Digital financial inclusion and Rural Poverty Reduction

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Abstract

Many policy measures are included in China's 2020 poverty reduction schedule by 2020. The advantages of digitization have been used to break through the realistic difficulties of traditional financial inclusion and effectively solve the problem of the last mile of financial inclusion. Using a generalized difference-in-differences method,this paper selects the digital financial inclusion indicator and China family panel studies, and analyzes the impact of the digital financial inclusion indicator on rural family poverty reduction . The following conclusions have been drawn through empirical study: First, the development of digital financial inclusion aids in the reduction of poverty among rural families. Second, there is regional heterogeneity in the impact of digital financial inclusion on poverty reduction among rural families. Third, the mechanisms of digital financial inclusion to reduce poverty in rural families include increasing wage income, easing credit constraints and encouraging entrepreneurship.

Keywords: Digital financial inclusion; Poverty reduction; PSM-DID JEL Classification Codes : G20 ; O18

1. Introduction

Rural areas are the key object of China's poverty reduction work, and the Chinese government advocates the promotion of targeted financial poverty reduction based on the "development of financial inclusion", which indicates that the development of financial inclusion is an important means of alleviating poverty in rural areas. Financial inclusion, originated from micro-credit, mainly provides low-income, poverty and other vulnerable groups with a safe, convenient, fast, affordable formal financial service, and is a means of assisting poor people in rapidly escaping poverty. (Banerjee et al., 2013). The empirical study found that the mechanisms of financial inclusion to alleviate poverty include, at least promoting regional economic growth and benefiting poor families through "trickle-

down effect", lowering the threshold and cost of formal financial services (Hanning and Jansen, 2015), easing household credit constraints to help them cope with adverse shocks (Rahman, 2009), improving unfair distribution, narrowing the gap between the rich and poor, etc. However, traditional financial institutions, which rely on their branches to develop inclusive financial services, face constraints such as the geographical conditions of rural areas, internal operating costs, limited customer size and so on, which results in the need to deepen inclusive financial services in rural areas. In recent years, with the popularization of smart phones and the improvement of network infrastructure, digital financial inclusion in China has a rapid development. Digital financial inclusion is a product of the mutual integration of digital technology and financial inclusion. Financial institutions are able to break away from branch restrictions and provide formal financial services to rural areas by utilizing digital technologies. The major paradox in Chinese society has now been turned into a conflict between people's growing desire for a better living and unbalanced and insufficient development. There is a substantial wealth difference in rural China, in addition to the urban-rural divide, and assisting impoverished families in rural areas escape poverty is a current emphasis of poverty reduction. However, the research on whether the development of digital financial inclusion has narrowed the wealth gap in rural areas is not abundant, which is also the topic of this paper.

This paper uses the digital financial inclusion indicator (DFIII) published by the Institute of Digital Finance, Peking University, and the panel data of China family panel studies (CFPS) from 2012 to 2018 and distinguishes rural families by whether they have left digital footprints (access to the Internet). The samples are divided into the "treatment group" with digital footprints (access to the Internet) and the "control group" without digital footprints (not access to the Internet), and the propensity score matching-generalized difference-in-differences (PSM-DID) method is used to study and explore whether the development of digital financial inclusion has reduced the relative poverty among rural families and narrowed the internal wealth gap in rural areas of each province. This paper finds that digital financial inclusion has reduced the relative poverty of rural areas with digital footprints. Because the experimental and control groups pass the parallel trend test, this conclusion is reliable. We employ propensity score matching to exclude samples that do not fit the common support domain and the lagged one-period indicator for regression to account for endogeneity. The ending is still important. According to another study, raising rural residents' wage income, promoting rural residents' entrepreneurship, and alleviating rural residents' credit constraints are among the processes of digital financial inclusion that can help alleviate relative poverty in rural families. This paper contributes to the current literature by investigating the promotion mechanism of digital financial inclusion for narrowing the internal wealth gap in rural areas, identifying the significant promoting effect of digital financial inclusion on poverty reduction among rural families with Internet access, and identifying three promoting mechanisms. The policy implications of this paper include that development of digital financial inclusion is significant for winning the key fight against poverty in rural areas, and increasing rural infrastructure and popularizing the Internet equipment are conductive to narrowing the wealth gap in rural areas, preventing the recurrence of absolute poverty, and helping to win the battle against

poverty in rural areas.

The next section of this paper is organized as follows: The second section introduces the status of poverty reduction and the development of digital financial inclusion in China. The third section sorts out the relevant literature and proposes research hypotheses. The fourth and fifth sections explain the sample data and model settings and report the empirical study results. The sixth section is the research conclusions and policy implications.

2.   Literature Review and Hypotheses

Since the time between proposal and development of digital financial inclusion is still short, there are relatively few studies on digital financial inclusion and poverty, especially the literature on the poverty reduction of rural families from the perspective of digital financial inclusion is deficient. Digital financial inclusion originated from financial inclusion and traditional finance. It is a supplement and improvement to financial inclusion and traditional finance and still belongs to the category of financial inclusion. Therefore, this paper uses the relevant studies on financial inclusion and poverty for reference to provide a solid theoretical basis for the research on digital financial inclusion and rural poverty reduction and gives the hypotheses of poverty reduction mechanism of digital financial inclusion based on literature.

