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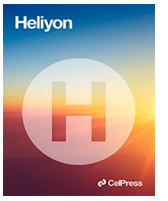

Research article

Digital financial inclusion and upgrading of consumption structure: Evidence from rural China☆

Jianguo Liu, Yuchen Yao *

School of Economics, Lanzhou University of Finance and Economics, No. 496, Duanjiatan Road, Lanzhou City, Gansu Province, Lanzhou 730020, PR China

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ABSTRACT

Based on the perspective of spatial economy, this paper focuses on the primary effects and spatial characteristics of Digital Financial Inclusion (DFI) on the upgrading of rural consumption structure (URCS) in China, conducting a literature review and theoretical analysis. It then uses statistical data collected over the years and the Digital Financial Inclusion Index (DFII) of Peking University to prepare panel data for 31 provinces in China (aside from Hong Kong, Macao, and Taiwan) from 2011 to 2020 for empirical testing. The results are as follows: DFI can considerably boost URCS, and there is a strong spatial neighbor impact, that is, it is affected by random shocks in surrounding provinces via its spatial effect; DFI has nonlinear characteristics in the process of fostering URCS, with the threshold variables of income level and family sizes; the impact of DFI on URCS is spatially heterogeneous, and the promotion of the eastern region is better than other zones. These results can inform policymakers about rural development and provide valuable references to push forward rural vitalization.

1. Introduction

China's economy has faced three pressures in recent years: shrinking demand, supply shocks, and weakening expectations. When domestic investment and export encounter bottlenecks, the importance of consumption to economic development gradually increases [1]. Consumption upgrading has naturally become one of the main ways to promote high-quality economic growth and internal circulation. In this critical period, the government should take appropriate measures to boost consumption upgrading and hedge the current downward financial pressure.

Researchers study consumption upgrading by increasing total consumption and optimizing consumption structure to investigate consumption potential [2,3]. Existing research indicates that consumption levels have improved to some extent, however, because of the significant gap in economic development under the urban-rural dual system, rural residents' total consumption expenditure and structure levels are lower than those of urban residents [4]. Therefore, effectively improving the consumption level of rural low-income groups is particularly important in promoting rural revitalization and achieving shared prosperity.

Widely relying on the Internet, big data, and artificial intelligence, digital technology provides consumers with more convenient purchase channels and diversified products. It has injected new vitality into economic and social development and brought new

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* Corresponding author.
E-mail addresses: jgliu@lzu.edu.cn (J. Liu), nmyaoyuchen@163.com (Y. Yao).

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opportunities for financial inclusion. First, DFI can expand the transaction boundary, lower the service threshold, provide more convenient financial services to people with various financial needs, break the time and space restrictions, and attract more customers; Second, the online services of DFI are conducive to reducing financial transaction costs, opening up information communication channels between the demand side and the supply side, providing more borrowing methods than traditional inclusive finance, and alleviating liquidity constraints to a certain extent [5]. The majority of residents, especially those living in rural areas, now have more convenient borrowing and financing options, thanks to DFI's creation of a favorable financial environment and promotion of innovative development [6], which has improved consumption by making up for the shortcomings of traditional inclusive finance.

Against this background, the advanced level of digital finance in China is increasingly apparent [3]. It has affected economic behaviors such as family, enterprise, government policies, and regional development. Therefore, different from previous studies, we used the theoretical model to deduce the mechanism of DFI's influence on URCS, adopted the spatial economic model to conduct the spatial correlation analysis, spatial panel regression, and spatial heterogeneity test of DFI's effect on URCS under the digital differences among provinces, and utilized personal income and family size as thresholds for threshold effect analysis, to provide feasible theoretical paths and research references for the academic community.

2. Literature review

The earliest basic meaning of inclusive finance is to provide diversified financial services for the majority of low-income groups, which can avoid the phenomenon of financial exclusion in remote areas [7]. DFI integrates all digital financial products and services profoundly into traditional inclusive finance, influencing payments, loans, and insurance from traditional finance with more forceful inclusiveness and coverage and eliminating obstacles to financial services for its citizens in many countries [5]. Most academics, domestically and abroad, concur that the growth of inclusive finance in the age of the digital economy is a terrific way to achieve sustainable financial development, increase access to finance for various groups and lower the cost of financial intermediation for banks and financial service providers [8,9,10]. Further evidence from pertinent research shows that the DFI regional development gap has shrunk, which is crucial for bridging the urban-rural digital divide in China's dual economic system [11]. Additionally, DFI can [12,13], improve the environment [14,15]and stimulate the consumption among urban and rural residents [16].

Up to now, three measurement schemes have made important contributions to the operational analysis of DFI: The first is the DFII jointly calculated by schools and enterprises. For example, the Chinese DFI system jointly compiled by Peking University and Ant Financial Services Group is constructed from the coverage breadth, usage depth, and digitization level, providing convenience for subsequent academic research and practical analysis [17]. The second is the data on digital finance included in the questionnaires. For instance, researchers, financial institutions, and administrative divisions frequently use the China Household Finance Survey (CHFS) data, the Rural Inclusive Finance Survey data, and the Inclusive Finance Index published by the People's Bank of China. The third is the new index system with comprehensive revision and expansion of previous data. Scholars construct DFII systems through other measurement methods depending on the research needs and finally obtain the corresponding index. Khera et al. [18]utilized a three-stage principal component approach to measure digital indicators of inclusive finance concerning payment. The index provides an opportunity to evaluate the extent of the digital gap and the likelihood of financial exclusion. Since DFII from Peking University is widely used in academia, this paper prioritizes using this data set in research.

The traditional consumption function highlights that the most important factor affecting individual consumption is income, including current and expected income. In reality, however, individual consumption is frequently affected by liquidity constraints [19]. According to the shopping time model, the consumption process has a time cost. Cash-dependent residents must obtain bank liquidity to achieve inter-temporal consumption [20]. The precautionary saving theory holds that savings can alleviate the consumption problems caused by liquidity constraints to some extent [21]. Modern finance provides more diverse payment, credit, and investment methods for most residents, to better smooth consumption for all ages, which deserves attention [22]. In addition to residents' income and liquidity constraints, family size, financial market development [23], human capital level [24], and social welfare degree [25] will also have an impact on the credit and consumption process of residents of different ages. Furthermore, the impact of DFI on individual consumption upgrading, particularly among Chinese large-scale rural people, is an issue with theoretical and policy significance.

