



# Digital financial inclusion and subjective well-being – Evidence from China health and retirement longitudinal study

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## ABSTRACT

This study investigates the impact of digital financial inclusion (DFI) on the subjective well-being of China's older population, specifically examining the effects on depression, life satisfaction, and self-reported health status. Drawing on data from the China Health and Retirement Longitudinal Study (CHARLS), our research reveals that the advancement of DFI has a significant positive impact on reducing symptoms of depression and improving the self-reported health status of elderly individuals. Furthermore, our analysis of heterogeneity indicates that these welfare improvements are more pronounced in rural areas compared to urban areas and among the non-multidimensional poverty (non-MP) group rather than the multidimensional poverty (MP) group. Moreover, we find that the impact of DFI on depression is more immediate, while its influence on self-rated health takes longer to manifest. These findings collectively suggest that enhancing digital finance can effectively improve subjective well-being, particularly among vulnerable groups such as the elderly population, individuals facing multidimensional poverty, and those residing in rural areas. The immediate relief of depression and the gradual improvement in self-reported health highlight the policy implications of leveraging digital finance to enhance subjective well-being.

## 1. Introduction

The pursuit of a better life is a shared aspiration among individuals, reflecting the vision of the Chinese government. Addressing the increasing demand for a better life has become a central objective in China's development agenda, as emphasized in the document announced during the 19th National Congress of the Party. Subjective well-being (SWB), encompassing physical health, psychological well-being, and life satisfaction, serves as a key indicator of a better life. Thus, satisfying this need for a better life through SWB has become a critical task for China's development in the new century.

This task arises against the backdrop of two significant trends. The first trend is, digitalization has emerged as a vital component of China's economy. The published by the China Academy of Information and Communications Technology, (CAICT), highlights the remarkable growth of China's digital economy. In 2021, the digital economy contributed 39.8% to the GDP, reaching an impressive 45.5 trillion RMB (China Academy of Information and Communications Technology, 2022).

The second trend is, China is experiencing a rapidly aging population. Projections estimate that by the end of 2022, there will be

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approximately 210 million individuals aged 65 and above, accounting for 14.9% of the total population (NBS, 2023). When the trend of digitalization intersects with the aging trend, concerns arise regarding the potential emergence of a “digital divide” that could disproportionately affect the vulnerable aging population. This cohort faces a higher likelihood of experiencing poorer health conditions and living in poverty. If their socioeconomic status further deteriorates due to the digital divide, they may experience increased depression and decreased life satisfaction, making the pursuit of a better life even more challenging. Traditional measures such as increasing public transfers to the elderly may provide limited assistance in narrowing the digital divide since transfers alone cannot address the challenges arising from digitalization.

Examining the potential impact of rapid digital financial inclusion on the subjective well-being of the Chinese elderly is of utmost importance. Digital finance, particularly in the form of fintech, has garnered significant attention due to its remarkable achievements in promoting financial inclusion within China (Dollar & Huang, 2022). The Financial Stability Board defines digital finance as “technology-enabled innovation in financial services that could result in new business models, applications, processes, or products with an associated material effect on the provision of financial services.” In China, the introduction of Yu'E Bao in 2013 is often regarded as the starting point for the country's digital financial development. Since then, various innovative financial models, such as digital payment, digital lending (including online lending, technology-driven lending, and bank lending based on digital technology), digital insurance, digital wealth management, and central bank digital currency, have experienced rapid growth.

Data from WIND reveals significant expansion in internet fund transactions, digital payment market size, internet consumer finance, and online lending from 2013 to 2016. During this period, internet fund transactions increased from 2.2 trillion yuan to 13.3 trillion yuan, the digital payment market grew from 16.9 trillion yuan to 154.9 trillion yuan, internet consumer finance surged from 6 billion yuan to 4.4 trillion yuan, and online lending expanded from 97.5 billion yuan to 2.3 trillion yuan. In comparison to traditional finance, the scale of internet finance cannot be overlooked. By the end of 2017, the size of internet money market funds accounted for approximately 8.6% of M2, online lending constituted around 6.9% of short-term personal loans, and internet insurance represented about 8.7% of the traditional insurance sector. Chinese fintech companies have surpassed 70% of the global valuation, with total personal mobile payments in China reaching 790 billion US dollars in 2016, which is 11 times that of the United States (Zhang & Chen, 2019). China has undeniably emerged as a global leader in digital finance within a short span of time, boasting leading fintech companies and outperforming international counterparts in third-party payments, online lending, digital insurance, and digital currencies.

The potential impact of this rapid digital financial inclusion on the subjective well-being of the Chinese elderly remains uncertain. On one hand, digital financial inclusion can enhance their financial well-being, social connectedness, and overall life satisfaction. By providing access to financial services, digital finance enables convenience and independence, promotes financial empowerment, fosters social inclusion and connectivity, ensures safety and security, facilitates lifelong learning and cognitive stimulation, and allows access to healthcare and wellness services. On the other hand, negative consequences may arise, such as technological barriers, digital exclusion, security concerns, limited human interaction, complexity, insufficient support, and potential exclusion from traditional services, particularly among different population segments. Therefore, it is worthwhile to empirically examine how digital financial inclusion affects the subjective well-being of the elderly population.

This study seeks to examine whether digital financial inclusion (DFI) can contribute to enhancing the subjective well-being of the older population in China. Using data from the China Health and Retirement Longitudinal Study (CHARLS) and the Peking University digital finance index as proxies for DFI, we investigate the effects of digital financial inclusion on the subjective well-being of the elderly. Additionally, we explore the heterogeneity of DFI's impact by considering two dimensions: urban versus rural residency and multidimensional poverty status. Furthermore, we analyze subsamples based on different waves of CHARLS data to assess how these impacts vary over time.

