

Article

Analyzing the Impact of Digital Inclusive Finance on Poverty Reduction: A Study Based on System GMM in China

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Abstract: This study investigates the potential of digital financial inclusion to reduce regional poverty in China, an issue that has received varying opinions from the academic community. Using panel data from 31 provinces, municipalities, and autonomous regions (2011–2020) and employing the system GMM, this paper analyzes the dynamic relationship between regional poverty and the growth of digital financial inclusion, as measured by the ‘Peking University Digital Financial Inclusion Index’. Controlling for factors such as the Gini coefficient, industrial structure, financial support for agriculture and education, and economic openness, this research finds that digital financial inclusion has a marked ability to reduce poverty rates. Moreover, our results indicate an intergenerational transmission characteristic in poverty, where prior levels significantly influence current poverty incidence. The study concludes that the recent acceleration of digital financial inclusion can be harnessed for meaningful poverty reduction. This study’s policy recommendations highlight the need for financial development to foster industrial and social growth and stress the importance of financial education for low-income populations. Additionally, it calls for increased management and oversight of inclusive and agricultural digital financial products and services.

Keywords: digital financial inclusion; system GMM; poverty reduction; financial poverty reduction



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1. Introduction

Over the past several years, the global battle against poverty has seen significant progress, with millions lifted out of extreme poverty through economic growth, social programs, and innovative interventions. Concurrently, the evolution of the financial inclusion index reflects the growing accessibility of financial services, even in remote or underserved areas. The advent of digitalization has been pivotal in this transformation. The development of digital inclusive finance, such as mobile banking, online microloans, and peer-to-peer lending, has democratized access to financial services. Digital technologies have enabled financial institutions to reach marginalized populations, providing them with tools to manage their financial lives and engage in economic activities previously beyond their reach. In many regions, particularly in developing countries, digital financial inclusion has not only contributed to poverty reduction but has also fostered economic empowerment and social inclusion. The confluence of poverty reduction strategies, the growth in financial inclusion, and digital innovation represents a synergistic triad that continues to shape global economic development and offers promising avenues for further research and policy formulation.

Poverty has always been a worldwide problem, attracting the attention of all countries, especially developing countries [1]. China has achieved significant strides in poverty alleviation in recent years. When counting the number of poor from 2015 to 2019, the score dropped from 55.75 million to 5.51 million, while poverty declined from 5.7% to 0.6% [2]. However, poverty has not been completely eradicated. As progress continues to be made in poverty alleviation, eradicating poverty among the remaining poor has

become a complex and challenging task. In 2005, the United Nations declared it the “International Year of Microcredit” and introduced the idea of inclusive finance [3]. This concept strives to enhance financial inclusivity by promoting microcredit services and providing appropriate financial services for marginalized groups. The ultimate goal is to improve the economic circumstances of those who have been financially excluded for a prolonged period, ultimately leading to the eradication of poverty.

Before the emergence of digital inclusive finance (DIF), customers were limited to conducting financial transactions in physical outlets of financial institutions [4,5]. Unfortunately, this was a challenge in poor areas where financial institutions had very few outlets, and the financial products and services available to residents were limited. To address this issue, it is essential to increase the availability of financial services, which is the core of inclusive finance [6]. However, expanding coverage under the traditional business model requires significant capital investment to establish more outlets, which increases the operating cost of financial institutions [7]. This cost can offset the benefits of regional coverage, making it difficult to achieve financial inclusion. The emergence of DIF has changed this narrative by allowing customers to access financial services from anywhere, at any time [8]. This has significantly reduced the cost of expanding coverage and increased access to financial services, particularly in poor areas. Consequently, DIF has become a vital tool in promoting financial inclusion and economic development.

When faced with the actual situation of vulnerable groups, their demand for financial services cannot be met by traditional models. It cannot match the financial services provided by financial institutions, which makes some groups and individuals incapable of entering the formal financial system and acquiring safe, appropriate, fair, and low-cost financial products and services from formal financial institutions [9]. To alter the status quo of financial exclusion, we need to promote the growth of inclusive finance. Inclusive finance can ensure that vulnerable groups have access to financial services and acquire adequate credit in a timely manner and at an affordable cost.