In the current development period, consumption has become the primary engine of economic growth throughout the current development phase. Most academics use Maslow's hierarchy of needs theory to examine the level of economic growth from the standpoint of improving consumption structure. Existing studies broadly divide consumption into three types: subsistence consumption,[1] developmental consumption, and hedonic consumption, and believe that if the proportion of the latter two levels of consumption in total consumption increases, there will be a consumption upgrade [26]. The developed coefficient method and the new Engel coefficient method, which measure the proportion of cultural and recreational consumption and the proportion of medical and recreational consumption, respectively, are then obtained from the macroscopic perspective. Measuring techniques, such as improving consumption quality, concepts, and systems, have been developed from a microscopic perspective. Most academics concur that the consumption pattern of urban and rural people is evolving, with regional variability, whether seen from a macro or micro perspective [27]. Those with opposing viewpoints, however, contend that there is neither an improvement in nor even a decline in consumption in rural areas because rural residents are subject to more severe liquidity restrictions than urban residents, who are overly sensitive to

[1] We adopted the ratio of other consumption (including developmental and hedonic consumption) and subsistence consumption expenditure to measure URCS.

current income and considerably influenced by previous consumption patterns [4].

In building a current development pattern, robust digital growth has supported an inclusive financial system, which can meet the financial needs of most citizens who find it challenging to access financial services through conventional channels, thereby boosting consumer demand.

To date, the viewpoints on the nexus of DFI and rural residents' consumption have fallen into two categories. The first kind proposes that DFI mainly promotes consumption through the provision of credit services and convenient payment methods [28], especially for residents in marginalized areas and low-income families [29,30,16]. The other kind holds that convenience payment plays a major role while relaxing consumption constraints is not the main reason [31]. Meanwhile, given the massive urban-rural gap in products and prices, the income level of rural residents has improved significantly. However, the consumption level has remained constant.

Further analysis and discussion are actively carried out based on the above categories. First of all, outstanding achievements have been made in three aspects of the research paradigm shift, mechanism mining and conclusion diversification. Du [32] took the lead in proposing a research paradigm shift from the traditional research paradigm (consumption and income) to the research paradigm (supply and demand structure) in the digital technology era and analyzed the effect of the Internet's influence on consumer upgrades. He found that Internet products, services, and channels can promote consumption upgrading by influencing consumption objects, consumption environment, and consumption methods. On this premise, Zhu [33], claimed that both demand and supply are conducive to URCS. In other words, on the demand side, information technology can release consumption demand, alleviate liquidity constraints, increase employment and entrepreneurship opportunities, and generate income effect. On the supply side, technological progress not only enables residents to obtain more information through the Internet and expand their consumption scope but also factors to reorganize and gather to reduce production costs. However, Li et al. [30] believe that DFI can increase the recurrent consumption expenditure of rural residents rather than the non-recurrent consumption expenditure so that the consumption upgrade of residents is not significant.

At the same time, existing research focuses on the difference between urban and rural consumption upgrades. Zou and Wang [34] concentrated on analyzing the internal mechanism of DFI affecting urban and rural consumption upgrading. They found that critical variables such as income and consumer credit can promote consumption levels. Jiang and Jiang [2] conducted a heterogeneity test and found that DFI has a more substantial promoting effect on rural areas than urban ones. Therefore, residents' consumption level and structure could be improved by narrowing the urban-rural income gap and optimizing industrial structure.

Combining related studies, we found few kinds of literature on URCS from spatial and functional perspectives. The possible marginal contributions of our research are as follows: firstly, drawing on the idea of structural functionalism, we constructed a new integrated analysis framework to reveal the primary mechanism and spatial characteristics of DFI and URCS. Secondly, we created a theoretical model for mathematical derivation and then built the Spatial Error Model (SEM) and threshold effect models (personal income and family size as thresholds) to conduct theoretical and empirical analysis. Thirdly, based on spatial economics, we analyzed the geographic heterogeneity of DFI in the dimension of specific economic regions on URCS.

3. Theoretical deduction

In the age of the digital economy, DFI is a crucial component of the financial sector. It is the growth and augmentation of traditional finance, inheriting its attributes while enhancing the meaning of digital finance [35]. Premised on a fundamental understanding of traditional finance, we divided the main functions of DFI into basic function, core function, and derivative function and analyze the primary mechanism of DFI to raise the consumption level of rural residents, referring to the traditional theoretical framework with income as the main variable and the demand-supply type analysis framework (Fig. 1).

The basic function of DFI is to use digital technologies to improve financial service capabilities, expand the financial scope, and show inclusiveness in remote regions. On the one hand, DFI can reduce service costs and reliance on offline outlets. Banks or operators

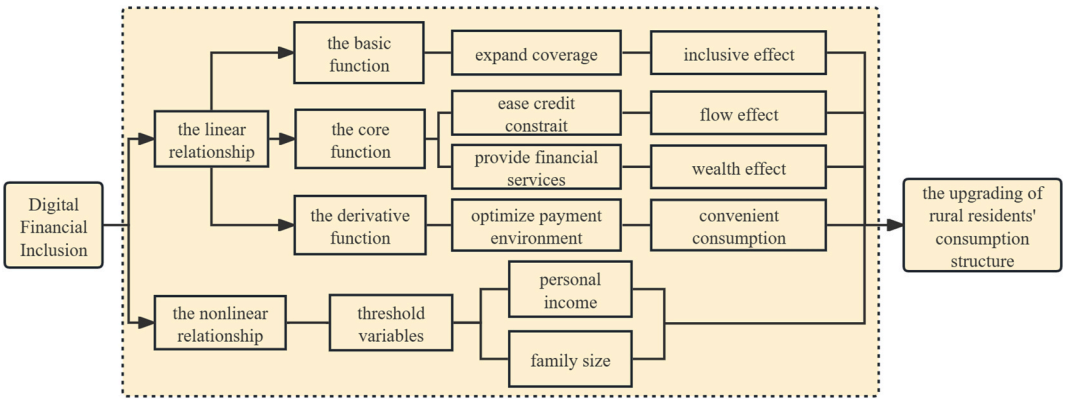

Fig. 1. The mechanism of DFI on URCS.

that previously abandoned remote markets can use DFI to provide miniature financial services again to alleviate the financial exclusion of underdeveloped areas. On the other hand, thanks to the platform economy and economies of scale, the online platform business model can overcome the previous problem of information asymmetry between supply and demand, and digital technologies can aggregate and collect credit histories, reducing rural residents' steps to access financial services and thereby boosting consumption.