We employ two-way fixed effects models as the baseline approach. To address potential endogeneity resulting from omitted variables or reverse causality, we also conduct instrumental variable regressions. In this regard, we utilize the implementation variation of the “Broadband China” strategy over time and across regions as an instrumental variable for DFI. Introduced by the State Council in 2013, this strategy aimed to promote the rapid and healthy development of broadband infrastructure throughout China, with specific goals set for urban fiber-to-the-building and to-the-home connectivity, rural broadband access in rural areas and villages, and broadband coverage for all administrative villages by 2020 (China Internet Network Information Center, 2022).

Our findings reveal that the advancement of digital financial inclusion significantly reduces symptoms of depression and improves self-reported health status among the elderly population in China. Notably, these positive impacts are more pronounced among rural residents compared to urban residents, providing direct evidence of the benefits of financial inclusion for subjective well-being. It is worth noting that the improvements in subjective well-being through DFI are primarily observed in the non-multidimensional poverty (non-MP) groups, and no statistically significant impact on life satisfaction is observed across all groups. Regarding the variation over time, we find that the effect of DFI on depression is more prominent in the short term and gradually attenuates, while its influence on self-reported health becomes more substantial over time.

This study contributes to the existing literature in several ways. Firstly, it examines the impact of digital financial inclusion on the subjective well-being of China's older population, highlighting the potential of narrowing the “digital divide” to enhance individual development potential and subjective well-being. Secondly, by analyzing the differential effects across poverty dimensions and residential areas, the study offers targeted solutions for precise improvements in subjective well-being. Thirdly, the study employs a multidimensional poverty measure that captures an individual's poverty status in education level, health, healthcare access, and living conditions. This measure is more relevant to sustainable development compared to the commonly used income poverty measure and aligns better with the role of digital financial inclusion. Lastly, by utilizing the “Broadband China” strategy as an exogenous shock to address endogeneity concerns, the study provides insights into practical approaches for improving subjective well-being through the

expansion of digital finance.

These findings hold significant policy implications. Firstly, there is a need for concerted efforts to strengthen digital infrastructure development, considering the strong evidence linking digital financial inclusion to improved subjective well-being. Secondly, precise targeting of vulnerable groups, including those experiencing multidimensional poverty, rural residents, and elderly individuals facing barriers to internet access and digital finance, is crucial for enhancing subjective well-being. Thirdly, policymakers should allow sufficient time for digital financial inclusion to take effect, as it demonstrates immediate relief in terms of alleviating depression and gradual improvement in self-reported health status. Lastly, enhancing digital infrastructure, such as through initiatives like the “Broadband China” program, can play a vital role in augmenting the impact of digital financial inclusion on the subjective well-being of disadvantaged elderly populations.

The paper is structured as follows: [Section 2](#) provides a review of the existing literature on digital finance, subjective well-being, and aging. [Section 3](#) offers an overview of the data and methodology employed in the study. [Section 4](#) presents the main empirical results. [Section 5](#) extends the analysis and presents robustness checks. Finally, [Section 6](#) concludes the paper and discusses the implications of the findings.

## 2. Literature review

This study connects three lines of research: digital finance, subjective well-being, and population aging. The literature on how digital finance impacts individual and household economic activities, such as income ([Zhang, Wan, & Wu, 2021](#); [Zhang, Yang, Wang, & Wan, 2020](#)), consumption ([Yang & Zhang, 2022](#)), investment, and employment, is extensive. Existing studies have identified various channels through which digital finance operates. For instance, digital technology can enhance access to financial services, thereby reducing credit constraints for individuals ([Wieser, Bruhn, Kinzinger, Ruckteschler, & Heitmann, 2019](#)). It can also influence consumption patterns by increasing rural residents’ consumption ([Liu, Jin, Pray, & Liu, 2020](#); [Zhang, Wan, Zhang, & He, 2020](#)), optimizing consumption structures ([Jiang & Jiang, 2020](#)), and facilitating the use of consumption coupons during the COVID-19 pandemic ([Lin, Shen, & Sun, 2020](#)). Furthermore, digital finance can expand investment opportunities for individuals ([Wu, Li, Li, & Zhou, 2021](#)) and contribute to increased employment through mobile payment platforms ([Lee, Morduch, Ravindran, Shonchoy, & Zaman, 2021](#)). [Zhang, Wan, et al. \(2020\)](#) further examine how digital finance promotes inclusive growth in China using CFPS data, finding that it helps narrow the urban-rural income gap and increases entrepreneurship opportunities for rural residents.

The literature on the measurement and causal factors of subjective well-being is also extensive ([Diener, 1984](#); [Diener & Ryan, 2009](#)). [Layard \(2010\)](#) suggests that happiness and life satisfaction can be used to measure subjective well-being, which is correlated with factors such as interactions with friends and physical functions. [Kahneman and Krueger \(2006\)](#) highlight the importance of individuals’ perceptions of their experiences in relation to subjective well-being. There are also several studies on the relationship between digital technology and subjective well-being, particularly during the COVID-19 period. A recent paper examines the effects of digital platforms on individuals’ subjective well-being during the COVID-19 pandemic and finds that remote work can induce technostress, leading to decreased subjective well-being ([Singh, Bala, Dey, & Filieri, 2022](#)). [Yoo and Jang \(2023\)](#) investigate the relationship between digital technology use and subjective well-being among migrant populations based on data from Korea. However, few studies have specifically addressed how digital finance affects subjective well-being.

While there is a vast body of literature on aging, our focus is on reviewing the major studies concerning the relationship between subjective well-being, health, and age. Previous research has shown that the model of happiness and age varies across different regions ([Diener & Ryan, 2009](#)). Regarding the impact of technology on the elderly population, the evidence is mixed. On one hand, the “digital divide” resulting from the digitalization process presents a significant challenge for senior citizens who may lack the knowledge or skills to effectively use technology ([Friemel, 2016](#)). For example, [Yang et al. \(2021\)](#) found a significant negative association between internet use and subjective well-being among Chinese elderly individuals, particularly among males, younger individuals, and those with lower levels of education. Additionally, empirical evidence based on CLASS data suggests that internet use increases the incidence of depressive symptoms among the elderly ([Xie et al., 2021](#)).

