration	−2.616	0.671	−3.804	−0.194	310
Indurs	Urban and rural social integration	−5.274	0.890	−8.764	−0.380	310
Indurr	Urban and rural ecological integration	−1.144	0.449	−2.481	−0.196	310
Indifi	Digital Financial Development	5.212	0.677	2.786	6.068	310
Incovdth	Coverage breadth	5.060	0.844	0.673	5.984	310
Inusapth	Use depth	5.195	0.651	1.911	6.192	310
Indigle	Degree of digitisation	5.510	0.698	2.026	6.136	310
Inpd	Population density	5.379	1.589	0.923	11.53	310
Ingov	Government intervention	3.210	0.476	2.475	4.927	310
Inubr	Level of urbanisation	4.035	0.234	3.127	4.495	310
Inopen	Level of openness	−1.795	0.986	−4.873	0.437	310
Inrat	Urban registered unemployment rate	1.153	0.230	0.182	1.526	310

Source: drawn by authors.

Table 3. Impact of digital financial development on economic growth and the urban–rural income gap.

Variable	Economic growth				Urban–rural income gap			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Indifi	0.144*** (4.97)				−0.081*** (−8.68)			
Incovdth		0.084*** (3.10)				−0.059*** (−6.87)		
Inusapth			0.124*** (3.33)				−0.058*** (−7.07)	
Indigle				0.112*** (7.58)				−0.057*** (−7.02)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES	YES
N	310	310	310	310	310	310	310	310
R ²	0.694	0.702	0.697	0.687	0.503	0.481	0.462	0.467

Note: Regression coefficients are not in parentheses, t-statistic values are in parentheses. *** p < 0.01, ** p < 0.05, and * p < 0.1.

Source: drawn by authors.

5. Econometric results

5.1. Impact of digital finance on economic growth and urban–rural income gap

Table 3 lists the empirical results of the effect of digital financial development on economic growth and urban–rural income gap. The results indicate that digital financial development can significantly boost economic growth and reduce the urban–rural income gap, consistent with the conclusions reached by the vast majority of studies in the literature. Considering that there may be heterogeneity in the effect of each dimension of digital finance development on economic growth and urban–rural income gap, this study empirically examines the effect of the breadth of digital finance coverage, and the depth of use and degree of digitisation on economic growth and urban–rural income gap. The empirical results show that the coverage breadth of digital finance, depth of use, and degree of digitisation all beneficial to economic growth and reduce the urban–rural income gap. However, the increase in the depth of use and digitisation is more beneficial to economic growth, while the increase in

breadth of coverage is more significant in reducing the urban–rural income gap. In the context of the widespread use of the Internet in financial services, the physical distance constraint is broken, and the coverage of financial services is higher. However, the increase in coverage does not indicate an increase in the depth of use and the degree of digitisation, since the depth of use and the degree of digitisation can be manifested only under the actual use of digital financial services, such that the probability of becoming ‘dormant capital’. Accordingly, policy makers can boost economic growth and reduce the urban–rural income gap by expanding the coverage of financial services, increasing the variety of financial services, and enhancing financial inclusion.

5.2. Impact of digital finance on the development of urban–rural integration

Table 4 lists the empirical results of the effect of digital finance on urban–rural integration. The results show that digital finance is beneficial to promoting urban–rural integration, specifically, every 1 standard deviation increase in digital finance can lead to increase of 7.7% in urban–rural integration. The inclusive characteristic of digital financial development helps low-income households to access appropriate and affordable financing services to expand their scale of production, boosts the level of entrepreneurship, and enhances households’ income generation capacity. The coverage breadth of digital finance, depth of use, and digitisation have positive implications for urban–rural integration, especially the significant effects of breadth of coverage and digitisation on urban–rural integration, while the contribution of depth of use to urban–rural integration does not pass the significance test. The breadth of coverage is related to the supply and quantity of financial services provided, and an increase in quantity and supply is beneficial to urban–rural integration. Then, the low costs and low thresholds associated with the degree of digitisation makes financial services affordable to rural households, which raises the demand for financial services. The effective demand and sufficient supply of funds can undoubtedly facilitate urban–rural integration. Moreover, along with the innovation and development of financial products, the variety of financial services increases to meet the residents’ demand for financial funds, whereas the increase in the depth of financial service use does not indicate an increase in effective demand, since

Table 4. Impact of digital finance on urban–rural integration.