The core function of DFI is to ease credit constraints and provide financial services. The consumer credit doctrine holds that consumers have the incentive to finance loans, to meet daily consumer needs. The development of DFI provides online micro-credit loans for people in remote areas, which can alleviate the liquidity constraints of such people, solve the problem of limited consumption in the current period, and then smooth consumption with a better and innovative way of borrowing and financing [36,37]. On the one hand, eligible consumers can directly borrow and raise funds through the digital platform, which is equivalent to increasing their current income and promoting consumption. On the other hand, Internet financing platforms have also increased entrepreneurial opportunities for rural residents, improving residents' income and consumption levels, promoting economic development in underdeveloped areas, and providing feasible ideas for rural revitalization [38,39]. The popularization of DFI not only overcomes liquidity barriers but also optimizes the asset allocation of residents by providing financial services. Through various micro-financial management methods, residents can allocate their assets by buying financial assets when the price decreases and selling assets when the financial price rises. Then they can accumulate wealth through financial management, thereby raising consumption levels.

The derivative function of DFI is to optimize the payment environment and enhance the convenience of consumption. With the help of electronic financial networks, consumers can use electronic money to complete the entire payment and settlement process, saving the time of procurement and relying on commercial banks and third-party payment institutions. According to the recent research by Zhang et al. [31], the development of DFI breaks the limitations of time and space, facilitates residents' payment, makes the shopping cash constraint smaller, and raises the consumption utility of residents. While meeting consumers' payment needs, DFI may bring new consumption needs and promote URCS.

According to the above analysis, DFI can smooth consumption and relieve liquidity constraints. Accordingly, based on the utility maximization theory of rational man and the correlation analysis of shopping time [20,31], this paper constructs the following benchmark model:

$$L(Y-\overline{Y})(1+r)=(Z+Q)\overline{Y} \tag{1}$$

Where L, Z, and Q represent children, young adults, and the elderly, respectively. Y represents the annual average disposable income of the working-age population, and R represents the interest rate of individual asset allocation, that is, the price of wealth. Suppose that the average annual consumption expenditure of rational people, denoted, is the same in the three stages of life, that is, the childhood period, the working age period, and the elderly period. Only the working-age population receives income, putting all the remaining income into the financial market for asset allocation.

If the per capita consumption in the current year is C, the price of unit consumer goods is P, and the shopping time cost of unit consumer goods is M, Eq. (2) can be obtained as follows:

$$\overline{Y}=C(P+M) \tag{2}$$

DFI reduces information costs acquired through the inclusive effect of expanding the coverage area and the cost of payment by improving the payment environment, which can effectively lower the price per unit of goods, including shopping time. Therefore, DFI development makes $M=f(DFI)$, then $\frac{dM}{dDFI}=\frac{df(DFI)}{dDFI}<0$.

Divide both ends of Eq. (1) by L to obtain Eq. (3):

$$(Y-\overline{Y})(1+r)=\frac{Z+Q}{L}\overline{Y} \tag{3}$$

In Eq. (3), $\frac{Z+Q}{L}$ represents the sum of the child and old-age dependency ratios.

Substituting Eq. (2) into Eq. (3), Eq. (4) can be obtained:

$$C=\frac{Y}{(P+M)\left(1+\frac{Z+Q}{L}\bullet\frac{1}{1+r}\right)} \tag{4}$$

Substituting $M=f(DFI)$ into Eq. (4), we could get Eq. (5):

$$C=\frac{Y}{[P+f(DFI)]\left(1+\frac{Z+Q}{L}\bullet\frac{1}{1+r}\right)} \tag{5}$$

Calculating the derivative of Eq. (5) with respect to DFI, the outcome is as follows:

$$\frac{\partial C}{\partial DFI}=-\frac{Y}{\left(1+\frac{Z+Q}{L}\bullet\frac{1}{1+r}\right)}\bullet\frac{1}{[P+f(DFI)]^2}\bullet\frac{df(DFI)}{dDFI} \tag{6}$$

Since $\frac{Y}{\left(1+\frac{Z+Q}{L}\bullet\frac{1}{1+r}\right)}\bullet\frac{1}{[P+f(DFI)]^2}>0$ and $\frac{df(DFI)}{dDFI}<0$, so $\frac{\partial C}{\partial DFI}>0$. Therefore, combined with theoretical analysis, the first research hypothesis

is proposed:

Hypothesis 1. DFI can promote URCS in China with spatial effects and spatial heterogeneity.

Next, Eq. (5) first takes the derivative of Y and then takes the derivative of DFI to obtain Eq. (7):

$$\frac{\partial C}{\partial Y}=\frac{1}{[P+f(DFI)]\left(1+\frac{Z+Q}{L}\bullet\frac{1}{1+r}\right)}>0,\frac{\partial\frac{\partial C}{\partial Y}}{\partial DFI}=\frac{1}{\left(1+\frac{Z+Q}{L}\bullet\frac{1}{1+r}\right)}\bullet\frac{1}{[P+f(DFI)]^2}>0 \tag{7}$$

As shown in Eq. (7), rising incomes can boost consumption, and the increase is related to DFI. Based on the literature review, the second hypothesis is put forth.

Hypothesis 2. DFI has a threshold effect on URCS, with personal income as the key factor.

Moreover, household size, as a crucial variable of household characteristics, can significantly impact consumption. As shown in Eq. (6), alteration in the population numbers of the three age groups will affect the efficiency of DFI in promoting URCS. Thus, the third hypothesis is put forward.

Hypothesis 3. DFI has nonlinear characteristics on URCS with family size as the threshold variable.