On the other hand, the literature also provides ample evidence supporting the idea that technological advancements can offer numerous benefits to seniors. For instance, [Lei, Shen, and Yang \(2022\)](#) used CHARLS data to find that digital technology helps the elderly reduce the risk of falling victim to scams and fraud. Several studies have shown that internet use significantly reduces depressive symptoms among Chinese elderly individuals ([Guo, Feng, & Liu, 2022](#); [Jing, Jin, Guo, Zhang, & Li, 2023](#)), improves the physical and mental health of middle-aged and older Chinese adults ([Wen, Zhang, Shi, & Li, 2023](#)), and enhances their subjective well-being ([Song, Ge, & Zhang, 2021](#)).

While each of these three lines of literature is extensive, the study on how digital finance affects the subjective well-being of the older population is still lacking, let alone further analysis of how its impact differs for different cohorts from the perspectives of rural/urban differences and multi-dimensional poverty status. We aim to fill this knowledge gap and contribute to the understanding of the relationship between digital financial inclusion and subjective well-being among the elderly population.

## 3. Data and methodology

### 3.1. Data

We utilized CHARLS data to gather comprehensive information on various aspects of individuals’ health status, including self-reported health and depression levels, as well as their life satisfaction, insurance coverage, housing conditions, internet usage, and

demographic characteristics. This survey provides nationally representative micro-level data specifically focused on middle-aged and elderly individuals. For our analysis, we utilized four waves of data collected in 2011, 2013, 2015, and 2018, which included over 10 thousand households.

To measure the degree of digital financial inclusion, we employed the Peking University Digital Finance index developed by Guo et al. (2020). This index is constructed using individual-level data from Ant Group, which includes information on Alipay account coverage, third-party digital payments (both online and offline), as well as online investment, credit, and insurance. The index comprises an aggregate index and three sub-indices: breadth of digital financial coverage, depth of usage, and degree of digitization. In our study, we focused on the aggregate index at the city level to assess the local development of digital financial inclusion (Guo et al., 2020). In our robustness checks, we also considered both the breadth and depth of digital financial inclusion to further examine its impact on subjective well-being.

### 3.2. Variables

Our study measures subjective well-being using three dependent variables: self-reported health, life satisfaction, and depression. Self-reported health status is assessed through a survey question where respondents rate their health from “very good” to “very poor.” To represent these options, values of 5 to 1 are assigned, with 5 indicating “very good” and 1 indicating “very poor.” Life satisfaction is measured by asking individuals to rate their level of satisfaction on a scale that includes options like “completely satisfied,” “very satisfied,” “somewhat satisfied,” “not very satisfied,” and “not at all satisfied.” Values of 5 to 1 are assigned, with 5 representing “completely satisfied” and 1 representing “not at all satisfied.” Higher values indicate higher levels of satisfaction. Depression is assessed using answers to ten questions in the CHARLS survey, with higher values indicating<sup>1</sup> a greater level of depression.

The main explanatory variable in our study is the Digital Finance Index (DFI), which measures the extent of digital financial inclusion. We use the overall index at the city level to approximate the regional development of digital finance. In our analysis, we also include control variables such as age, gender, and household size. Household size is determined by the number of individuals living within each family unit.

To examine heterogeneity, we analyze differences based on residency status, specifically the urban-rural divide. Another dimension of heterogeneity we consider is multi-dimensional poverty status. This measure captures deprivation across various dimensions, including education, health, and living standards, and goes beyond income or consumption measures of poverty (Alkire & Foster, 2011a, 2011b). In our study, multi-dimensional poverty status is represented by a dummy variable called “MP,” which takes a value of 1 if the family is in multi-dimensional poverty and 0 otherwise.<sup>2</sup> Appendix 1 provides descriptive statistics that further detail the characteristics of the variables used in the study.

### 3.3. Empirical methodology

We start with a two-way fixed effect model to examine the effects of digital financial inclusion on subjective well-being. This model allows us to account for both province and time fixed effects, controlling for unobserved heterogeneity and time-invariant characteristics that may influence subjective well-being:

$$Y_{it} = \alpha_0 + \alpha_1 DFI_{ct} + \theta X_{it} + u_p + \lambda_t + \mu_{it}, \quad (1)$$

where  $Y_{it}$  represents the subjective well-being outcome variable for individual  $i$  at time  $t$ ;  $DFI_{ct}$  denotes digital financial inclusion of city  $c$  in year  $t$ ;  $X_{it}$  represents a vector of control variables, including age, household size, residence, and gender;  $u_p$  and  $\lambda_t$  represent the fixed effect of the province and the survey wave, and  $\mu_{it}$  is the error term capturing unobserved factors and random shocks.

<sup>1</sup> CHARLS ask about “being bothered by things that don’t usually bother me”, “having trouble keeping my mind on what I was doing”, “feeling depressed”, “feeling everything I did was an effort”, “feeling hopeful about the future”, “feeling fearful”, “restless sleep”, “feeling happy”, and “couldn’t get going”. Response options include “rarely or none of the time (< 1 day)”, “some or a little of the time”, “occasionally or a moderate amount of the time (3–4 days)”, and “most or all of the time (5–7 days)”. The positively-framed indicators (feeling hopeful, happy, and satisfied) are first transformed into negative indicators. Following this, values of 0, 1, 2, and 3 are assigned to the various response options. Ultimately, the scores of the ten questions are summed to determine the level of depression at the individual level.