2.1 The Influence of Financial Inclusion Development on Poverty

Financial inclusion, originated from micro-credit, provides a safe, convenient, fast, and affordable formal financial service for low-income, poor and other vulnerable groups, and is a means that can help poor groups to get rid of poverty rapidly (Banerjee et al., 2013); Poor groups often do not have access to credit funds due to the threshold of traditional finance, resulting in the failure to improve the state of poverty. Financial inclusion breaks down the barriers of traditional financial thresholds and makes financial products and services accessible to otherwise excluded poor groups, thus increasing income, and getting rid of existing poverty bottleneck (Cleassens and Feyen, 2007; Beck et al., 2007). Financial inclusion improves the efficiency of resource allocation and ensures that low-income, poor and other vulnerable groups have access to affordable and economical formal financial services (Hanning and Jansen, 2010). In poor areas with low coverage of financial institutions, financial inclusion acts as an equalizer between financial inclusion and economic growth (Gomez et al., 2015), and can help poor groups to solve the problem of "financing difficulty" to a great extent, thereby boosting the labor market, increasing job opportunities, and promoting the development of rural economy. Financial inclusion promotes residents to solve problems such as employment, financing and so on, and helps the poor to solve the problem of financing difficulty through agricultural credit, thus improving the rural living environment (Gomez et al., 2015). The agricultural credit also helps to mitigate the negative impacts of financial fluctuations or natural disasters on poor groups in rural areas, thus ensuring the income stability of rural poor groups (Rahman, 2009). By expanding the coverage of financial services, financial inclusion enables poor groups in rural and remote areas to enjoy

financial services, which increases the usage rate of financial services, improves credit constraints, promotes local economic growth, increases the income level of rural and remote areas, helps the poverty reduction in rural and remote areas and reduce the wealth gap. The development of financial inclusion not only solve the problem of employment for poor groups and increase their income level, but also helps them to improve the sanitary living environment and self-quality, thus promoting social stability (Sarma and Pais, 2011).

Financial inclusion, with inclusiveness at its core, serves all sectors and groups of society, especially the poor and other vulnerable groups that have been excluded from the financial system, can enjoy affordable and economical financial services through mobile and convenient way, thereby improving the existing unequal distribution of resource allocation. Financial inclusion system will open up financial markets to the vast majority of people in developing countries, including the rural residents in poorer and more remote areas that are inaccessible in the past, and provide credit, insurance and fund settlement services to poor residents. Financial inclusion breaks through the boundary of traditional finance, enriches financial products, provides affordable loans to the poor, increases risk-resistance capacity, and has a positive impact on poverty reduction in rural and remote areas.

2.2 The Influence of Digital Financial Inclusion Development on Poverty

Different from financial services in the traditional sense, digital finance relies on technology rather than human to determine the inclusiveness of its financial service system. With the continuous improvement of digital finance infrastructure, all social groups can easily obtain financial services at a lower cost. Vigorously developing financial technology is conducive to improving the financial system and plays a significant role in promoting economic development, export transformation and upgrading, and structural optimization (Sarma and Pais, 2011). The inclusiveness of digital financial inclusion determines that its crucial role in the national strategy of poverty reduction and elimination. When poor groups engage in formal financial activities, they will accumulate a large amount of behavioral data, which will be analyzed through big data technology, so as to construct the credit model for poor groups, alleviate the weakness of insufficient credit information for poor groups, and help them cross the entrepreneurial threshold of capital constraint. Traditional financial inclusion restricts poor groups to some extent from obtaining funds for investment and entrepreneurship due to low efficiency of resource allocation and inadequate supply (Aghion et al., 2007; Demirguc-Kunt and Peria, 2007), which has led to the birth of digital financial inclusion and its rapid development in China. Digital technology is integrated with financial inclusion, and digital information technology can reduce information asymmetry and improve the efficiency of resource allocation. Digital financial inclusion relies on digital information technology, which reduces financial transaction cost, broadens financial coverage breadth and depth of use, and enhances inclusiveness. Digital financial inclusion breaks through the geographical space constraints, which can better improve the financial availability of low-income people, poor groups and other vulnerable groups, give full play to the strengths of low cost, wide coverage and deep usage, and alleviate the "last-mile" problem of financial inclusion, thus

promoting poverty reduction and income growth. The development of digital financial inclusion in rural and remote areas can improve the financial infrastructure, provide convenient and affordable financial services for local poor groups, increase the availability of financial services, and help poor groups to make venture capital investments, thus providing the possibility of "corner overtaking". The digital financial inclusion indicator published by the Institute of Digital Finance, Peking University (2011-2018) can be used to measure the development status of digital financial inclusion in China (Guo et al., 2019), which provides data support for the study of digital financial inclusion in China.

Based on the characteristics of the Internet, digital financial inclusion breaks the limitations of traditional finance relying on branches, and provides online financial products and services for many low income people, rural poor groups and other vulnerable groups by means of mobile Internet, which significantly lowers the financial threshold. It has not only improved the life quality of poor groups, but also provided financial support for poor groups to engage in investment and entrepreneurship, thus promoting inclusive growth in rural areas.

2.3 Hypotheses on the Mechanism for Digital Financial Inclusion to Reduce the Relative Poverty Depth of Rural Families

Digital financial inclusion is a product of the mutual integration of financial inclusion and digital technology and have the characteristics of both financial inclusion and digital technology. Digital technology helps financial inclusion break the geographical space constraints, realize the "inclusiveness" and expand the coverage of financial services. Digital technology reduces search costs and improves the efficiency through accurate imaging, which makes "benefit" possible. Through the combination of "inclusiveness" and "benefit", the rural poor groups, who are otherwise excluded from financial services, can also enjoy financial services, thus achieving the aim of poverty reduction. As a result, this paper proposes three mechanism hypotheses of digital financial inclusion development on the poverty reduction of rural families:

Digital financial inclusion helps rural families get rid of poverty through the "trickle-down effect" of local economic development. The "trickle-down effect" refers that financial services are given priority to provide for rich people and other powerful groups in the economic development and their created value in the financial activities of social economy is used to promote the economic growth, drive the increase of employment opportunities and wage income, so that the poor groups in rural areas can accumulate more wealth, like "trickling down" of water, which plays a role in rural poor groups through forward diffusion and makes rural families get rid of poverty. Theoretically, the development of digital financial inclusion will contribute to the growth of the local economy, while the economic growth will improve the wage income of rural poor families through "trickle-down effect", thereby narrowing the internal wealth gap in rural areas.

Research in international trade find that financial markets influence firm export behavior (including export quantity, export quality and export mode, etc.) and high efficiency of the financial system and

financial development have great positive influence on the behavior of firms exports (Chor and Manova, 2012; Feenstra, 2014; Manova and Yu, 2016). Digital finance may help Chinese firms in rural areas export their products, which will significantly promote local economy development and increase wage income. Thus, we have hypothesis 1:

Hypothesis 1: Digital financial inclusion drives the wage income increase of residents to alleviate poverty.