4. Empirical strategy

4.1. Data

We used the DFII of Peking University and panel data from the China Rural Statistical Yearbook (2012–2021), China Statistical Yearbook (2012–2021), and provincial statistical yearbooks for the 2011–2020 years. Since there are fewer missing values completed by the interpolation method, the overall data can reflect the actual situation.

4.2. Variables

We briefly described the main variables used in the empirical analysis here. The explained variable in our research is URCS. Drawing on existing studies' classification of consumption expenditure, we divided consumption expenditure into subsistence consumption and developmental and hedonic consumption. Among them, food, clothing, and housing expenditure are classified as subsistence, while the remaining categories are categorized as developmental and hedonic. Thus, we used the ratio of hedonic and developmental consumption to subsistence consumption to measure URCS.

After thoroughly comparing several representative indices, we chose the province DFII of Peking University as the core explanatory variable to gauge the impact of DFI [17]. This data set is measured by the analytic hierarchy process, including thirty-three indicators in three parts. It has good explanatory power in the empirical study because of its strong time continuity, broad spatial coverage, and high digital level.

Some other factors might affect the relationship between DFI and URCS. Referring to the previous research, we controlled for an array of characteristics, including personal income, family size, aging level [40], human capital level [24], social security [25], and market-oriented development [23]. Table 1 provides detailed information on all variables.

The descriptive statistics in Table 2 show that the consumption upgrading of rural residents varied noticeably across provinces from 2011 to 2020. While the minimum value is merely 31%, the maximum value is 117%. The maximum value of DFI is 431.9, the minimum value is 16.22, and the standard deviation (SD) is 97.03, with a significant regional variation. Every province also has considerable regional variations in terms of other variables, such as personal income, family size, and market-oriented development. Through the multicollinearity test, we found that the variance inflation factor of each variable is less than 5, and the mean value is 2.77, indicating no multicollinearity problem between variables. This section of the research lays the groundwork for the subsequent spatial and mechanism analysis.

4.3. Model

4.3.1. Global spatial correlation test

Due to the imbalance in the digital transformation, there are differences in factors such as endowment, policy support, and location conditions among provinces [6]. The analysis carried out in this paper focuses on the analysis from the spatial perspective and needs to judge the spatial effect of the research object. Before that, we were supposed to study its spatial correlation. To a certain extent, the spatial correlation can be reflected by Moran's I. Therefore, we used Global Moran's Index of DFI and URCS with a 0-1 adjacent matrix to determine whether it is necessary to introduce spatial factors into the panel data.

As shown in Table 3, the Global Moran's Indices are all greater than 0, indicating that DFI and URCS in China exhibited a spatial agglomeration phenomenon. Relying on advanced digital information technology, DFI reduces the spatial and temporal barriers, flow, and transaction costs of resource elements, accelerates the development process of financial agglomeration and diffusion, and plays a more significant spatial interaction between regions in China. Meanwhile, rural residents also can rely on the platform economy to consume, breaking the constraints of traditional space. Therefore, in general, it is appropriate to choose the spatial econometric model.

Table 1
Variables definitions.

Variable	Name	Abbreviation	Related explanations
Explained variable	Upgrading of rural consumption structure	URCS	The ratio of rural hedonic and developmental consumption to subsistence consumption
Explanatory variable	Digital Financial Inclusion	DFI	Digital Financial Inclusion Index of Peking University
Control variables	Personal income	PI	Per capita disposable income of rural residents (1000 yuan)
	Family size	FS	The proportion of the number of three-person rural households in the number of total rural household households
	The aging level	AL	The population over 65 years old to 15–64 years old ratio
	Human capital level	HCL	Average years of schooling of the rural working-age population
	Social security	SS	DEA-Malmquist is used to calculate the total factor productivity of fiscal medical and health expenditure [41] [2]
	Market-oriented development	MOD	The total score of the market-oriented development process [42,43]

[2] The input variable is per capita local financial health expenditure (yuan), and the output variables are the number of medical and health institutions per 10,000 people, medical and health institutions' beds per 10,000 people (piece), and the number of health technicians per 10,000 population (person).

Table 2
Descriptive statistics of the variables.

Name	Obs.	Mean	SD	Min	Max	Variance inflation factor
URCS	310	0.687	0.173	0.310	1.170	–
DFI	310	216.2	97.03	16.22	431.9	3.48
PI	310	12.49	5.504	3.910	34.91	4.61
AL	310	0.176	0.0643	0.0700	0.450	2.08
FS	310	0.210	0.0342	0.100	0.310	1.32
HCL	310	11.44	1.288	5.400	15.35	2.31
MOD	310	6.586	2.322	−1.420	11.40	4.42
SS	310	0.921	0.113	0.500	1.650	1.14

Table 3
Global Moran's I of the core variables.

year	DFI		URCS	
	Moran's I	P-value	Moran's I	P- value
2011	0.4903	0.0000	0.6629	0.0000
2012	0.4868	0.0000	0.6555	0.0000
2013	0.4562	0.0000	0.4023	0.0003
2014	0.4531	0.0000	0.3501	0.0011
2015	0.4163	0.0001	0.3757	0.0006
2016	0.4378	0.0001	0.2670	0.0107
2017	0.4978	0.0000	0.3833	0.0004
2018	0.5440	0.0000	0.4812	0.0000
2019	0.5445	0.0000	0.5116	0.0000
2020	0.5628	0.0000	0.3913	0.0004

4.3.2. Local spatial correlation test

The global spatial correlation can convey the qualities of the study variables' general geographical correlation. However, it is possible to overlook the atypical properties of local provinces. Therefore, this research uses local Moran Scatter Plots to test whether there are clusters in local provinces.[3] A positive Moran's Index means that areas with a similar degree of development are adjacent (H–H or L-L), and a negative Moran's Index means that areas with different levels of development are adjacent (H-L or L-H).

From the perspective of the local spatial part, all production factors can break through geographical restrictions to achieve cross-regional flow. The closer the geographical distance, the higher the efficiency of factor flow between regions. Therefore, the neighboring areas have particular relevance in production, economic development, and other aspects, and financial development is often consistent with regional economic development. Figs. 2 and 3 show that DFI and URCS are principally distributed in two quadrants, showing a clustering trend of "H–H" and "L-L." Hence, we focused on these two quadrants in Table 4.