<sup>2</sup> The construction of multidimensional poverty is based on the Alkire-Foster method, which takes into account poverty across dimensions such as education, health, and living conditions. The education dimension includes the schooling levels of respondents, their spouses, and children, and consists of two indicators. The first indicator assesses whether both the respondent and spouse have education levels below primary school, while the second indicator examines whether their children’s education is below the primary school level. A household is classified as experiencing education poverty if at least one of these indicators equals 1. The health dimension also comprises two indicators. The first indicator evaluates whether the respondent and spouse have any health insurance, while the second indicator considers whether they face difficulties in performing daily activities (ADL) such as dressing, bathing, eating, waking up, using the toilet, and controlling urination and defecation. A household is categorized as experiencing health poverty if at least one of these indicators equals 1. The living dimension consists of six indicators that assess whether a household lacks access to basic infrastructures, including electricity, flushable toilets, tap water, durable goods, and modern fuels. Durable goods encompass items such as TVs, telephones, motorcycles or refrigerators, and electric cars, while charcoal and coal are not considered modern fuels. To identify individuals experiencing multidimensional poverty, we employ a threshold of 1/3 of the total number of poverty indicators.

The two-way fixed effect model may suffer from time-variant omitted variable biases or reverse causality. We employ the instrumental variable (IV) approach to tackle such a challenge, where the implementation variation of “Broadband China” is used as the instrumental variable to address the potential endogeneity issue,

$$DFI_{ct} = \beta_0 + \beta_1 \text{Broadband}_{ct} + \theta X_{it} + w_p + \lambda_t + \varepsilon_{it},$$

where dummy  $\text{Broadband}_{ct}$  equals 1 if “Broadband China” is implemented in city  $c$  in year  $t$ . “Broadband China” was introduced in 2013 by the State Council to improve local communication infrastructure and promote digitization. The implementation of this strategy commenced in 2014, with 39 cities adopting it in that year, followed by 37 cities in 2015 and another 37 cities in 2016. By 2022, the goal of achieving “broadband access in villages” had been accomplished in all administrative villages, and the internet coverage rate in rural areas reached 58.8% (China Internet Network Information Center, 2022). The gradual implementation of this strategy has resulted in exogenous variation in the quality of regional digital infrastructure, which is a crucial factor for the development of digital finance. Therefore, it can serve as an instrumental variable for measuring the impact of DFI. Appendix 2 provides a list of the number of new cities that have adopted the “Broadband China” strategy based on the CHARLS data.

### 3.4. The association between SWB and DFI

Fig. 1 showcases scatterplots and fitted lines illustrating the relationship between the three subjective well-being measures (depression, life satisfaction, and self-rated health) and DFI for each city. The y-axis represents subjective well-being (SWB), while the x-axis represents DFI.

The scatterplot analysis reveals interesting patterns. Specifically, there is a negative correlation between DFI and depression, indicating that as the level of digital financial inclusion increases in a city, individuals living there tend to experience lower levels of depression. On the other hand, there is a positive correlation between DFI and life satisfaction as well as self-reported health. This implies that as DFI increases, individuals in the city tend to report higher levels of life satisfaction and better self-reported health.

Overall, Fig. 1 demonstrates the association between DFI and subjective well-being measures, suggesting that greater digital financial inclusion is linked to improved mental health (reduced depression) and enhanced overall well-being (higher life satisfaction and better self-reported health) for individuals residing in the respective cities.

Notes: Panels A, B, and C display the scatterplots and fitted lines illustrating the association between DFI (digital financial inclusion) and SWB (measured by depression score, satisfaction rank, and SRH score). All graphs are constructed based on individual-level data from CHARLS 2011, 2013, 2015, and 2018.

## 4. Empirical results

In this section, we present the estimation results of our study. We begin by providing the baseline regression results using a two-way fixed effects model, followed by the instrumental variable regression results. Heterogeneity analysis is also conducted.

### 4.1. Two-way fixed estimation results

Table 1 displays the results of the two-way fixed effects regression. In all the regression models, we include control variables at the individual level, such as age, gender, place of residence, and household size. The regression results demonstrate a significant positive impact of digital financial inclusion on subjective well-being. Specifically, a one standard deviation increase in DFI is associated with an average decrease of 1.692 points in an individual’s depression score. Moreover, it leads to an increase of 0.098 in life satisfaction scores and an increase of 0.213 in self-rated health scores. These results are consistent with the descriptive pattern depicted in Fig. 1, indicating that even after accounting for a comprehensive set of controls, higher levels of digital financial inclusion remain associated

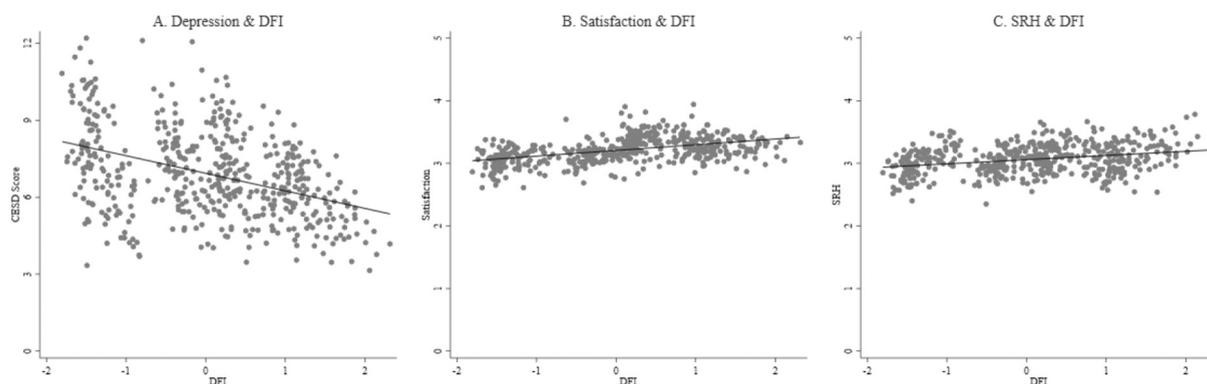


Fig. 1. The relation between digital financial inclusion and subjective well-being.