Additional from breaking through physical distance, digital finance also alleviates institutional barriers of financial service suppling in rural areas. As intermediates goods, financial service is hardly dependent on local institutional environment, such as formal institution and informal institution like clan (Cheng et al., 2021) and rice-wheat planning (Talhelm et al., 2014), mainly because services products such as financial products are different from tangible physical intermediates goods with characters of Standard, storable, tradable. While financial technology has little to do with the local institutional environment, thus weakening barrier effects of local institutional environment on financial services in rural areas. The development of digital financial inclusion has increased the availability of resident credit and eased their constraints of loans, which helps rural families to use loan funds to cope with adverse health shocks, alleviate poverty and prevent rural families from falling back into poverty due to illness, while at the same time, under the condition of easing the constraints of loans, rural families can arrange inter-period optimal consumption and improve the welfare level.

Hypothesis 2: The development of digital financial inclusion alleviates the constraints of rural family loans.

The development of digital financial inclusion has promoted local economic development, invigorated the local economy, and provided market opportunities for entrepreneurship of poor families. At the same time, digital financial inclusion has eased credit constraints, so that poor families can invest in their labor forces and funds for entrepreneurship, which narrows the wealth gap with other rural families. Digital finance accelerates the capital turnover of entrepreneurial firms, reduces the financing constraints on the payment of fixed and variable costs, and especially reduces the negative impact on working capital investment. By stabilizing cash flow, reducing working capital and fixed investment fluctuations, firms can increase investment in technology and relationship-specific investments and improve technology level and product quality (Nunn, 2007, Ding et al., 2013).

Hypothesis 3: Digital financial inclusion promotes entrepreneurship of rural families and alleviates poverty.

The financial development of digital inclusive finance has promoted the development of local economy, invigorated local economy, and provided market opportunities for poor families to start businesses. Meanwhile, digital inclusive finance has relaxed credit constraints, enabling poor families to invest their own labor and capital to start businesses, and narrowing the wealth gap with other rural families.

3. Poverty Reduction and Development of Digital financial inclusion in China

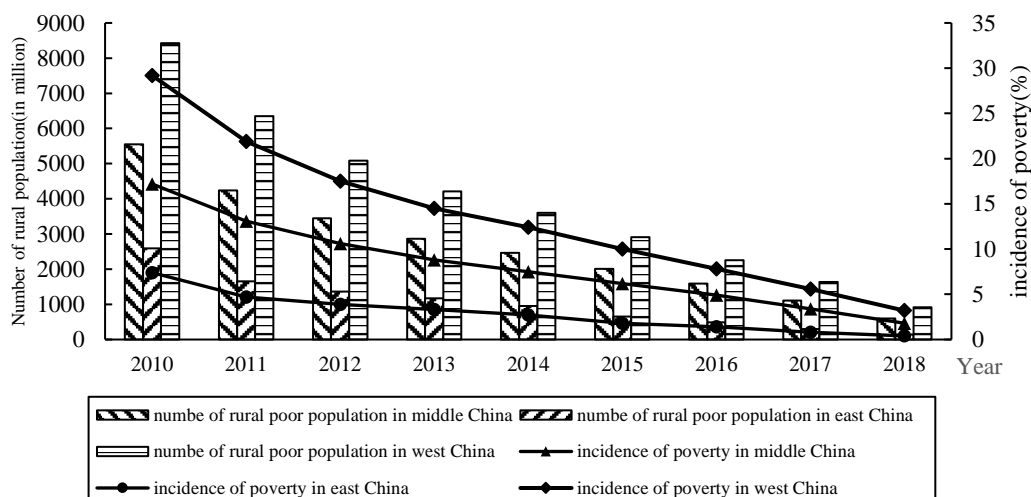### *3.1 Current Status of Poverty Reduction in China*

Figure 1. Poverty population size and poverty incidence rate in eastern, central and western China from 2010 to 2018

Data source: The State Statistics Bureau in 2019
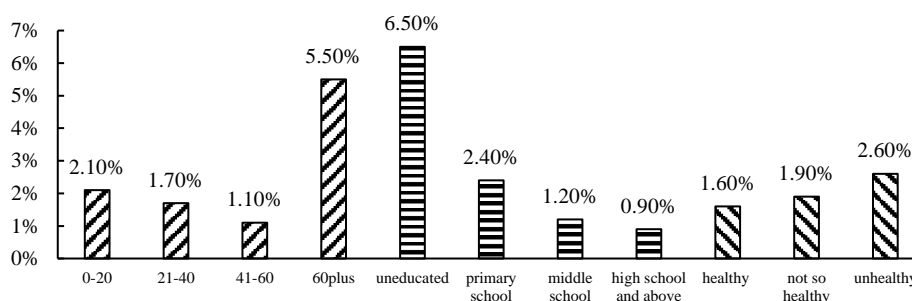
Figure 2. Poverty incidence rate by age, education, and health in 2018

Data source: The State Statistics Bureau in 201

The distribution of poverty in rural areas is influenced by various factors, and there are differences in several aspects: Firstly, elderly people over 60 years old are the main distribution target of poverty group, because they have limited working capacity, are not well educated and have little access to modern means (smart-phones and the Internet) to improve their economic situation, resulting in a high

poverty incidence rate among those over 60 years old. Secondly, the low level of education of rural families increases the poverty incidence rate, cause rural residents who have received education will have a certain level of scientific and cultural quality and can quickly receive modern digital information and adapt to the Internet and other digital technologies compared with rural families who have not received education. The higher the level of education, the faster the acceptance. Thirdly, the rural residents with good health can effectively reduce the poverty incidence rate because the poorer health of rural residents limits their range of labor, resulting in lower economic income and decline of living standard (see Figure 2).