[3] The numbers 1–31 represent 31 provinces.

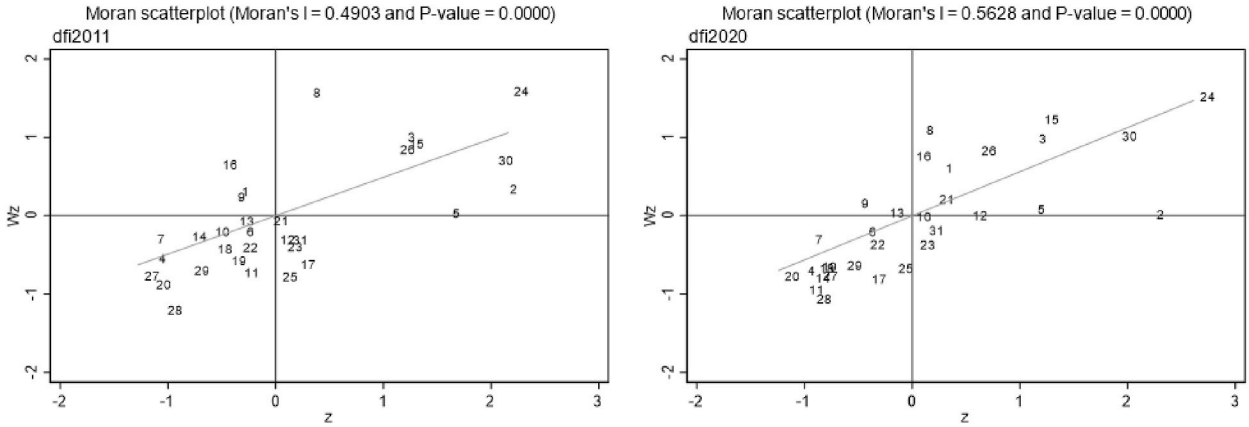

Fig. 2. Local Moran map of DFI in 2011 and 2020.

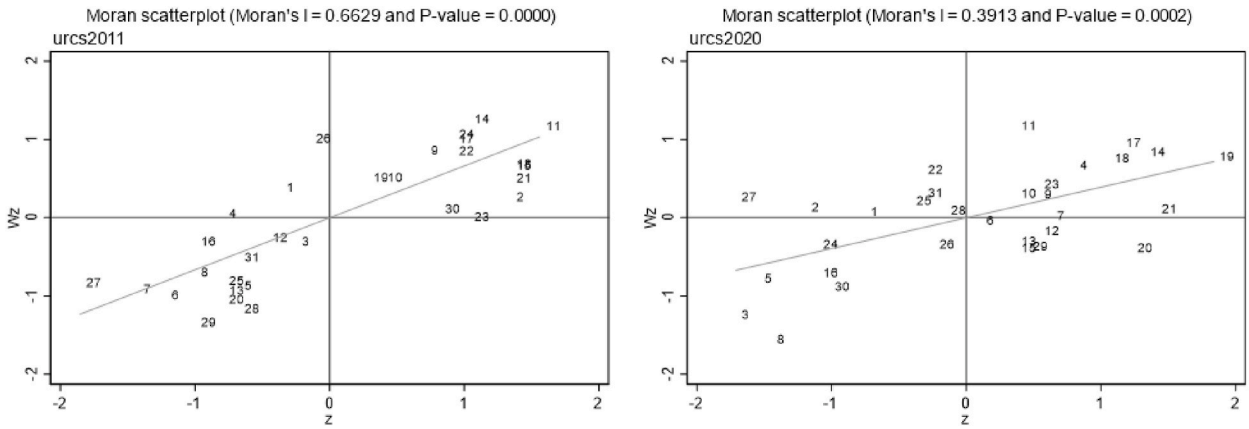

Fig. 3. Local Moran map of URCS in 2011 and 2020.

Table 4
Local spatial correlation test for DFI and URCS.

	year	The first quadrant (H–H)	The third quadrant (L-L)
DFI	2011	Beijing, Tianjin, Shanghai, Zhejiang, Jiangsu, Fujian, Hainan, Guangdong (8)	Hunan, Guangxi, Henan, Shanxi, Jilin, Inner Mongolia, Ningxia, Heilongjiang, Guizhou, Gansu, Yunnan, Tibet, Qinghai, Xinjiang (14)
	2020	Beijing, Tianjin, Shanghai, Zhejiang, Jiangsu, Fujian, Shandong, Guangdong, Anhui, Hubei, Hainan, Jiangxi, Henan (13)	Guangxi, Shanxi, Jilin, Inner Mongolia, Ningxia, Heilongjiang, Guizhou, Gansu, Yunnan, Tibet, Qinghai, Xinjiang, Sichuan, Liaoning (14)
URCS	2011	Beijing, Shanghai, Zhejiang, Jiangsu, Shandong, Shanxi, Shaanxi, Henan, Hebei, Inner Mongolia, Ningxia, Heilongjiang, Jilin, Liaoning (14)	Tibet, Guizhou, Guangxi, Jiangxi, Hainan, Yunnan, Xinjiang, Qinghai, Hunan, Sichuan, Chongqing, Hubei, Fujian, Guangdong (14)
	2020	Ningxia, Shandong, Guizhou, Henan, Hebei, Shaanxi, Heilongjiang, Gansu, Inner Mongolia, Liaoning, Jilin (11)	Tianjin, Shanghai, Jiangxi, Zhejiang, Guangdong, Fujian, Hainan (7)

Table 4 displays that the provinces in the first quadrant are mainly located in the east, such as Beijing, Shanghai, and Zhejiang. The provinces in the third quadrant are chiefly located in the west, such as Tibet and Gansu. The coverage of DFI has increased significantly in the provinces of "H–H" over time, reflecting the inclusive effect of DFI. However, the number of "L-L" regions is still large, showing that the development of DFI is uneven in Chinese regions. Regarding URCS, the provinces in the first quadrant are mainly concentrated in the southwest and northeast, while the provinces in the third quadrant are scattered everywhere. That is, the consumption levels of rural residents require balanced development. By comparing different years, in 2020, there were much fewer provinces in the third quadrant than in 2011, indicating that the consumption condition of rural citizens in provinces has improved recently.