**Table 1.**  
Two-way fixed effects estimation of DFI on subjective well-being.

	(1)	(2)	(3)
	Depression	Satisfaction	SRH
DFI	-1.692*** (0.299)	0.098*** (0.026)	0.213*** (0.058)
Age	0.013*** (0.004)	0.005*** (0.001)	-0.013*** (0.001)
Rural	1.294*** (0.136)	-0.035*** (0.012)	-0.130*** (0.025)
Female	1.814*** (0.106)	-0.039*** (0.006)	-0.176*** (0.011)
Household size	-0.139*** (0.023)	0.016*** (0.003)	0.001 (0.004)
Constant	5.383*** (0.224)	2.849*** (0.048)	3.982*** (0.045)
Observations	71,590	64,083	68,342
R-squared	0.076	0.053	0.061

Notes: (1) Province and year effects are controlled in all regressions. (2) Standard errors are clustered at the province level. (3) \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

with lower levels of depression, increased life satisfaction, and better self-rated health. These findings suggest that digital financial inclusion plays a crucial role in promoting subjective well-being among the population under study.

The regression results also provide insights into the effects of control variables on subjective well-being. We find that older cohorts are more likely to report poorer health status. Rural residents tend to experience higher levels of depression compared to their urban counterparts, while urban residents report higher life satisfaction and better health status. Females are more prone to depression and tend to report lower life satisfaction and poorer self-rated health compared to males. Additionally, larger household size is associated with lower levels of depression and higher life satisfaction among individuals. We will not further discuss these variables in our subsequent analyses, as their effects are relatively stable.

#### 4.2. Instrumental variable estimation

Although the baseline two-way fixed effects model has controlled the unobservable heterogeneity in both ways, there may still exist endogeneity problems driven by variant unobservable factors or by reverse causality. To address this concern, we employ an instrumental variable (IV) approach using the “Broadband China” strategy as the instrument for DFI. Table 2 presents the IV estimation results for subjective well-being using the full sample. Column 1 displays the results for the first stage, while Columns 2–4 present the second-stage results for depression, life satisfaction, and self-reported health.

The results indicate that “Broadband China” is a strong instrument, as evidenced by its statistically significant coefficient at the 1% level and a large F statistic of 21.91 in the first-stage regression (Column 1). This suggests that cities implementing the “Broadband China” strategy exhibit a higher digital financial inclusion index by 0.204 standard deviations compared to cities that do not

**Table 2.**  
Instrument variable estimation of DFI on subjective well-being: the full sample.

	(1)	(2)	(3)	(4)
	The first stage: DFI	Depression	Satisfaction	SRH
Broadband China	0.204*** (0.044)			
DFI		-1.544*** (0.546)	0.010 (0.071)	0.264** (0.102)
Age	-0.000 (0.000)	0.013*** (0.004)	0.005*** (0.001)	-0.013*** (0.001)
Rural	-0.101*** (0.023)	1.311*** (0.158)	-0.045*** (0.016)	-0.124*** (0.025)
Female	-0.002** (0.001)	1.814*** (0.106)	-0.039*** (0.006)	-0.176*** (0.011)
Household size	-0.006** (0.002)	-0.138*** (0.024)	0.016*** (0.003)	0.002 (0.004)
Constant	0.148*** (0.032)			
F Values	21.91			
Observations	71,598	71,590	64,083	68,342
R-squared	0.963	0.043	0.006	0.033

Notes: (1) Province and year effects are controlled in all regressions. (2) Standard errors are clustered at the province level. (3) \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

implement the strategy.

The coefficients for DFI in Columns 2–4 align with the findings from the two-way fixed effects regression. However, the coefficient for life satisfaction is no longer statistically significant in the instrumental variable regressions (Column 3). Nonetheless, the IV regressions indicate that the development of digital financial inclusion significantly reduces individuals' depression and improves their self-reported health status.

These results provide further evidence supporting the positive impact of digital financial inclusion on subjective well-being while addressing the potential endogeneity concerns through the use of instrumental variables.

#### 4.3. Heterogeneity analysis

Table 3 presents the results of heterogeneity analysis based on urban/rural residence, multidimensional poverty status, and time length in Panels A, B, and C, respectively.

In Panel A, focusing on rural/urban differences, two key findings emerge. First, digital financial inclusion is associated with reduced depression levels for both urban and rural areas, but the impact is twice as large for the rural subsample compared to the urban subsample. This suggests that digital financial inclusion has a more pronounced effect on alleviating depression in rural areas. Second, DFI improves self-reported health status specifically in rural areas, indicating that digital financial inclusion has a positive impact on the health outcomes of individuals residing in rural regions.

Moving to Panel B, which examines the impact of DFI by multidimensional poverty status, the regression results indicate that the beneficial effects of DFI primarily accrue to the non-MP groups, referring to individuals with higher socioeconomic status. For this group, improvements in depression levels and self-rated health are observed, suggesting that digital financial inclusion contributes to enhancing well-being among individuals with better socioeconomic conditions.

Panel C investigates the immediate and accumulated effects of DFI over time. The results reveal that the relieving effect of DFI on depression is more substantial in the 2015 wave (−1.953) compared to the 2018 wave (−1.282). However, concerning self-rated health, the effect is smaller in the early period (0.209) and becomes more pronounced in the later period (0.338). These findings suggest that the impact of DFI on depression is immediate, while its influence on self-rated health takes more time to manifest, potentially reflecting the gradual improvement of overall well-being with increased digital financial inclusion.

Overall, these heterogeneity analysis results underscore the importance of considering variations in urban/rural residence, multidimensional poverty status, and time length when examining the effects of digital financial inclusion on subjective well-being. The findings highlight the differential impacts of DFI across these dimensions, emphasizing the need for targeted interventions to address disparities and promote well-being for different population groups.