3.2 Development Status of Digital Financial Inclusion in China

Digital financial inclusion is the expansion and extension of financial inclusion, the product of continuous collision and integration of digital technology and finance under the background of the big data era, and a new form of financial inclusion development. The continuously improved infrastructure and enormous Internet users are the foundation for the development of digital financial inclusion in China. By the end of 2018, China had become the country with the most extensive 4G network coverage in the world, and the number of 4G mobile base stations in China had reached 3.72 million, with an increase of 3.657 million compared with that in 2013 and a year-on-year growth of 5900%. The deep coverage of the 4G network and the continuous elimination of blind spot areas have made it possible to develop digital financial inclusion in rural and remote areas. By the end of 2018, the number of Chinese netizens reached 829 million, and the network coverage in rural areas was 38.4%, with an increase of 34.2% and 10.3% compared with that in 2013 respectively. The 4G network started late in China, but under the guideline of building a cyberpower, it had a rapid growth. Since 2014, the 4G network has covered the whole country rapidly. By the first half of 2018, the penetration rate of 4G users had reached 73.5%, which was far ahead of the average of OECD countries and the global average, and became a cyberpower in the world. With the full coverage of 4G network and its popularization to poor and remote areas, the service capacity and quality of mobile network have been effectively improved. According to data released by the Ministry of Industry and Information Technology of the People's Republic of China, the popularity rate of smartphone is 68%, while the average level in developing countries is only 45%.

Benefiting、 from continuously improved infrastructure and enormous Internet users, the digital financial inclusion has a rapid development in China in recent years. According to the digital financial inclusion indicators jointly compiled by the Institute of Digital Finance, Peking University and Ant Financial Services Group, China's digital financial inclusion (on average) grew from 40.00 in 2011 to 300.21 in 2018. Based on geographical location, this paper divides provinces in China into eastern, central and western areas (excluding Tibet and Xinjiang). Among them, the eastern area includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. The central area includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan, and the western area includes Sichuan, Chongqing, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia,

Guangxi and Inner Mongolia. From the perspective of area, there are differences between regions in the development of digital financial inclusion, of which the eastern area has the highest development degree, followed by the central area while the western area has the lowest development degree. In terms of the growth speed between regions, the growth rate of digital financial inclusion in the central and western areas is faster than that in the eastern area, and the central and western areas show a catch-up trend in the development of digital financial inclusion. However, as far as the relative poverty depth within the provinces concerned by this paper, whether rural families in the central and western provinces have reduced their relative poverty depth through the catch-up development of digital financial inclusion needs further investigation.

Table 1. Regional development indicator of digital financial inclusion in China

Area	year of 2011	year of 2018
Whole country(average)	40.00	300.21
Eastern area	59.16	327.78
Central area	31.91	292.07
Western area	21.85	281.82

4. Data Source and Model Settings

4.1 Data Source

The data in this paper comes from two databases. The first data is the digital financial inclusion indicator (DIF) published by the Institute of Digital Finance, Peking University, which can be used to measure the development of digital financial inclusion in China (Guo et al., 2019). The data is jointly made by the Institute of Digital Finance, Peking University and Alipay (China) Network Technology Co. Ltd. By using the relevant data of Alipay which is widely used in China, this paper selects the provincial-level digital financial inclusion index, use depth and degree of digital support service and the sample interval is from 2012 to 2018. China family panel studies (CFPS), a nationwide social tracking survey, has started since 2010 and is updated every two years, covering 162 counties in 25 provinces/municipalities/autonomous regions, with data at the individual, household and community levels. The survey content covers various aspects, such as working income, family status, family economy, health degree, education and other data. Due to data limitations, this paper only selects data at the provincial level and the family level, and the sample interval is from 2012 to 2018.

4.2 Model Settings

（1） *Generalized Difference-in-differences*

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A generalized difference-in-differences is established between digital financial inclusion and relative poverty depth of rural families as follows:

$$rpd_{jt} = \alpha_0 + \alpha_1 DIF_{it} * Internet_{ij} + \alpha_2 X_{ijt} + \emptyset_{ij} + \varphi_t + u_{ijt} \qquad (1)$$

This paper focuses on the wealth gap in rural areas of each province. By referring Foster et al. (1984), this paper assumes that in the year of t, if the per capita consumption of rural families j last year is c_j, and 50% of the per capita consumption expenditure of residents in the province i is the poverty line z_i, the relative poverty depth of rural families is:

$$\text{Relative poverty depth } rpd_{jt} = \begin{cases} \frac{z_i - c_j}{z_i} \text{ if } z_i > c_j \\ 0 \qquad \text{if } z_i \leq c_j \end{cases} \qquad (2)$$

This paper studies the promoting role of digital financial inclusion development in poverty reduction of rural families. Among them, rpd_{ij} represents the relative poverty depth of family j in the i province. In terms of micro-family, family is the receiver of the development achievements of of digital financial inclusion in the province, and the development of digital financial inclusion in the province has strong exogeneity. Digital financial inclusion has different development levels in various provinces, and it also has various promoting effects on poverty reduction among rural families. Furthermore, only those rural residents leaving digital footprints, that is, have access to the Internet, can directly benefit from the development of digital financial inclusion. DIF_{it} indicates the digital financial inclusion indicator of the rural family j in the province i in the year of t, and $Internet_{jt}$ represents whether the rural family j left digital footprints (with access to the Internet) in the year of t. 1 is taken to indicate that the family has left digital footprints as the treatment group, while 0 is taken to indicate that the family has not left digital footprints as the control group. α_1 is used to measure the overall impact of digital financial inclusion on the relative poverty depth of rural families that have left digital footprints. X_{ijt} represents the control variable of the rural family j in the i province, and $\emptyset_{ij}$ represents the fixed effect of the rural family j in the i province. φ_t represents the fixed effect of year, and u_{ijt} represents the random disturbance. In addition, since this paper analyzes the relationship between digital financial development at the regional level and the relative poverty depth of rural families, the standard error is clustered to the family level to avoid the influence of inter-regional correlation on the estimated results. Through the continuous variable DIF_{it} by using generalized difference-in-differences, the development levels of digital financial inclusion in different provinces have been obtained.

The control variables selected in this paper include characteristic variables of rural families and

provincial economic development variables. Among them, the variables at the rural family level include the gender, age, education years, politics status, marital status and health level of family members. The provincial economic development variables take the per capita GPD of the province where the rural family is located and the level of urban financial development (measured by the ratio of RMB loan balances of financial institutions to GDP) as the substitute variables of regional economic financial variables.