China has made remarkable strides in poverty reduction and digital financial inclusion in recent years, distinguishing itself from many other countries worldwide. The Chinese government’s targeted poverty alleviation programs have lifted millions out of poverty, reducing the poverty headcount ratio significantly. In contrast, while global poverty rates have generally decreased, some regions still struggle with persistent poverty challenges. On the digital financial inclusion front, China’s rapid expansion of digital financial services, such as mobile payments and online banking, has made financial products more accessible to underserved populations. Figure 1 shows the population in poverty and the national average digital inclusive finance index in China from 2011 to 2020. The growth of tech giants like Alipay and WeChat Pay demonstrates China’s leading position in this domain. Meanwhile, other countries have exhibited varying degrees of progress in digital financial inclusion. While developed nations continue to innovate in digital finance, many developing countries are still in the early stages of embracing these technologies. In summary, China’s achievements in poverty reduction and digital financial inclusion are noteworthy, with a unique blend of policy, innovation, and technology fostering this success. Its experience can offer lessons for other countries working towards similar goals.

With the rise of digital technologies in the financial sector, digital inclusive finance has emerged as a potential means to make financial services more accessible to a broader range of the population, including those in low-income and impoverished areas. This can be particularly impactful in a country like China, where there may be stark economic disparities across different regions and communities. This study focuses on utilizing the system generalized method of moments (GMM), which allows for a nuanced understanding of the complex relationships among various variables. The motivation thus includes not only a theoretical interest in the relationship between digital inclusive finance and poverty but also a practical concern regarding how these insights might be applied to policy and practice in China to more effectively target poverty reduction initiatives. In summary, this study seeks to bridge the gap in understanding how digital inclusive finance can be a tool

for poverty alleviation, providing valuable insights that could inform policy-making and strategies for sustainable economic development in China.

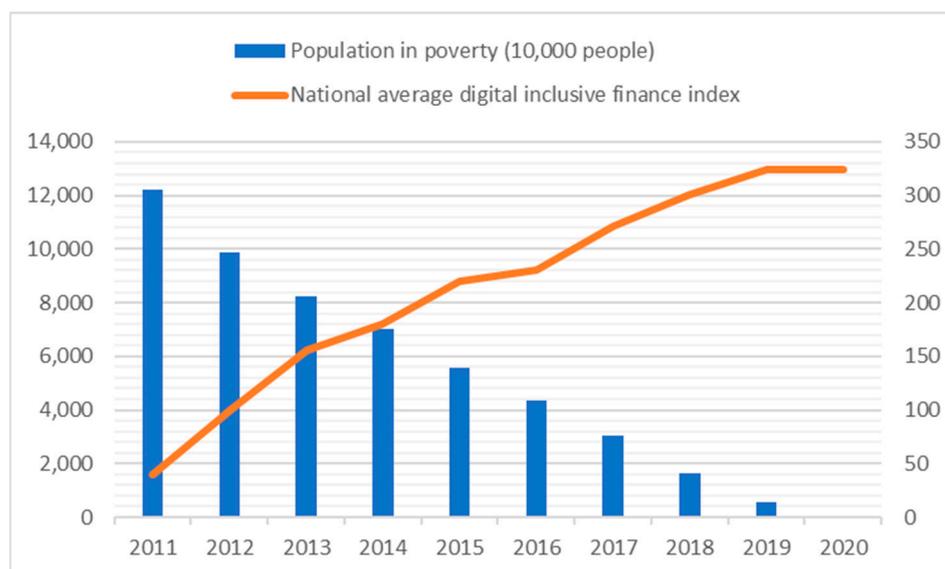


Figure 1. The population in poverty and the national average digital inclusive finance index in China from 2011 to 2020. (Source: People’s Government of China, White Paper on China’s Practice of Human Poverty Reduction, https://www.gov.cn/zhengce/2021-04/06/content_5597952.htm (accessed on 1 May 2022); The Peking University Digital Financial Inclusion Index of China from 2011 to 2020, <https://idf.pku.edu.cn/yjcg/zsbj/513800.htm> (accessed on 1 May 2022)).