4.3.3. Spatial panel model

In the spatial observations of economic activity, spatial auto-correlation and dependence are frequent. According to the sources of

spatial correlation effects, spatial econometric models are classified into Spatial Lag Model (SAM), Spatial Error Model (SEM), and Spatial Durbin Model (SDM). The SAM believes that spatial correlation effects primarily come from explained variables, the SEM assumes that spatial correlation effects are caused by spatial correlation of error terms, and the SDM considers that spatial correlation effects mainly originate from the spatial association effect of the explanatory variables.

This paper conducts a model selection test after taking logarithms of all variables to clarify the main effects of DFI on URCS. As shown in Table 5, we conducted LM, Hausman, and fixed effects texts, using the geographic distance matrix.[4]

In Table 5, firstly, the LM test proves that the model passes the SEM test but fails the SAR test. That is, the SEM[5] is more suitable for the study. Secondly, the Hausman test results show that the fixed effects of the proposed model are better. Finally, the joint test of fixed effects shows that the choice of the spatial econometric model with temporal and spatial fixation fixed effects is optimal. Based on the test results, we selected the SEM based on double fixed effects for our study. The specific formulas are as follows[6]:

$$\begin{cases} lnURCS_{it} = \alpha_1 lnDFI + \alpha_2 lnPI + \alpha_3 lnAL + \alpha_3 lnFS + \alpha_4 lnHCL \\ \qquad +\alpha_5 lnMOD + \alpha_6 lnSS + \mu_i + \gamma_t + \varepsilon \\ \qquad \varepsilon = \lambda \sum W_{it}\varepsilon_{it} + \nu_{it} \end{cases} \tag{8}$$

Where W_{it} is the geographic distance weight matrix, $\sum W_{it}\varepsilon_{it}$ is the spatial lag term of the error term, λ is the spatial error correlation coefficient, μ_i is the individual effect, γ_t is the time effect, and ε is the random disturbance term. The definitions of the other variables are the same as in Table 1.

5. Empirical results

5.1. Analysis of SEM results

We used three matrices (the geographic distance, the 0-1 adjacent, and the DFI nested matrices) to conduct SEM analysis of temporal and spatial fixation, better comparing the regression results under different models. The SEM results[7] are in Table 6.

The value of the spatial error correlation coefficient λ is significantly positive, indicating that the random shocks of other provinces can promote URCS in these matrices. Meanwhile, the coefficient of DIF has a favorable effect on URCS, confirming the contribution of the development of DIF to the enhancement of URCS. When other things are equal, increasing 1 unit in the logarithm of DFI can take the logarithm of URCS nearly 0.4 units better off. It demonstrates how DFI in China can ease consumers' liquidity concerns, overcome geographical constraints, pay attention to the "tail" group, and offer convenient payment to encourage locals' purchasing. Thus, Hypothesis 1 is verified.

From the perspective of control variables, the estimated parameters of rural residents' per capita income, family size, and human capital level variables are all positive, which is consistent with theoretical expectations. Among them, the parameters of per capita income and human capital level are significant. Increasing income allows residents to expand their real money balance through the wealth effect and promote consumption upgrading for the transaction demand. And the improvement of human capital level can increase the probability of rural residents using digital platforms for loans and financial planning. Furthermore, the coefficients of the aging level, market-oriented development, and social security are negative, revealing that the aging process can discourage spending among rural people, the external cost effect of marketization can inhibit consumption and the government's medical and health expenditure has a crowding-out effect on consumption.

5.2. Spatial heterogeneity analysis

Considering the uneven regional growth of China [44,45], this paper, dividing 31 provinces into eastern and non-eastern parts,[8] attempts to analyze the spatial heterogeneity of the impact of DFI on URCS from the perspective of a "smooth economy" in modern economics and a "block economy," namely an agglomeration economy, which is advocated by spatial economics.

The SEM is employed in this research to further illuminate the effect of DIF on URCS in the eastern and non-eastern regions by the optimal model identified by the aforementioned analysis. According to Table 7, the eastern region's provinces are less impacted by the

[4] The spatial weight matrix is used to measure the spatial relationship. This paper considers that the research content is related to geographical distance, so it mainly uses a spatial inverse distance matrix to discuss. The standardized inverse distance matrix is selected as the research matrix, and its matrix elements are derived from the reciprocal of the distance calculated according to the longitude and latitude. The matrix is strictly exogenous, which is convenient for scholars to study. We also used the 0-1 adjacent matrix and the DFI nested matrix to measure and obtain similar answers.

[5] The SEM is a statistical model used to explain the statistical behavior of spatial data. It assumes an asymmetrical interrelationship between spatial data. That is, spatial data is affected by its surroundings, while other data is not. It can accurately predict the spatial relationship between data.

[6] In this paper, heteroscedasticity is avoided by taking logarithms of variables.

[7] The results of SDM and SAR using the geographical distance matrix are included in the appendix.

[8] In the sample, Eastern China includes Liaoning, Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Hainan; non-eastern China consists of Jilin, Heilongjiang, Inner Mongolia, Shanxi, Henan, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, and Xizang.

Table 5
Model selection test.

	Model test	Statistic	P-value
LM test	LM-Error	382.317	0.000
	Robust LM-Error	269.511	0.000
	LM-Lag	113.449	0.000
	Robust LM-Lag	0.641	0.423
Hausman test	Null hypothesis: The model passed the random effects test	438.09	0.000
Fixed effects test	Null hypothesis: Individual fixation is superior to temporal and spatial fixation	41.04	0.000
	Null hypothesis: Temporal fixation is superior to temporal and spatial fixation	430.95	0.000

Table 6
The estimated results of SEM.