**Table 3.**  
Heterogeneity analysis: impacts of DFI on subjective well-being using IV estimation.

DFI	(1)	(2)	(3)
	Depression	Satisfaction	SRH
Panel A			
Urban	−1.047* (0.598)	−0.090 (0.082)	−0.009 (0.138)
Rural	−2.057** (0.867)	0.091 (0.134)	0.545*** (0.185)
Panel B			
Non-MP	−1.315*** (0.465)	−0.031 (0.074)	0.216* (0.111)
MP	−1.193 (1.617)	0.090 (0.211)	0.130 (0.164)
Panel C			
11,13 benchmark impact on 2015	−1.953*** (0.684)	−0.024 (0.084)	0.209* (0.116)
11,13 benchmark impact on 2018	−1.282* (0.644)	0.013 (0.087)	0.338** (0.148)

Notes: (1) MP refers to multidimensional poverty in the dimensions of education, health, and living conditions. (2) Individual-level factors (such as age, gender, place of residence, and household size), province and year effects are controlled in all regressions in Panels B and C. In Panel A, only the effect of residence is not controlled in regressions and control variables are the same as the Panel A settings. (3) Standard errors are clustered at the province level. (4)\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

## 5. Extension and robustness check

### 5.1. Effects of breadth and depth of DFI

The above analysis provides evidence that increased digital financial inclusion can reduce depression and improve the health status of the older population. It is necessary to delve deeper into how digital financial inclusion can achieve these effects. One aspect to consider is that digital financial inclusion represents a transformative change, as access to digital technologies itself can be beneficial (“zero to one” change). For instance, the availability of mobile payments enables the elderly to engage in broader consumption, including online shopping. Improved living conditions can contribute to subjective well-being. Additionally, digital financial inclusion may lead to cascading effects (“one to N” type changes), where individuals can enhance their subjective well-being by participating in digital lending, digital wealth management, digital insurance, and similar activities. To examine whether these two channels effectively improve subjective well-being, further research is needed to explore the impact of the breadth and/or depth of financial inclusion.

In this subsection, we examine how the breadth and depth of digital financial inclusion affect subjective well-being using two sub-indices on DFI, and present the regression results in Tables 4 and 5, respectively. Table 4 illustrates the impact of DFI breadth on depression (Column 2), life satisfaction (Column 3), and self-reported health status (Column 4). Overall, this table confirms the presence of the “zero to one” financial inclusion effect. It significantly reduces depression and improves health status for the entire sample (Panel A), but with interesting variations in different groups. These impacts are primarily observed among rural residents (Panel B) and the non-MP group (Panel C), and the time-varying effects are similar to those identified in Table 3.

Table 5 presents the regression results regarding the impact of DFI depth on subjective well-being. It reveals similar findings: an increase in the depth of financial inclusion also contributes to improvements in subjective well-being (for the full sample). However, once again, these effects are particularly pronounced among rural residents (Panel B) and the Non-MP group (Panel C). The time-varying impacts align with the previous findings. By considering the results from Tables 4 and 5 collectively, the main takeaway is that digital financial inclusion has both the “zero to one” and the “one to N” effects on enhancing subjective well-being.

### 5.2. Robustness check: using binary measures of subjective well-being

The impact of DFI on SWB may vary depending on how SWB is measured. In the robustness check, we substitute continuous measures of SWB with binary measurements and present the results in Table 6. We utilize a depression score of 10 as the threshold for defining individuals as depressed, and we use dichotomous variables to measure satisfaction and self-reported health, assigning a value of 1 if the score is 4 or 5, and 0 otherwise. According to these criteria, approximately 30% of the CHARLS sample has a depression score above 10, 88% express satisfaction with their lives, and 75% perceive their health as good or above (see Appendix 1).

**Table 4.**  
The breadth of DFI on subjective well-being using IV estimation.

Breadth	(1)	(2)	(3)
	Depression	Satisfaction	SRH
Panel A			
The full sample	−1.173** (0.430)	0.007 (0.054)	0.201** (0.080)
Panel B			
Urban	−0.784 (0.463)	−0.067 (0.061)	−0.007 (0.103)
Rural	−1.622** (0.694)	0.072 (0.103)	0.430*** (0.139)
Panel C			
Non-MP	−0.994*** (0.357)	−0.023 (0.056)	0.164* (0.085)
MP	−0.916 (1.257)	0.068 (0.160)	0.100 (0.128)
Panel D			
11,13 benchmark impact on 2015	−1.326** (0.484)	−0.016 (0.057)	0.142* (0.081)
11,13 benchmark impact on 2018	−1.122* (0.552)	0.012 (0.076)	0.297** (0.133)

Notes: (1) MP refers to multidimensional poverty in the dimensions of education, health, and living conditions. (2) Individual-level factors (such as age, gender, place of residence, and household size), province and year effects are controlled in all regressions in Panels A, C and D. In panel B, only the effect of residence is not controlled in regressions and control variables are the same as the Panel A settings. (3) Standard errors are clustered at the province level. (4) \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

**Table 5.**  
Instrumental variable estimation of the depth of DFI on subjective well-being.

Depth	(1)	(2)	(3)
	Depression	Satisfaction	SRH
Panel A			
The full sample	−1.861*** (0.614)	0.012 (0.086)	0.317** (0.122)
Panel B			
Urban	−0.784 (0.463)	−0.067 (0.061)	−0.007 (0.103)
Rural	−1.622** (0.694)	0.072 (0.103)	0.430*** (0.139)
Panel C			
Non-MP	−0.994*** (0.357)	−0.023 (0.056)	0.164* (0.085)
MP	−0.916 (1.257)	0.068 (0.160)	0.100 (0.128)
Panel D			
11,13 benchmark impact on 2015	−1.326** (0.484)	−0.016 (0.057)	0.142* (0.081)
11,13 benchmark impact on 2018	−1.122* (0.552)	0.012 (0.076)	0.297*** (0.133)