（2） *Propensity Score Matching*

Since whether the family has left digital footprints is not random, the direct use of formula (1) may suffer from the bias error of sample selection, that is, some unobserved factors may influence whether an individual leaves digital footprint, and these factors may also influence poverty reduction of families. The instrumental variables are difficult to obtain because most of factors that influence the access to the Internet also affect the family poverty level. In this paper, the original sample is resampled by using year-by-year propensity score matching to ensure that the matching group can be found for families that have left digital footprints. Specifically, the matching process in this paper draws on the algorithms provided by Becker and Ichino (2002) and Leuven and Sianesi (2003) to match the Internet access year by year. Considering that the sample quantity ratio of experimental sample to control sample is 1:3, this paper uses K-nearest neighbor (K=3) to eliminate samples that are not in the common support domain and merges the historical data to reconstruct the panel data. At this point, after controlling the remaining variables, the individual has entered the treatment group (rural families with digital footprints) or the control group (rural families without digital footprints), which has no correlation with potential results, and the endogeneity has been mitigated.

5. Empirical Results

5.1 Sample Data Processing

（1）*Descriptive Statistics of Samples*

In this paper, the data from the China Family Tracking Survey (CFPS) in 2012, 2014, 2016 and 2018 are combined with the provincial-level data from the digital financial inclusion indicator from 2012 to 2018 as the dataset for the empirical test, and after using the year-by-year propensity score matching, the samples that do not exist in the common support domain are excluded to reconstruct the panel data. The descriptive statistics of the sample variables concerned by this paper are shown in Table 2.

Table 2.　Descriptive statistics of main variables

Variable	Sample size	Mean value	Standard deviation	Minimum value	Maximum value
Relative poverty depth	17663	0.177	0.276	0	1
DFIII/100	17663	2.29	0.514	1.55	3.78

Digital footprints (Yes=1)	17663	0.236	0.425	0	1
Age	17663	50.75	13.38	14	88
Gender (Male=1)	17663	0.563	0.496	0	1
Health	17663	3.158	1.279	1	5
Education years	17663	2.389	1.456	1	9
Politics status (Party number=1)	17663	0.027	0.161	0	1
Marital status (Married=1)	17663	0.867	0.359	0	1
GDP per capital	17663	10.729	0.388	10.147	11.851
Financial development level (Loans/GDP)	17663	1.404	0.432	0.769	2.515

（2） *Parallel Trend Test by Generalized Difference-in-differences*

After completing the matching, this paper tests whether the data meet the two prerequisites of the generalized difference-in-differences. First, the process of sample selection cannot be interfered by other factors and this process is random, otherwise the results will be unreliable. Second, the control group (i.e., rural families without digital footprints) have the similar characteristic, that is, the parallel trend, with the treatment group (i.e., rural families with digital footprints) before the role of digital financial inclusion. The generalized difference-in-differences test can be performed only if both conditions are met simultaneously.
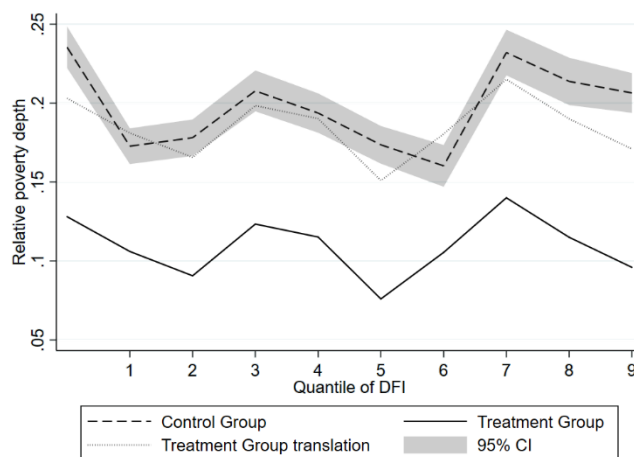
Figure 3．Parallel trend chart

In order to ensure randomness in the selection of the implementation year for the treatment group, this paper adds the time fixed effect on the basis of reference model to control the possible differences in different years. To ensure randomness in the selection of families in the treatment group, this paper adds the family fixed effect based on reference model to control the possible differences in different

provinces.

Figure 3 depicts the trend of relative poverty depth of two groups of digital financial inclusion of rural families at different stages, and the digital financial inclusion indicator in this paper is divided into 10 parts according to the equal quantiles. The relative poverty depth of two groups of rural families (with digital footprints/without digital footprints) within each quantile is calculated. It is found that in the early development stage of digital financial inclusion (first to fourth quantile), the development of digital financial inclusion has little impact on the poverty level of the two groups of rural families and is almost in a parallel trend. As the development of digital financial inclusion starts to have divergence (fifth to seventh quantile), the rise in rural families with digital footprints (treatment group) at this stage may be due to the fact that rural families have incurred additional costs in the digital infrastructure construction, such as time and equipment costs, resulting in a slight increase in poverty depth. However, the increase in poverty depth is relatively less than that of rural families without digital footprints(control group). When the development degree of digital financial inclusion is high (seventh to tenth quantile), there is a significant decline in poverty depth for rural families with digital footprints (treatment group) compared with rural families without digital footprints (control group). The higher the digital financial inclusion indicator, the more obvious the poverty reduction for rural families with digital footprints.

When the development level of digital financial inclusion is low, the difference in poverty depth between rural families with digital footprints (treatment group) and rural families without digital footprints (control group) is small. When the development of digital financial inclusion reaches a certain level, the difference in poverty depth between the two groups of rural families becomes larger, which breaks the previous parallel trend.