Variable	(1)	(2)	(3)	(4)
Indifi	0.077** (2.16)			
Incovdth		0.063** (2.09)		
Inusapth			0.043 (1.39)	
Indigle				0.062*** (2.81)
Controls	YES	YES	YES	YES
Region	YES	YES	YES	YES
Year	YES	YES	YES	YES
N	310	310	310	310
R ²	0.516	0.516	0.536	0.525

Note: Regression coefficients are not in parentheses, t-statistic values are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Source: drawn by authors.

rural residents have to pay an access cost to use new financial products, which is closely correlated with residents' financial knowledge and may determine their ability to use financial services. Thus, in the short term, the depth of use of financial services may facilitate urban–rural integration.

5.3. Robustness analysis

To test the robustness of the empirical findings, this study conducts a robustness analysis in the following three aspects. First, before testing the role of digital finance on urban–rural integration, we first empirically analyse the effect of digital financial development on economic growth and urban–rural income gap. The results confirm that digital financial development can facilitate economic growth and narrow the urban–rural income gap, which is consistent with the literature. We then test the effect of digital finance on urban–rural integration has a degree of robustness.

Second, in addition to the empirical analysis of the effect of digital finance on urban–rural integration, the effects of the breadth of coverage, depth of use, and digitalisation of digital finance on urban–rural integration are also tested. The results confirm that the breadth of coverage, depth of use, and digitalisation differ slightly at the significance level, but all have positive significance on urban–rural integration.

Third, the empirical estimation of Tables 3 and 4 is re-estimated using the systematic GMM. The results confirm that digital financial development boosts economic growth and reduces the urban–rural income gap, and that digital finance helps to expedite the realisation of urban–rural integration, which is sufficient to indicate the robustness of the empirical results. (Tables 5 and 6)

5.4. Analysis of regional differences in the impact of digital finance on the development of urban–rural integration

Table 7 summarises the empirical results of regional heterogeneity in the effect of digital finance on urban–rural integration. The results show that the estimated

Table 5. Robustness analysis of the impact of digital financial development on economic growth and the urban–rural income gap.

Variable	Economic growth				Urban–rural income gap			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Indifi	0.268*** (3.61)				−0.202*** (−7.61)			
Incovdth		0.217*** (3.12)				−0.211*** (−8.70)		
Inusapth			0.183** (2.35)				−0.039* (−1.77)	
Indigle				0.180*** (4.02)				−0.137*** (−8.47)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
N	279	279	279	279	279	279	279	279
AR(1) pValue	0.849	0.858	0.116	0.587	0.221	0.268	0.029	0.008
AR(2) pValue	0.259	0.925	0.016	0.965	0.000	0.003	0.000	0.000
Hansen pValue	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: Regression coefficients are not in parentheses, z-statistic values are in parentheses. *** p < 0.01, ** p < 0.05, and * p < 0.1.

Source: drawn by authors.

Table 6. Robustness analysis of the impact of digital finance development on urban–rural integration.

Variable	(1)	(2)	(3)	(4)
Indifi	0.237*** (4.25)			
Incovdth		0.227*** (2.96)		
Inusapth			0.065 (1.64)	
Indigle				0.186*** (4.34)
Controls	YES	YES	YES	YES
N	279	279	279	279
AR(1) pValue	0.082	0.086	0.084	0.083
AR(2) pValue	0.621	0.506	0.519	0.602
Hansen pValue	1.000	1.000	1.000	1.000

Note: Regression coefficients are not in parentheses, z-statistic values are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. Source: drawn by authors.

Table 7. Regional heterogeneity in the impact of digital financial development on urban–rural integration.

Panel A	East	Middle	West	East	Middle	West
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Indifi	0.059** (2.58)	0.117 (0.90)	0.001 (0.02)			
Incovdth				0.070** (2.97)	0.128 (1.13)	0.026 (0.84)
Controls	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
N	110	80	120	110	80	120
R ²	0.851	0.589	0.116	0.849	0.587	0.111
Panel B	East	Middle	West	East	Middle	West
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Inusapth	0.047* (2.15)	0.024 (0.20)	−0.020 (−0.50)			
Indigle				0.018 (1.01)	0.114 (1.11)	0.010 (0.27)
Controls	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
N	110	80	120	110	80	120
R ²	0.853	0.602	0.120	0.855	0.595	0.115

Note: Regression coefficients are not in parentheses, t-statistic values are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Source: drawn by authors.

coefficients and significance levels of digital financial development differ significantly among the regions; all of them contribute to urban–rural integration, and the significance levels of the estimated coefficients are higher in China’s eastern region than in the middle and western regions. As China’s middle and western regions are not statistically significant, the development of digital finance is more beneficial to urban–rural integration in China’s eastern region. The possible reason is that the eastern region has a relatively higher level of economic development, greater equity in access to basic public services, unparalleled advantages in information accessibility, transportation convenience between urbans and rural areas, and residents have a higher level

of education. The latter makes access costs lower when providing financial services. Residents have a greater ability to use financial services, so digital financial development is more beneficial to the urban–rural integration in the eastern region. However, due to the radiation and spill-over effects of the eastern region in the long term, the middle and western regions can also make a breakthrough in urban–rural integration.