DIF has emerged as a significant theoretical and empirical concept in the arena of economic development and poverty reduction. Aligning with current studies [10,11], this research recognizes the transformative potential of DIF to bridge financial gaps and enhance accessibility to financial services, particularly in underprivileged regions. Various scholars [12] have examined the conventional financial systems and their limitations in addressing poverty, highlighting the need for innovative approaches such as DIF. Building on existing theories, this study employs the system GMM to delve into the complex relationships among DIF, economic growth, and poverty alleviation in China. This methodological choice allows for the capture of non-linear and dynamic relationships that simple linear models may overlook [13]. Furthermore, this study recognizes the unique socioeconomic landscape of China, where rapid technological advancement has revolutionized the financial sector, making the analysis contextually relevant [14]. By situating the investigation within a rich theoretical framework and utilizing a sophisticated statistical model, this research contributes to both the theoretical discourse and practical understanding of how DIF can be leveraged to reduce poverty in China and potentially other developing regions.

This study aims to investigate the consequences of financial poverty reduction from the perspective of digital inclusive finance, taking into consideration both provincial panel data and the existing theoretical frameworks that explore the link between digital financial inclusion and poverty alleviation. Current studies emphasize that traditional methods of poverty alleviation [15], such as direct financial support likened to ‘drinking poison to quench thirst’, may provide temporary relief but fail to create sustainable solutions for long-term regional development [6]. In contrast, digital inclusive finance, characterized by its broad coverage, rapid information transmission, and low transaction costs, represents a more progressive and sustainable approach. By synthesizing contemporary theories with empirical analysis, this study seeks to examine the effectiveness of DIF, aligning with the growing scholarly discourse on the role of technology in economic development. The insights derived from this research could contribute to an enriched understanding of how

digital finance mechanisms can support enduring poverty alleviation and economic growth in a region, thus extending the theoretical and practical implications of current studies.

This study contributes to the existing literature in the following ways: First, by using GMM, the approach can capture the complex and heterogeneous nature of poverty and financial inclusion [16]. This allows for a more nuanced and accurate understanding of the poverty reduction effect of DIF. Second, this study addresses some of the key limitations of existing research on DIF and poverty reduction. For example, many studies have relied on simple regression models that do not account for the complex relationships among poverty, financial inclusion, and other socioeconomic factors. Third, the study contributes to the understanding of the mechanisms through which DIF can reduce poverty [17]. Through theoretical and empirical research, this study aims to study the effects of digital financial inclusion on China's poverty reduction and discusses the various steps involved in the digital financial inclusion process [18].

Overall, by providing a more rigorous and nuanced understanding of the impact of DIF on poverty reduction, using the GMM method can help policymakers and practitioners to design more effective interventions and programs [19]. Moreover, the approach can contribute to ongoing efforts to achieve the United Nations' Sustainable Development Goals, particularly the goal of eradicating poverty in all its forms and dimensions. The findings of this study are of significance in the quest to discover efficacious methods of enhancing the well-being of individuals residing in underprivileged nations and developing countries.

The remainder of this research is structured as follows. Section 2 summarizes the related literature, while Section 3 presents the methodology and data. Sections 4 and 5 presents results and discussion, respectively. Finally, Section 6 concludes the research and provides recommendations and limitations.

2. Literature Review

Due to the various factors that affect the relationship between poverty alleviation and financial development, the exact relationship has not been established. Scholars have three main views on the relationship: The first is that financial development can help improve the living conditions of the poor. The second argues that it will worsen the poverty rate, while the third believes that it can only be achieved once a certain level of financial development is reached.

For the first view, Dollar and Kraay [20] believed that financial development promotes poverty alleviation in an indirect way by affecting economic growth; that is, by the "trickle-down effect" where the poor enjoy the benefits of economic growth. According to Zhang and Zhan [21], financial development has an effect on the urban–rural income disparity via the threshold effect, the imbalanced effect, and the poverty alleviation effect. Financial development contributes to closing the income divide between urban and rural areas and alleviating poverty. Beck et al. [22] showed that financial development is connected with a decline in the proportion of the population living on less than \$1 per day, a finding that holds true even when average growth is taken into account. According to Jeanneney and Kpodar [23], impoverished individuals in developing nations profited from the banking system's ability to stimulate transactions and give savings possibilities between 1966 and 2000, and financial growth directly contributed to poverty reduction through distributive effects. Financial development is associated with financial instability, which is especially detrimental to the poor, yet the advantages of financial development exceed the drawbacks.