5.2 The Promotion of Digital Financial Inclusion to the Poverty Reduction of Rural Families: Benchmark Analysis

Table 3 reports the regression results of panel fixed effect for the year-by-year propensity score matching-generalized difference-in-differences. The results show that on the national scale, digital financial inclusion has the effect of reducing the relative poverty depth of rural families, which is significant at the level of 5%, and each 1% of increase in the development level of digital financial inclusion can reduce the relative poverty depth of rural families with digital footprints by 0.023%. In terms of control variables, age, health and poverty depth have a significant correlation and are significant at the level of 1%, which indicates that the younger the average age of family members, the lower the relative poverty depth. The better the health, the lower the relative poverty depth. In this paper, heterogeneity analysis is conducted for the eastern area, central area and western area in China respectively, and the empirical results are shown in columns (3) to (5). The poverty reduction effect of digital financial inclusion has regional heterogeneity. In the eastern area, the development of digital financial inclusion slows down the relative poverty depth of rural families, which is significant at the level of 1%, but it is not significant in the central and western areas. This indicates that there are

regional differences in the impact of the development of digital financial inclusion on reducing the poverty gap in rural areas, that is, in the eastern area where the development of digital financial inclusion is relatively high, rural families with digital footprints significantly reduce the poverty depth compared with those without digital footprints, while rural families in the central and western areas do not significantly benefit from digital financial inclusion and reduce the relative poverty depth. This may be due to the fact that the central and remote western areas have bad geographical positions, digital financial inclusion is in the initial stage and the development of digital financial inclusion has no significant impact on mitigating the poverty depth of the two groups of families, resulting in no significant impact on the poverty depth of the two groups of rural families in the central and western areas.

Table 3. Benchmark Results

Variable	(1) Relative poverty depth	(2) Relative poverty depth	(3) Relative poverty depth in the eastern area	(4) Relative poverty depth in the central area	(5) Relative poverty depth in the western area
DFII*Digital footprint	-0.023**	-0.022**	-0.052***	0.004	-0.015
	(0.010)	(0.010)	(0.010)	(0.022)	(0.021)
Age	0.001***		0.002**	0.001	0.001
	(0.000)		(0.001)	(0.001)	(0.001)
Gender	-0.009		-0.019	-0.008	-0.003
	(0.006)		(0.013)	(0.020)	(0.009)
Health	-0.010***		-0.007***	-0.002	-0.018**
	(0.002)		(0.001)	(0.004)	(0.006)
Education	-0.000		0.006	-0.014	0.001
	(0.002)		(0.004)	(0.012)	(0.006)
Party member	-0.013		-0.013	0.034	-0.054**
	(0.013)		(0.029)	(0.022)	(0.017)
Married	-0.014		-0.026	0.011	-0.022

	(0.012)		(0.015)	(0.027)	(0.016)
GDP per capita	-0.045*		0.056	-0.320***	-0.279
	(0.027)		(0.049)	(0.076)	(0.160)
Urban financial development level	-0.031		0.066	-0.368***	-0.110
	(0.020)		(0.042)	(0.095)	(0.067)
Constant	0.841***	0.379***	-0.436	3.474***	3.260
	(0.274)	(0.085)	(0.617)	(0.928)	(1.697)
Observation	16,326	16,326	5,826	4,574	5,855
R^2	0.548	0.546	0.547	0.551	0.543

Note: (1) Significant level: ***$p < 0.01$, **$p < 0.05$, * $p < 0.1$ (2) The figure in the bracket is the standard error

5.3 Robustness Test

（1）Endogeneity Discussion

From the perspective of empirical approach, there are unavoidable endogeneity problems in studying the promoting role of digital financial inclusion development in rural poverty reduction. Firstly, the model in this paper may have the problem of missing variables. Whether residents leave digital footprints is not random, and this factor may be influenced by some unobservable factors that may influence the poverty reduction of residents. In this regard, this paper uses the two-way fixed effects model to control the characteristics at the family level that do not change over time, as well as characteristics of different years that do not change with families. Secondly, the model in this paper may have the problem of reciprocal causation. On the one hand, the development of digital financial inclusion may contribute to family poverty reduction, but the families after getting rid of poverty may have a stronger ability to use digital financial inclusion services, so the regression formula (2) has certain reverse causality. However, since the poverty reduction, the explained variable, is the family micro-data, while digital inclusion development is the provincial data. It is difficult for micro-individual behaviors to have an impact on the provincial situation. At the same time, poverty reduction may also have an impact on whether families leave digital footprints. Therefore, this paper carries out resampling by propensity score matching and eliminates samples that are not in the common support domain, which mitigates such endogeneity. In addition, considering that the development of digital financial inclusion may have time lag for promoting the poverty reduction of rural families, that is, poor rural families need time to improve their life, this paper also uses the digital financial inclusion indicators with 1 period lag as the explained variables for the regression. The model is set up as in

formula (6), and the empirical results are shown in columns (1)and (2) of Table 4. Column (1) is the regression result of two-way fixed effects model with the addition of control variables. Column (2) is the regression result of two-way fixed effects model without adding control variables. The results show that the interaction term between the digital financial inclusion indicators with 1 period lag and the digital footprints is still significant, so the conclusions in this paper have better robustness.

$$rpd_{jt} = \alpha_0 + \alpha_1 DIF_{it-1} * Internet_{ij} + \alpha_2 X_{ijt} + \emptyset_{ij} + \varphi_t + u_{ijt} \qquad (6)$$

（2）*Discussion of Model Settings*

In formula (1), all negative numbers of relative poverty depth are merged to zero. It means that the relative poverty depth can not be negative, so that all the negative points in the variable of relative poverty depth will be concentrated at zero point, while the rest will be positive. When this situation happens, the estimation by OLS method may be biased, so the regression with fixed effect is replaced by the regression with tobit, as shown in formula (7). The empirical results are still significant in column (3) of Table 4, which indicates that digital financial inclusion has the effect of reducing relative poverty depth for rural families, which is roughly the same as the benchmark regression. Therefore, the empirical results of this paper are robust.

Table 4. Robustness test

Variable	(1) Relative poverty depth	(2) Relative poverty depth	(3) Relative poverty depth
DFII*Digital footprint	-0.0002**	-0.0002**	-0.0511**
	(0.0001)	(0.0001)	(0.0253)
Age	0.0015***		0.0048***
	(0.0004)		(0.0005)
Gender	-0.0085		-0.0020
	(0.0065)		(0.0114)
Health	-0.0098***		-0.0147***
	(0.0024)		(0.0043)
Education	-0.0001		-0.0218***
	(0.0024)		(0.0039)
Party member	-0.0090		-0.0615*
	(0.0127)		(0.0322)
Married	-0.0148		-0.0704***
	(0.0117)		(0.0161)
GDP per capita	-0.0107		-0.1275*
	(0.0302)		(0.0652)

Financial development	0.0017		-0.1322**
	(0.0223)		(0.0514)
Constant	0.6050**	0.5566***	1.7155**
	(0.2890)	(0.0998)	(0.8489)
Observation	16,284	16,284	17,676
R^2	0.5506	0.5492	0.0372

5.4 Influencing Mechanism and Channel Test

It has been verified above that the development of digital financial inclusion can significantly reduce the relative poverty depth of rural families with digital footprints. This paper further tests its influencing mechanism. In the third section, this paper puts forward three hypotheses on the poverty reduction effect mechanism of digital financial inclusion, namely, the mechanism of increasing wage income, the mechanism of easing credit constraints and the mechanism of encouraging entrepreneurship. Now, the empirical tests are carried out for these three mechanisms.