5.5. Impact of digital finance on the Sub-dimensions of urban–rural integration

Table 8 lists the empirical estimation results of the effect of digital financial development on the sub-dimensions of urban–rural integration. Panel A's columns (1)–(4) show that digital financial development has a significant promotion effect on both urban–rural economic and population integration. This suggests that digital financial development helps to improve the level of investment in rural areas, raise the income level of rural households, narrow the urban–rural development gap, and accelerate household consumption and thus boost rural economic development. Digital financial development can alleviate information asymmetry between urban and rural areas, solve the problem of financing constraints in rural areas, encourage talents to return to their hometowns to start businesses, improve employment opportunities for rural residents to a certain extent, improve the structure of rural labour force, and expedite the accumulation of rural human capital.

Digital financial development can therefore contribute to the integrated development of urban and rural economies and populations. The effect of digital financial development on the integrated development of urban and rural societies is not statistically significant. This finding suggests that sustained, long-term efforts, as well as strong government support are required to improve infrastructure construction and enhance social security in rural areas. At the present stage, there is a dilemma between protecting the rural resources and environment and developing rural economies, and a dynamic game exists between environmental protection and economic development.

Thus, the development of digital finance does not facilitate the integration of urban and rural resources and environment in the short term. As depicted in Panel A's columns (5)–(8), the breadth of digital finance coverage can significantly contribute to the development of urban–rural economic and social integration, rather than to the development of urban–rural population and ecological integration. As depicted in Panel B, the depth of digital finance usage does not pass the significance test for urban–rural economic, population, social and ecological, while the digitalisation of digital finance contributes more to the integrated development of urban–rural population and society.

6. Analysis of the transmission mechanism

Digital finance is capable of improving the income level of rural residents and boosting the equalisation of income distribution, and its development is conducive to facilitating urban–rural integration. The approach described by Zhang and Li (2022),

Table 8. Impact of digital financial development on the sub-dimensions of urban-rural integration.

Panel A Variable	Economic integration (1)	Population integration (2)	Social integration (3)	Ecological integration (4)	Economic integration (5)	Population integration (6)	Social integration (7)	Ecological integration (8)
Indifi	0.051** (2.32)	0.056* (1.74)	0.077 (1.55)	-0.023 (-0.34)				
Incovdth					0.052*** (3.22)	0.028 (1.24)	0.078* (1.89)	0.024 (0.52)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES	YES
N	310	310	310	310	310	310	310	310
R ²	0.498	0.457	0.336	0.652	0.509	0.446	0.339	0.652
Panel B Variable	Economic Integration (1)	Population Integration (2)	Social Integration (3)	Ecological Integration (4)	Economic Integration (5)	Population Integration (6)	Social Integration (7)	Ecological Integration (8)
Inusapth	0.032 (1.57)	0.056 (1.64)	0.030 (0.67)	-0.115 (-1.69)				
Indigle					0.023 (1.19)	0.046** (2.52)	0.059* (1.92)	0.005 (0.12)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES	YES
N	310	310	310	310	310	310	310	310
R ²	0.485	0.456	0.332	0.663	0.486	0.463	0.337	0.651

Note: Regression coefficients are not in parentheses, t-statistic values are in parentheses. *** p < 0.01, ** p < 0.05, and * p < 0.1.
Source: drawn by authors.

Table 9. Analysis of the action mechanism of the impact of digital financial development on urban–rural integration.

Variable	National (1)	East (2)	Middle (3)	West (4)
Indifi_Inlen	0.021*** (2.90)	0.013* (2.22)	−0.006 (−0.24)	0.010 (0.78)
Controls	YES	YES	YES	YES
Region	YES	YES	YES	YES
Year	YES	YES	YES	YES
N	310	110	80	120
R ²	0.446	0.594	0.664	0.119

Note: Regression coefficients are not in parentheses, t-statistic values are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Source: drawn by authors.

where the level of entrepreneurship is determined by the proportion of self-employment in private enterprises to the total population, is adopted in this study to test whether digital finance boosts urban–rural integration by improving entrepreneurship levels, and whether there is regional heterogeneity in the mechanism of action.