For the second view, some scholars believe that financial development is negatively correlated with poverty alleviation. According to Arestis and Caner [24], financial liberalization will increase capital flow to unproductive sectors, making it more difficult for the poor to acquire financial services, hence lowering income and impeding poverty reduction. Wen et al. [25] used data from 1952 to 2003 to perform an empirical study on the link between China's general financial development, rural financial development, and farmer income growth. The findings indicated that China's financial development did not only not boost farmer income growth but also stifled it, thereby contributing to the widening of the

urban–rural income divide and the strengthening of the “dual structure”. The term dual structure refers to an economy in which the urban sector is dominated by contemporary, large-scale industrial output, while the rural sector is dominated by traditional, small-scale peasant production. Roads, communications, health, and education infrastructure are established in cities, whereas rural infrastructure lags behind. Cities have far higher per capita consumption than rural areas. Rural regions, in comparison to cities, have a higher proportion of poor individuals. From 1980 to 2002, Kai and Hamori [26] analyzed the link between globalization, financial deepening, and inequality in Sub-Saharan Africa and discovered that the affluent became richer and the poor became poorer. Ang [27] examined how finance influences income inequality in India over a half-century using yearly time series data. While financial progress appears to contribute to the reduction in economic disparity, financial liberalization appears to increase it. Wang et al. [28] examined the influence of rural finance on poverty alleviation in the Hubei Province and discovered that rural financial institutions’ coverage continued to expand, credit increased, and the service subject remained single. The credit structure is constantly optimized, and the ability of financial innovation is enhanced, but the rural financial exclusion is serious. Hence, the effect on poverty alleviation is unclear, as it does not result in a large rise in resident income or a reduction in income disparities across regions, urban and rural areas, and industries. Deng [29] analyzed the impact of agriculture-related loans, a major financial tool for poverty alleviation and benefit to farmers, on local farmers’ income through the panel data of three counties and one district in Bazhong City, Sichuan Province, from the first quarter of 2011 to the second quarter of 2014, and found that the increase in the proportion of agriculture-related loans did not improve farmers’ income.

The third view is that financial development affects the distribution of income, which then leads to a “U” shaped relationship between poverty alleviation and financial development. Financial development affects poverty alleviation through income distribution, then resulting in a “U” shaped nonlinear relationship between financial development and poverty alleviation. During the early stages of economic development, the activities were mainly unorganized. As the income distribution increased, the pace of growth grew faster, and the inequality between the rich and the poor increased [30]. By the time the economy matures, it will have a complete financial structure and stable income distribution, alleviating poverty. Barro [31] pointed out that, in the USA, when GDP per capita is less than \$2000, growth tends to slow as inequality rises, and when GDP per capita is greater than \$2000, growth tends to accelerate as inequality rises. Cui and Sun [14] found that financial development could improve the level of income distribution for the poor, but it would also reduce the poverty reduction effect. The researchers noted that the effects of financial development on the reduction in poverty will start to improve after the implementation of financial regulations. An empirical study by Law et al. [12] demonstrated that there is really a threshold impact on institutional quality between financial development and income inequality using the threshold regression approach. Income disparity is often reduced only when financial development achieves a particular degree of institutional quality. Prior to it, financial development had no effect on income inequality.

The concept of digital financial inclusion is also related to the development of poverty alleviation. According to scholars, this concept can help improve the living conditions of the poor. For example, Chibba [32] pointed out that financial inclusion provides incremental and complementary solutions to poverty alleviation, inclusive development, and the achievement of the Millennium development goals, among other objectives. Through the inclusion of various social strata, such as low-income groups, financial services can help the poor improve their lives [33]. According to Park and Mercado [34], financial inclusion has a major impact on poverty and income disparity reduction. A better rule of law system, which includes the enforcement of financial contracts and the monitoring of the financial regulatory system, would also aid in the expansion of financial inclusion, so contributing to the reduction in poverty and income inequality. Jia and Xiao [35] pointed out that the improvement in rural financial inclusion degree effectively alleviates the contradiction

between supply and demand of rural finance, and its innovative model, “Mutual fund cooperative”, not only directly alleviates the financing difficulty and high financing from the rural areas but also effectively improves the quality of life of middle and low income and poor population.