（1）The Mechanism of Increasing Wage Income

Wage income is an important income source for most rural families in China, and digital financial inclusion raises rural family income by revitalizing the local economy and creating jobs, that is, the "trickle-down effect". This paper uses formula (3) to test whether the development of digital financial inclusion raises the wage income of rural families with digital footprints, and $wage_{ij}$ comes from the answer to question F07 "total wage income (yuan)" in the CFPS survey.

$$wage_{jt} = \alpha_0 + \alpha_1 DIF_{it} * Internet_{jt} + \alpha_2 X_{ijt} + \emptyset_{ij} + \varphi_t + u_{ijt} \qquad (3)$$

Table 5 reports the regression results between digital financial inclusion and rural family wage income. The results indicate that digital financial inclusion can promote the increase of rural family wage income, and is significant at the level of 1%. For rural families with digital footprints, the development of digital financial inclusion raises their family wage income. Each 1% of increase in digital financial inclusion helps the family with footprints raise 4554 yuan in family wage income. Regional regression results show that among the rural areas with digital footprints, the wage income of rural families in the central and eastern and western areas does not significantly benefit from the development of digital financial inclusion, while the development of digital financial inclusion increases the wage income of rural families in the central area at the significant level of 10%, which suggests that there is a "trickle-down effect" of economic development in the central rural areas, while it is significant in the eastern and western areas.

Table 5. The test of mechanism of increasing the wage income

Variable	(1) Wage income	(2) Wage income in the eastern area	(3) Wage income in the central area	(4) Wage income in the western area
DFII*Digital footprint	0.283*	-0.247	0.786**	0.298
	(0.168)	(0.275)	(0.313)	(0.283)
Age	-0.019***	-0.042***	-0.021**	0.002
	(0.005)	(0.010)	(0.010)	(0.007)
Gender	0.044	0.149	0.034	-0.040
	(0.084)	(0.143)	(0.166)	(0.128)
Health	-0.048	-0.043	-0.007	-0.076*
	(0.029)	(0.052)	(0.053)	(0.045)
Education	0.036	0.016	0.040	0.019
	(0.023)	(0.058)	(0.057)	(0.026)
Party member	0.378*	0.401	0.009	0.709**
	(0.207)	(0.407)	(0.375)	(0.304)
Married	0.067	0.436*	-0.535*	0.053
	(0.151)	(0.262)	(0.302)	(0.227)
GDP per capita	0.749**	0.098	6.633***	2.357
	(0.376)	(0.599)	(1.949)	(1.971)
Financial development	0.236	-1.237**	4.898***	1.765***
	(0.275)	(0.542)	(1.752)	(0.659)
Constant	-3.647	12.375*	-72.828***	-27.079
	(4.115)	(6.904)	(20.762)	(17.083)
Observation	16,248	6,186	4,562	5,433
R^2	0.586	0.607	0.562	0.579

Note: (1) Significant level: ***$p < 0.01$, **$p < 0.05$, * $p < 0.1$ (2) The figure in the bracket is the standard error

（2）*The Mechanism of Easing Credit Constraints*

The mechanism of digital financial inclusion for alleviating the credit constraints of rural families and reducing poverty is that the digital financial inclusion provides formal loans for more rural families, help rural families cope with negative shocks, and provides rural families with start-up capital for individual businesses. This paper uses two-way fixed effects probit model, where $\emptyset_i$ is the provincial fixed effect and φ_t is the fixed affect of year, so as to test whether digital financial

inclusion has eased credit constraints on rural families, as shown in formula(4). getloan_{jt} comes from the answer of FT8 in the CFPS questionnaire, which suggests whether the rural family j can borrow loans smoothly in the year of t. 1 is taken to indicate that the loans are borrowed smoothly, while 0 is taken to indicate that the loans are not borrowed.

$$\text{Probit}(\text{getloan}_{jt} = 1) = \alpha_0 + \alpha_1 \text{DIF}_{it} * \text{Internet}_{jt} + \alpha_2 X_{ijt} + \emptyset_i + \varphi_t + u_{ijt} \qquad (4)$$

The results in Table 6 show that the development of digital financial inclusion has eased the credit constraints of rural families and helped them to borrow loans smoothly. In terms of control variables, age, gender, health, marital status, economic development level of the location and financial development level are all significantly related to the credit constraints of rural families. In terms of region, for rural families with digital footprints in the western area, the development of digital financial inclusion has significantly eased their credit constraints, while rural families in the eastern and central areas have not significantly benefited from the development of digital financial inclusion in terms of credit constraints.

Table 6. Test of mechanism of easing credit constraints

Variable	(1) Borrowing loans smoothly	(2) Borrowing loans smoothly in the eastern area	(3) Borrowing loans smoothly in the central area	(4) Borrowing loans smoothly in the western area
DFII*Digital footprint	0.130**	0.112	0.120	0.167*
	(0.059)	(0.093)	(0.083)	(0.088)
Age	-0.003***	-0.003	-0.005***	-0.003***
	(0.001)	(0.003)	(0.001)	(0.001)
Gender	-0.058**	-0.091**	-0.084**	-0.000
	(0.023)	(0.036)	(0.036)	(0.033)
Health	-0.044***	-0.050***	-0.027	-0.051***
	(0.007)	(0.010)	(0.017)	(0.008)
Education	0.004	0.033***	-0.002	-0.004
	(0.006)	(0.013)	(0.012)	(0.004)
Party member	-0.023	-0.093	-0.010	0.020
	(0.063)	(0.076)	(0.071)	(0.136)
Married	0.182***	0.164***	0.256***	0.148***
	(0.035)	(0.046)	(0.073)	(0.055)
GDP per capita	0.523***	0.022	0.652*	0.341