As depicted in Table 9, overall digital finance can expedite urban–rural integration by elevating the level of entrepreneurship, and the level of entrepreneurship can serve as a vital channel. Moreover, the same conclusion can be drawn for the eastern region, whereas the middle and western regions do not achieve statistical significance. The reason for this result is that higher levels of regional digital finance development are associated with more active financial services and better financial infrastructure, which significantly foster residents' entrepreneurship. On that basis, compared with the middle and western regions, the eastern region has a more complete financial system with developed payment transaction settlement tools and mature financial market services. These factors are beneficial to the development of digital finance to foster entrepreneurship and urban–rural integration.

To further analyse the mechanism of digital finance on urban–rural integration from the perspective of human capital heterogeneity. This study estimates the model separately by dividing the sample into two parts with low human capital and high human capital within the sample period using the average years of education as the boundary, and the human capital level is measured by the average years of education. Table 10 summarises the empirical results of the mechanism of the role of digital

Table 10. Analysis of the mechanism of the role of digital finance on urban–rural integration under the heterogeneity of human capital.

Variable	National		East		Middle		West	
	Low (1)	High (2)	Low (3)	High (4)	Low (5)	High (6)	Low (7)	High (8)
Indifi_Inlen	0.020*** (3.68)	−0.002 (−0.20)	−0.004 (−0.78)	0.017** (2.76)	0.190 (1.99)	−0.038 (−1.86)	0.018** (2.90)	−0.031** (−2.79)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES	YES
N	140	170	23	87	30	50	87	33
R ²	0.477	0.660	0.599	0.848	0.678	0.265	0.113	0.154

Note: Regression coefficients are outside of parentheses, t-statistic values are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

Source: drawn by authors.

finance on urban–rural integration under different human capital levels. As depicted in columns (1) and (2), the mechanism of the role of digital finance in promoting urban–rural integration by raising the level of entrepreneurship is mainly revealed in groups with a low level of human capital, which has certain inclusive characteristics. These groups are mainly concentrated in rural areas, and they have insufficient capacity to raise the income levels of rural residents. Low-income groups are more severely constrained by financing. Digital finance provides financial services for their entrepreneurship, helps them to increase their income, and is particularly significant in improving the farming environment and increasing investment. The estimation results for China’s middle and western regions are largely consistent with this finding. For the eastern region, the mechanism of digital finance in promoting urban–rural integration by enhancing entrepreneurship level is mainly revealed in the group with a higher human capital level. The eastern region exhibits a higher level of economic development, with high levels of urbanisation, a relatively high degree of urban–rural integration, more concentrated human resources, and generally higher education levels than the middle and western regions. In addition, its entrepreneurship threshold is high and difficult to reach. Groups with higher levels of human capital have more advantages in entrepreneurship.

7. Conclusions and policy implications

Financial services are an essential source of capital for rural economic development and urban–rural integration. This study empirically analyses the effect of digital finance on urban–rural integration and its mechanism based on China’s provincial panel data from 2011 to 2020.

The results show that digital financial development can facilitate economic growth, narrow the urban–rural income gap, and beneficial to boost urban–rural integration. For every 1 standard deviation increase in digital financial development, urban–rural integration can increase by 7.7% on average. Both the breadth of coverage and the degree of digitisation of digital finance can boost urban–rural integration, while the depth of use is not statistically significant. Digital financial development is more beneficial to urban–rural integration in China’s eastern region, thus suggesting the existence of regional heterogeneity. The sub-dimension of urban–rural integration shows that digital finance is beneficial to urban–rural economic and population integration, and the impact on urban–rural social and ecological integration is not statistically significant. The level of entrepreneurship could be a vital channel for digital finance to boost urban–rural integration. The mechanism of action of digital finance to boost urban–rural integration through improving the level of entrepreneurship is mainly revealed in the group with a lower level of human capital, which has certain inclusive characteristics.

This study’s policy recommendations can be summarised as follows. First, infrastructure construction should be strengthened in rural areas to increase the penetration rate and usage efficiency of smartphone so that the role of digital financial development can be fully utilised in alleviating urban–rural asymmetry information, making financial services popular and beneficial to households. This would in turn

prompt them to start their own businesses, thus raising their income levels, improving the rural habitat, and promoting urban–rural integration.

Second, the development of digital finance can make up for a lack of financial services in rural areas, and an improvement of coverage breadth will give rural households greater access to financial services. However, financial knowledge and ability to use financial services should be cultivated, which could help to generate actual demand, help farmers increase their income, boost capital investment in rural areas, and revitalise the economic development of rural areas.

Third, it is imperative to strengthen the use and promotion of payment tools in rural areas, build a good payment environment and business environment, enhance human capital construction, and improve the overall human capital level in rural areas, which can be beneficial to create new income growth points, improve the overall welfare level in rural areas, and expedite urban–rural integration.

Data availability statement

All data will be available upon request from the first author.

Disclosure statement

No potential conflict of interest was reported by the authors.

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