Internet finance (ITFIN), which is an important part of digital finance, is a financial model originating in China. It refers to a new financial paradigm in which conventional financial institutions and online firms collaborate to provide capital finance, payment, investment, and information intermediary services via the internet and communication technologies [36]. ITFIN’s specific models include crowdfunding, P2P (peer-to-peer) online lending, third-party payment, digital currency, mobile payment, big data finance, etc. Internet finance is also called digital finance by some scholars. According to scholars who have studied the impact of internet-inclusive finance on reducing poverty, it lowers the entry barrier to traditional financial services, allowing middle- and lower-income groups to take advantage of convenient financial services, thereby increasing the income of middle- and lower-income groups and contributing to targeted poverty alleviation.

As Dong et al. [37] pointed out, the shortcomings of traditional finance may be compensated for by rural internet finance, which represents a novel method for solving rural financial difficulties. By using big data technology, internet finance can improve the precision of poverty alleviation, design credit products with flexible cycles according to the actual needs of rural areas, meet the financing characteristics of farmers with “short, frequent and urgent”, and promote the return of urban funds to rural areas to feed poor areas. Yan and Zhong [38] pointed out that compared with traditional finance, internet finance can serve poor areas more quickly and achieve targeted poverty alleviation better. However, poverty alleviation through Internet finance is not a charity, but by finding the right policy entry point and reducing financing costs through the Internet, both the supply and demand of funds can obtain a win–win situation. Li and Wang [39] said that “Although lack of physical capital, poor people can still benefit from the financial market to get out of poverty and be better off with the support of credit capital through internet finance”. The study by Wang and He [10] demonstrated that farmers’ usage of online financial services has a favorable influence on their vulnerability to poverty by lowering their reliance on cash crops. Further study has discovered that this benefit is mostly dependent on farmers’ capacity to manage risk, which is to say, on their ability to reduce their exposure to risk. Further analysis reveals that online financial services have a higher influence on the vulnerability of farmers when compared to traditional banks. Table 1 summarizes the literatures.

Table 1. Literature summaries.

| Reference | Research Method | Main Findings | Unique Aspects |
|----------------------------------|--------------------------------|--|--|
| [20] Dollar and Kraay (2002) | Theoretical Analysis | Financial development promotes poverty alleviation through economic growth (“trickle-down effect”) | Focus on indirect effect through economic growth |
| [21] Zhang and Zhan (2006) | Theoretical Analysis | Financial development alleviates urban–rural income disparity and poverty | Urban–rural disparity focus |
| [22] Beck et al. (2007) | Empirical Analysis | Financial development reduces the proportion of the population living on less than \$1 per day. | Global perspective |
| [23] Jeanneney and Kpodar (2011) | Empirical Analysis (1966–2000) | Banking system’s role in poverty reduction through distributive effects | Focus on developing nations |

Table 1. Cont.

| Reference | Research Method | Main Findings | Unique Aspects |
|--|--|--|--|
| [24] Arestis and Caner (2004) | Theoretical Analysis | Financial liberalization impedes poverty reduction, lowers income | Focus on unproductive sectors |
| [25] Wen et al. (2005) | Empirical Analysis (1952–2003), China | Financial development stifles farmer income growth, widens urban–rural income divide | Focus on China’s rural economics |
| [26] Kai and Hamori (2009) | Empirical Analysis (1980–2002), Sub-Saharan Africa | Globalization and financial deepening increase inequality | Focus on Sub-Saharan Africa |
| [27] Ang (2010) | Empirical Analysis, India | Financial progress reduces inequality, while liberalization increases it | Focus on India |
| [28] Wang et al. (2012) | Empirical Analysis, Hubei Province | Unclear effect on poverty alleviation by rural finance in Hubei Province | Focus on rural financial exclusion |
| [29] Deng (2015) | Panel Data Analysis (2011–2014), Sichuan Province | Agriculture-related loans do not improve farmers’ income | Focus on specific financial tool |
| [31] Barro (2000) | Theoretical Analysis | “U” shaped relationship between financial development and poverty alleviation in the USA | Introduces “U” shaped relationship |
| [14] Cui and Sun (2012) | Empirical Analysis | Financial development can reduce poverty after financial regulations | Focus on financial regulations |
| [12] Law et al. (2014) | Threshold Regression Approach | Threshold effect of institutional quality between financial development and income inequality | Introduces threshold effect |
| [32] Chibba (2009); [34] Park and Mercado (2015); [35] Jia and Xiao (2017) | Theoretical and Empirical Analysis | Financial inclusion and digital finance promote poverty alleviation and improve living conditions for the poor | Focus on digital finance and financial inclusion |
| [37] Dong et al. (2016); [38] Yan and Zhong (2016); [39] Li and Wang (2017); [10] Wang and He (2020) | Theoretical and Empirical Analysis | Internet finance and digital finance offer solutions for poverty alleviation and cater to middle and lower-income groups | Focus on Internet finance, digital technology |