	SEM		
Variables	Geographic distance matrix	0-1 adjacent matrix	DFI nested matrix
lnDFI	0.384***	0.372***	0.367***
	(8.31)	(7.65)	(7.41)
lnPI	0.375**	0.293*	0.381**
	(2.66)	(2.02)	(2.65)
lnAL	−0.110**	−0.103*	−0.117**
	(−2.58)	(−2.40)	(−2.73)
lnFS	0.0378	0.0209	0.0177
	(0.65)	(0.37)	(0.30)
lnHCL	0.357*	0.379**	0.363*
	(2.38)	(2.58)	(2.45)
lnMOD	−0.0694***	−0.0709***	−0.0673***
	(−5.35)	(−5.79)	(−5.39)
lnSS	−0.0129	0.00596	0.0102
	(−0.30)	(0.14)	(0.23)
λ	0.337*	0.330***	0.213***
	(2.05)	(4.42)	(3.65)
Obs	310	310	310
Log-L	387.4092	394.4548	392.0679

Note:(1) t statistics in parentheses. (2) *p < 0.05, **p < 0.01, ***p < 0.001.

spatial impact of random shocks from other regions than the non-eastern provinces because the coefficient of the lag term of the spatial error is insignificant in the eastern but significant in the non-eastern region. Furthermore, we found that DFI has a different impact on the URCS in the two regions. In eastern China, the logarithm of URCS increases by more than 0.5 for every 1 unit increase in the logarithm of DFI, which is nearly 0.2 greater than that in non-eastern China. In other words, the impact of DFI on URCS is more significant in the eastern region than in the non-eastern part, which is different from previous studies [16].

Table 7
Results of sub-regional spatial regression.

	Eastern China			Non-eastern China		
Variables	Geographic distance matrix	0-1 adjacent matrix	DFI nested matrix	Geographic distance matrix	0-1 adjacent matrix	DFI nested matrix
lnDFI	0.536***	0.551***	0.555***	0.326***	0.343***	0.285***
	(6.54)	(6.47)	(6.54)	(4.75)	(5.09)	(4.04)
lnPI	−0.849***	−0.674**	−0.706**	0.562**	0.478*	0.540*
	(−3.92)	(−3.07)	(−3.01)	(2.72)	(2.29)	(2.55)
lnAL	−0.0779	−0.0801	−0.0800	−0.0717	−0.0607	−0.0803
	(−1.70)	(−1.71)	(−1.71)	(−0.93)	(−0.79)	(−1.05)
lnFS	0.160*	0.135*	0.138*	−0.0473	−0.0647	−0.0744
	(2.51)	(2.10)	(2.14)	(−0.52)	(−0.73)	(−0.82)
lnHCL	−0.592	−0.689*	−0.665*	0.500**	0.548***	0.507**
	(−1.89)	(−2.17)	(−2.07)	(3.05)	(3.41)	(3.13)
lnMOD	0.111	0.147	0.144	−0.0673***	−0.0713***	−0.0643***
	(0.83)	(1.15)	(1.11)	(−4.87)	(−5.48)	(−4.96)
lnSS	−0.0240	−0.0227	−0.0228	0.0644	0.0737	0.0719
	(−0.47)	(−0.44)	(−0.45)	(0.87)	(1.05)	(1.05)
λ	−0.515*	−0.0285	−0.0533	0.194*	0.312***	0.233***
	(−2.36)	(−0.26)	(−0.46)	(1.02)	(3.42)	(3.39)
Obs	110	110	110	200	200	200
Log-L	174.3379	158.9179	158.9927	294.8965	261.2567	261.4389

There are three possible reasons: firstly, compared with non-eastern regions, eastern regions have a more developed economic level and more complete digital financial services, which can provide more opportunities to participate in digital credit and meet the needs of rural residents for high-level consumption. Secondly, compared with the eastern region, the penetration rate of digital knowledge in the non-eastern region is lower, and some rural residents are stuck in the traditional way of borrowing and unwilling to bear the risk of participating in digital finance. Thirdly, due to the influence of the "ratchet effect," rural residents in non-eastern areas are more inclined to buy subsistence commodities than those in western areas, even if the real money balance is increased by digital means, thus inhibiting URCS.

6. Further research: nonlinear regression

The impact of DFI on the URCS may have nonlinear characteristics. On the one hand, the data elements used in DFI possess the scale economy effect due to the agglomeration economy. The marginal cost of financial goods and services is almost zero once a DFI's degree of development crosses a specific threshold, encouraging consumers to increase their consumption. On the other hand, the overlapping of DFI with technology and cyber risks is likely to breed new risks. When this kind of risk concentration level exceeds a certain threshold, it may have an uncertain impact on the consumption promotion function of DFI.

According to the above, this paper draws on Hansen's analysis. As for the path of threshold model analysis, the personal income and family size of rural residents are taken as the threshold variables of DFI affecting URCS to test and analyze. Numerous academic works have demonstrated the significant impact that income level has on consumption. The academic community has gradually come to understand the significance of family size in influencing consumer choices throughout time [46]. Using the ratio of three-person households, which is currently common in China, as a household size variable, this paper analyzes changes in the level of rural consumption structure under different household sizes, in contrast to previous literature that concentrated on micro household data in consumption research [31].

The following panel threshold effect model is built:

$$URCS_{it} = \pi_0 + \pi_1 DFI_{it} \times I(M_{it} \le \theta_1) + \pi_2 DFI_{it} \times I(\theta_1 < M_{it} \le \theta_2) + \cdots$$

$$+\pi_n DFI_{it} \times I(\theta_{n-1} < M_{it} \le \theta_n) + \omega Z_{it} + \mu_i + \varepsilon_{it} \tag{9}$$

Where, M_{it} represents the threshold variable, θ_1、$\theta_2 \cdots \theta_n$ are the threshold values, I is the indicator function, Z_{it} is the control variable, μ_i represents the individual effect, and ε_{it} represents the random disturbance term.

Table 8 demonstrates that the PI threshold variable passes the double threshold test, with an estimated threshold value of 12.88 and 25.52. Meanwhile, the threshold variable of FS passes the single threshold test with its threshold estimate of 0.22, which is significant at 0.05. Examining PI and FS, this paper adopts the double threshold and the single threshold models, respectively. The analysis findings are displayed in Table 9.