Notes: (1) MP refers to multidimensional poverty in the dimensions of education, health, and living conditions. (2) Individual-level factors (such as age, gender, place of residence, and household size), province and year effects are controlled in all regressions in Panels A, C and D. In panel B, only the effect of residence is not controlled in regressions and control variables are the same as the Panel A settings. (3) Standard errors are clustered at the province level. (4) \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

**Table 6.**  
DFI on subjective well-being: dichotomous outcomes.

DFI	(1)	(2)	(3)
	Depressed	Satisfied	Good SRH
Panel A			
The full sample	−0.095** (0.044)	0.023 (0.029)	0.108*** (0.037)
Panel B			
Urban	−0.040 (0.042)	−0.040* (0.023)	0.009 (0.060)
Rural	−0.157** (0.076)	0.111** (0.052)	0.228*** (0.065)
Panel C			
Non-MP	−0.096** (0.038)	−0.012 (0.027)	0.087** (0.036)
MP	0.019 (0.134)	0.122 (0.077)	0.039 (0.088)
Panel D			
11,13 benchmark impact on 2015	−0.125** (0.054)	−0.002 (0.036)	0.111** (0.052)
11,13 benchmark impact on 2018	−0.069 (0.048)	0.033 (0.034)	0.108* (0.053)

Notes: (1) MP refers to multidimensional poverty in the dimensions of education, health, and living conditions. (2) Individual-level factors (such as age, gender, place of residence, and household size), province and year effects are controlled in all regressions in Panels A, C and D. In Panel B, only the effect of residence is not controlled in regressions and control variables are the same as the Panel A settings. (3) Standard errors are clustered at the province level. (4) \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Overall, the results in Table 6 demonstrate robustness, as DFI continues to reduce depression and improve health status even when using dichotomous measures of subjective well-being. The findings in the subsamples generally align with previous results, albeit with slight changes. For instance, when life satisfaction is measured dichotomously, DFI still has no significant impact on the full sample, but it exerts a significant positive impact on rural residents and a negative impact on urban residents (Panel B). This finding indicates that the impact of DFI is not monotonic, and the negative impact on urban residents may serve as evidence of the digital divide. Another notable finding is that the time-varying effects still persist, but the relative magnitudes change. The impact of relieving depression disappears in the long term, while the beneficial effect on health status remains of a similar magnitude.

## 6. Conclusion

The 19th National Congress of the Communist Party of China recognized the primary conflict in Chinese society as the disparity between the growing needs of the people for a better life and the imbalanced and insufficient development. In the new era, characterized by digitalization and rapid aging, a vulnerable group emerges—the elderly who are left behind due to their limited access to and use of digital technology. This digital divide poses a significant obstacle for a large proportion of the Chinese population in their pursuit of a better life. Meanwhile, digital technology has both positive and negative impacts on the subjective well-being of the elderly. On one hand, it improves their financial well-being, social engagement, cognitive stimulation, and overall life satisfaction. On the other hand, they encounter challenges like technological barriers, digital exclusion, security concerns, lack of human interaction, complexity, inadequate support, and potential exclusion from traditional services. Therefore, a rigorous study is crucial to address this conflict and understand the impact of digital technology on the subjective well-being of China's older population.

This paper focuses on digital financial inclusion as a major form of digital technology innovation. Using CHARLS data, we aim to investigate whether and how digital financial inclusion affects the subjective well-being of Chinese older residents.

Our findings demonstrate ample evidence that the development of digital financial inclusion significantly reduces symptoms of depression and improves self-reported health status among individuals. To gain further insights into who benefits more from this new technology, we conduct heterogeneity analysis. The positive impacts are particularly pronounced among rural residents compared to urban residents, which is encouraging news. However, it is worth noting that currently, individuals not in multidimensional poverty are the primary beneficiaries of this new financial inclusion. This implies that individuals in multidimensional poverty may still experience the negative effects of the digital divide, highlighting the need for targeted interventions to ensure inclusive digital financial inclusion for all segments of the population.

Another important dimension to consider is the variation of the effect of digital financial inclusion over time. Our findings reveal interesting patterns: digital financial inclusion has an immediate effect on relieving depression, but this impact tends to diminish over time. On the other hand, its impact on health status is more persistent and tends to grow over time. We did not find a statistically significant impact on life satisfaction yet, but this could be due to the time window of our study not being long enough to capture the full effect.

The key message derived from these findings is that promoting digital financial inclusion is an effective strategy for improving subjective well-being. Therefore, it is essential to allocate more efforts towards building robust digital financial infrastructure, expanding the implementation of strategies like "Broadband China" on a larger scale, and ensuring that they reach the more vulnerable groups in society. Additionally, precise targeting measures should be developed to expedite the positive impact of digital financial inclusion, with particular attention to individuals in multidimensional poverty status who are at a higher risk of being left behind in the digital divide.

Lastly, it is crucial for policymakers to understand that the impact of digital financial inclusion takes time to fully manifest. Therefore, patience and persistence in implementing policy measures are necessary. Given enough time, the beneficial effects of digital financial inclusion on depression, health status, and life satisfaction can be realized to their fullest extent, ultimately helping the Chinese population achieve a better quality of life.

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## Data availability

Data will be made available on request.

## Appendix

### Appendix 1

The descriptive analysis: grouped by multidimensional poverty and residence.