	(0.192)	(0.124)	(0.338)	(0.433)
Financial development	0.335*	0.120	0.322	0.066
	(0.176)	(0.198)	(0.272)	(0.344)
Constant	-6.582**	-1.941	-5.821**	-1.206
	(3.082)	(2.583)	(2.766)	(4.099)
Observation	17,673	6,414	4,984	6,275
Pseudo R^2	0.0173	0.0275	0.0149	0.0140

Note: (1) Significant level: ***$p < 0.01$, **$p < 0.05$, * $p < 0.1$ (2) The figure in the bracket is the standard error

（3）*Mechanism of encouraging entrepreneurship*

The mechanism of encouraging entrepreneurship in digital financial inclusion for poverty reduction is that the development of digital financial inclusion not only improves the local economy and provides opportunities for entrepreneurship, but also provides credit funds for the entrepreneurship of rural families, so that they can put capital into production with labor forces. This paper takes advantage of the answer of FM2 "How many private activities are you engaged in" in the CFPS questionnaire and uses the two-way fixed effects model to test the entrepreneurship mechanism, as shown in formula (5). $entrepreneur_{jt}$ is the number of private enterprises owned by the rural family j in the year of t.

$$entrepreneur_{jt} = \alpha_0 + \alpha_1 DIF_{it} * Internet_{jt} + \alpha_2 X_{ijt} + \emptyset_{ij} + \varphi_t + u_{ijt} \qquad (5)$$

The results in Table 7 show that the mechanism for encouraging entrepreneurship in poverty reduction through digital financial inclusion is significant throughout the country. Rural families with digital footprints have benefited from the development of digital financial inclusion, and the gender of the head of household and the financial development level of the province have a significant relation with the rural entrepreneurship level. In terms of region, rural families with digital footprints in the central area have significantly benefited from the development of digital financial inclusion, while rural families in the eastern and western areas have not significantly benefited from the development of digital financial inclusion.

Table 7. Test of mechanism of encouraging entrepreneurship

Variable	(1) The number of owned private enterprises	(2) The number of owned private enterprises in the eastern area	(3) The number of owned private enterprises in the central area	(4) The number of owned private enterprises in the western area
DFII*Digital	0.023*	0.011	0.045*	0.025

footprint				
	(0.013)	(0.017)	(0.023)	(0.020)
Age	-0.000	0.000	-0.001	-0.000
	(0.000)	(0.001)	(0.001)	(0.001)
Gender	0.011*	0.013***	0.012	0.003
	(0.006)	(0.004)	(0.013)	(0.013)
Health	0.001	0.001	0.001	0.002
	(0.002)	(0.007)	(0.004)	(0.002)
Education	0.000	0.000	0.004	-0.000
	(0.001)	(0.005)	(0.007)	(0.002)
Party member	0.004	0.014	-0.005	0.001
	(0.014)	(0.028)	(0.023)	(0.032)
Married	-0.011	-0.019	-0.030	0.010
	(0.012)	(0.017)	(0.026)	(0.013)
GDP per capita	-0.010	-0.052	-0.261	0.034
	(0.027)	(0.033)	(0.223)	(0.037)
Financial development	-0.024	-0.093**	-0.169	0.003
	(0.022)	(0.034)	(0.191)	(0.018)
Constant	0.342	0.908**	2.829	-0.173
	(0.307)	(0.360)	(2.411)	(0.447)
Observation	16,284	5,805	4,570	5,840
R^2	0.652	0.685	0.637	0.635

Note: (1) Significant level: ***$p < 0.01$, **$p < 0.05$, * $p < 0.1$ (2) The figure in the bracket is the standard error

6. Conclusions and Policy Implications

This paper constructs a "quasi-natural experiment" using propensity score matching-generalized difference-in-differences and empirically analyzes the poverty reduction effect of digital financial inclusion development on rural families using provincial-level data from 2012 to 2018 combined with China family panel studies. The findings demonstrate that increasing digital financial inclusion can lower rural families' relative poverty levels and narrow the wealth gap in rural areas. When compared to rural households without digital footprints, every 1% increase in digital financial inclusion helps rural families with digital footprints reduce their relative poverty depth by 0.022 percent. In terms of regional heterogeneity, the expansion of digital financial inclusion reduces the internal relative wealth difference in eastern rural areas significantly, while having little effect on the wealth gap in central

rural areas.In terms of poverty reduction mechanism, this paper finds that digital financial inclusion has alleviated the relative poverty depth of rural families through three mechanisms: increasing wage income, easing credit constraints, and encouraging entrepreneurship, while poverty reduction mechanisms also have heterogeneity, with rural families in the eastern area benefiting from increasing wage income, rural families in the central area benefiting from entrepreneurship opportunities, and rural families in the western area benefiting from easing credit constraints.

The policy suggestions in this paper are as follows: First, the digital infrastructure construction should be strengthened, and the development of digital financial inclusion should be regarded as an important means to winning the fight against poverty. According to the conclusions of this paper, digital financial inclusion can effectively reduce the poverty incidence rate of rural areas, while its development necessitates the development of digital infrastructure. Therefore, enhancing the digital infrastructure construction in rural areas is beneficial to win the fight against poverty reduction in China. Second, the investment in central and western rural areas should be increased. Rural families in central and western areas of China have not significantly benefited from digital financial inclusion, which may be related to the limited development level in central and western rural areas. Despite the rapid expansion of digital financial inclusion, other factors in the area may drag down the poverty reduction of rural families. Third, each area should adjust measures to local conditions, appropriately formulate digital financial inclusion development strategies, and use digital financial inclusion to strengthen weak linkages. For example, rural families in the central area have benefited from the entrepreneurial opportunities of digital financial inclusion, indicating that the central area can use digital financial inclusion to optimize the business environment, and rural families in the western area have benefited from easing credit constraints by digital financial inclusion, which suggests that the western area should increase subsidies for digital financial inclusion loans and use digital financial inclusion loans to prevent the occurrence of extreme poverty.

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