As shown in Table 9, PI is divided into three intervals by the threshold values. In the first interval, DFI can promote URCS. When PI reaches the first threshold value, the promoting effect of DFI decreases by about 30%. When PI approaches the second threshold value, the promotion effect of DFI reduces by about 44%. That is to say, the "marginal effect" of rural residents' consumption upgrading is decreasing. Although the aggregation of data elements makes the development of DFI beneficial to consumption upgrading, with the increase in income level, the superposition of financial risks and network risks can reduce consumers' purchase intention, which restrains consumption upgrading to a certain extent. Then, Hypothesis 2 is confirmed.

In terms of FS, DFI encourages rural consumption upgrading when the FS is low. After exceeding the threshold value, the effect of DFI rises by around 10%. In other words, the promotion of DFI is stronger after the percentage of three-person families crosses the threshold figure. This finding demonstrates how the upgrading of home consumption in the age of the digital economy is facilitated by household downsizing. Finally, Hypothesis 3 is proved.

Unlike existing studies that attribute the impact of DFI on consumption upgrading to income level and credit constraints, this paper finds that family size also affects the research process, thus expanding the corresponding research.

7. Conclusion

This paper summarizes the literature, theoretical analysis, and mathematical model derivation of the influence of DFI on rural residents' consumption. The spatial and threshold effect effects are then analyzed using provincial data from 2011 to 2020 in China, and spatial heterogeneity is analyzed for eastern and non-eastern regions. This paper attempts to elucidate the main mechanism effects

Table 8
Estimation results of threshold values.

Threshold variable	Model	Estimate of threshold	F-value	P-value	BS number	The critical value		
						1%	5%	10%
PI	Single threshold	12.88	31.82	0.00	300	13.99	16.74	23.69
	Double threshold	25.52	23.72	0.00	300	12.98	15.03	19.92
FS	Double threshold	0.21	9.54	0.04	300	7.11	8.76	10.91

Table 9
Regression results of threshold model.

Threshold variable	Variable	The coefficient	T-value	P-value
PI	DFI (PI $\leq$ 12.8800)	0.0013674***	9.25	0.000
	DFI (12.8800 $<$ PI $\leq$ 25.5200)	0.0009518***	6.45	0.000
	DFI (25.5200 $<$ PI)	0.0007088***	4.18	0.000
FS	DFI (FS $\leq$ 0.2100)	0.001817***	7.88	0.000
	DFI (0.2100 $<$ FS)	0.0020752***	8.93	0.000

and spatial characteristics of DFI to URCS from both theoretical and empirical aspects. At the same time, the robustness of regression analysis is ensured by replacing the spatial weight matrix.

We concluded as follows.

(1) The development of DFI can significantly promote URCS through its basic, core, and derivative functions, which can alleviate the urban-rural wealth gap and promoting internal circulation. By replacing the spatial weight matrix to solve the robustness, the conclusion is still credible. At the same time, the spatial random effect of DFI on rural consumption level is significant, indicating that rural residents' consumption habits are not only affected by their province but also affected by the random shocks of other provinces. This conclusion is consistent with current research.
(2) In the spatial heterogeneity analysis of the two regions, the villagers in eastern China are the primary beneficiaries of DFI. Their consumption structure upgrading is more significant than that in non-eastern China. In other words, the consumption upgrading of the eastern region is more evident in the spatial economy. Meanwhile, the utilization efficiency of DFI could be lower in other gathering areas where financial marketization is developing slowly. The current impact of DFI on URCS is limited in less developed areas, which is different from previous studies. At the same time, non-eastern regions are more vulnerable to random shocks than non-eastern regions.
(3) The threshold effect of PI and FS in the relationship between DFI and URCS has been confirmed. When PI is taken as the critical variable, the promotion effect of DFI on URCS continues to decline after crossing the threshold value. When the FS is used as the threshold variable, the process shows an increasing trend of "marginal effect." Family miniaturization can improve rural consumption levels, thus expanding the contents of previous research.

Thus, we could get the following enlightenment.

(1) The Chinese government should promote the integration of online financial services and build a more modern and digital financial market system so that the vast majority of rural residents who are relatively poor in digital financial knowledge can understand and learn relevant knowledge. As a result, residents can convert their earnings into spending.
(2) The Chinese government should continue to push for rural digital economy construction., increase the investment in the basic network, reduce the data and the financial risk, fully display inclusiveness and convenience, play a financial flow and wealth effect of the core of the financial function, and improve the urban and rural residents' life.
(3) The Chinese government should strengthen regional exchanges and cooperation, leveraging the spatial effect of DFI to promote remote economic development. Meanwhile, underdeveloped regions can learn advanced technology and experience. Then these ways can affect the economic activities of the residents, improve people's well-being, and promote common prosperity.

Generally speaking, social innovation initiatives are conducive to sustainable rural development [47]. The government should maximize the synergistic effect of DFI and other factors. The improvement of the consumption structure depends on many factors, including the development of DFI. Only by coordinating and cooperating with these aspects can the upgrading of consumption be more effectively promoted.

We are looking forward to the content of this article:

Due to the availability of data, the period of this paper is 2011–2020, 2011 is the period of rapid development of China's digital economy, and the relevant calculation data of the state and institutions started from this year. Subsequent scholars can expand the time to conduct relevant research further. At the same time, Because of the development limitation of the spatial instrumental variable method, we did not carry out the endogeneity test of the spatial error model so that subsequent scholars can conduct relevant analysis.

Data availability statement & rsquo

The data included in this study are available upon request by contact with the corresponding author.

CRediT authorship contribution statement

Jianguo Liu: Writing – original draft. **Yuchen Yao:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

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

Appendix

Table A1
The estimated results of SDM and SAR.

	SDM	SAR
Variables		
lnDFI	0.241***	0.368***
	(4.88)	(8.13)
lnPI	0.376*	0.286*
	(2.23)	(2.00)
lnAL	0.0511	0.0208
	(0.76)	(0.30)
lnFS	−0.0974*	−0.118*
	(−2.12)	(−2.51)
lnHCL	0.646**	0.604**
	(3.27)	(3.09)
lnMOD	−0.00939	−0.0165
	(−0.21)	(−0.37)
lnSS	−0.0582***	−0.0691***
	(−4.27)	(−5.34)
W × lnDFI	0.656*	
	(1.99)	
ρ	0.239	0.488***
	(1.30)	(3.53)
Obs	310	310
Log-L	405.8180	389.4495

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