	(1)	(2)	(3)	(4)	(5)
	All	Non-MP	MP	Urban	Rural
Dependent variables					
Depression	7.07	6.41	9.32	6.10	7.72
Depressed	0.30	0.25	0.45	0.24	0.34
Satisfaction	3.22	3.25	3.10	3.24	3.20
Satisfied	0.88	0.90	0.81	0.90	0.87
SRH	3.04	3.15	2.67	3.14	2.97
Good SRH	0.75	0.80	0.57	0.80	0.72
Independent variables					
DFI (standardized)	0.07	0.15	-0.18	0.16	0.02
Breadth (standardized)	0.07	0.15	-0.21	0.18	-0.01
Depth (standardized)	0.10	0.17	-0.12	0.18	0.05
Broadband China	0.17	0.18	0.12	0.21	0.14
Control variables					
Multidimensional poverty	0.23			0.13	0.29
Rural	0.60	0.55	0.77		
Age	60.49	59.07	65.30	60.41	60.54
Household size	5.14	5.19	4.99	5.04	5.21
Female	0.52	0.48	0.64	0.52	0.51

### Appendix 2

The number of new cities implementing the “Broadband China” strategy in CHARLS.

Province	2014	2015	2016	Province	2014	2015	2016
Beijing	1			Jiangxi	2	1	1
Tianjin	1			Shandong	3	1	1
Hebei	1			Henan	2		1
Shanxi			1	Hubei		1	
Neimenggu		1		Hunan	1	1	1
Liaoning	2	1		Guangdong	2		
Heilongjiang	1			Guangxi			1
Shanghai	1			Chongqing		1	
Jiangsu	1	1	1	Sichuan	1	3	1
Zhejiang		1	1	Shaanxi			1
Anhui	1	1	1	Gansu		2	
Fujian		1		Total	20	16	11

### Appendix 3

Heterogeneity analysis: the first stage of IV estimation of the DFI.

	By residence		By MP		By time length	
	Urban	Rural	Non-MP	MP	11,13 benchmark impact on 2015	11,13 benchmark impact on 2018
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband China	0.247*** (0.048)	0.153*** (0.047)	0.205*** (0.045)	0.188*** (0.038)	0.209*** (0.043)	0.190*** (0.045)
Age	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	0.000* (0.000)	-0.000 (0.000)	-0.000 (0.000)
Rural			-0.102*** (0.022)	-0.068* (0.036)	-0.100*** (0.022)	-0.105*** (0.025)
Female	-0.003 (0.002)	-0.002 (0.001)	0.003 (0.002)	-0.003 (0.002)	-0.002** (0.001)	-0.002* (0.001)
Household size	-0.008** (0.004)	-0.005** (0.002)	-0.007** (0.003)	-0.004* (0.002)	-0.007*** (0.003)	-0.007** (0.003)
Constant	0.131*** (0.032)	0.048* (0.024)	0.197*** (0.033)	-0.157*** (0.042)	-0.260*** (0.031)	0.043 (0.035)
Observations	28,708	42,890	55,289	16,309	52,982	52,543
R-squared	0.956	0.973	0.960	0.972	0.946	0.970

Notes: (1) MP refers to multidimensional poverty in the dimensions of education, health, and living conditions. (2) Province and year effects are controlled in all regressions. (3) Standard errors are clustered at the province level. (4) \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

## Appendix 4

Heterogeneity analysis: the first stage of IV estimation of the breadth of DFI.

	By residence		By MP		By time length	
	Urban	Rural	Non-MP	MP	11,13 benchmark impact on 2015	11,13 benchmark impact on 2018
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband China	0.331*** (0.071)	0.194*** (0.068)	0.271*** (0.066)	0.245*** (0.056)	0.308*** (0.066)	0.217*** (0.061)
Age	0.000 (0.001)	-0.001 (0.000)	0.000 (0.000)	0.001 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Rural			-0.143*** (0.031)	-0.096* (0.054)	-0.146*** (0.033)	-0.149*** (0.037)
Female	-0.005 (0.003)	-0.002 (0.002)	0.004 (0.003)	-0.004 (0.003)	-0.004** (0.002)	-0.003* (0.002)
Household size	-0.012** (0.006)	-0.008** (0.003)	-0.011** (0.004)	-0.007** (0.003)	-0.012*** (0.004)	-0.011** (0.004)
Constant	0.165*** (0.046)	0.048 (0.036)	0.232*** (0.047)	-0.167** (0.064)	-0.191*** (0.047)	0.078 (0.051)
Observations	28,708	42,890	55,289	16,309	52,982	52,543
R-squared	0.903	0.946	0.917	0.942	0.884	0.937

Notes: (1) MP refers to multidimensional poverty in the dimensions of education, health, and living conditions. (2) Province and year effects are controlled in all regressions. (3) Standard errors are clustered at the province level. (4) \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

## Appendix 5

Heterogeneity analysis: the first stage of IV estimation of the depth DFI.

	By residence		By MP		By time length	
	Urban	Rural	Non-MP	MP	11,13 benchmark impact on 2015	11,13 benchmark impact on 2018
	(1)	(2)	(3)	(4)	(5)	(6)
Broadband China	0.194*** (0.036)	0.145*** (0.036)	0.169*** (0.031)	0.164*** (0.030)	0.160*** (0.031)	0.169*** (0.035)
Age	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Rural			-0.087*** (0.018)	-0.054* (0.029)	-0.082*** (0.017)	-0.084*** (0.020)
Female	-0.002 (0.001)	-0.002* (0.001)	0.001 (0.002)	-0.004 (0.003)	-0.002*** (0.001)	-0.002** (0.001)
Household size	-0.007** (0.003)	-0.004** (0.002)	-0.007*** (0.002)	-0.002 (0.002)	-0.006*** (0.002)	-0.006*** (0.002)
Constant	0.164*** (0.027)	0.071*** (0.019)	0.214*** (0.025)	-0.107*** (0.028)	-0.292*** (0.023)	0.160*** (0.026)
Observations	28,708	42,890	55,289	16,309	52,982	52,543
R-squared	0.962	0.968	0.962	0.969	0.930	0.971

Notes: (1) MP refers to multidimensional poverty in the dimensions of education, health, and living conditions. (2) Province and year effects are controlled in all regressions. (3) Standard errors are clustered at the province level. (4) \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

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