Although the advancement in digital technology has opened up new avenues for inclusive finance to alleviate poverty, the majority of current research is still focused on the theoretical aspects of the poverty reduction effects of inclusive finance. For this reason, this study investigates the impact of digital inclusive finance on poverty reduction, drawing upon current theoretical research while also conducting empirical research in order to further complement and extend the existing research. Thanks to the digital inclusive finance index updated by the digital finance research center of Peking University in 2021. This paper will further expand the research period, use the system GMM model to dynamically analyze the panel data of 31 provinces and cities in China from 2011 to 2020, and verify the impact mechanism of digital inclusive finance to reduce poverty in order to put forward more specific suggestions on the development of digital inclusive finance.

Based on the literature research on financial development and poverty issues mentioned above, an intriguing pattern emerges that suggests the potential role of digital mechanisms in addressing regional poverty. In order to explore the relationship between digital inclusive finance and regional poverty alleviation, this article proposes the following research hypothesis: the development of digital inclusive finance can effectively reduce the incidence of regional poverty.

The emergence of digital inclusive finance has been heralded as a transformative tool that can extend financial services to previously underserved or marginalized communities. By utilizing technology to lower barriers to access, digital inclusive finance can potentially create a more equitable distribution of resources and opportunities. This hypothesis is grounded in the observed success of various digital financial platforms that have facilitated economic empowerment and inclusion in different parts of the world.

3. Methodology and Data

Panel data from 31 provinces from 2011 to 2020 will be used as the study sample in this work, which will be selected from the panel data. To empirically assess the poverty reduction effect of digital inclusive finance and to empirically examine the process of poverty reduction, the system GMM method will be used.

3.1. Methodology

The persistence and continuity of poverty necessitate a modeling approach that accurately captures its dynamic nature. The inclusion of lag variables in the model is pivotal, given poverty's strong continuity, yet this presents challenges with traditional estimation approaches. The dynamic panel model, which easily overcomes issues of reverse and legacy causality, could lead to unintentional problems with the lag term. Traditional estimation might result in skewed parameter estimates, failing to truly reflect the essence of the subject under investigation. The GMM estimation, however, bypasses this issue by not requiring assumptions about the variable's distribution or random variables' distribution characteristics. Among the two types of GMM estimation, namely first-order difference GMM [40] and system GMM, the latter is preferred in this context. System GMM provides a more comprehensive estimation by utilizing additional moment conditions, enhancing efficiency, and addressing potential endogeneity problems, making it particularly suited for analyzing the complexities of poverty [41]. In contrast, the first-order difference GMM may not adequately capture these multifaceted relationships. This distinct advantage makes system GMM the preferred modeling approach for this study.

Su and Liao [42] utilized a system GMM estimator and investigated the influence of financial development on income distribution and poverty, using data from China's provinces collected between 2001 and 2007. Cui [13] empirically evaluated the association between financial development (financial size and financial efficiency), urbanization, and poverty alleviation using China's inter-provincial panel data from 1978 to 2010, using systematic GMM estimates, and the results were positive. Using the GMM dynamic panel approach, Liu et al. [11] investigated the poverty reduction effect of financial development on impoverished counties from the perspectives of financial development size and efficiency, as well as from the perspective of poverty reduction. Using the system GMM technique, Liu and Bi [43] explored the direct and indirect effects of inclusive finance on the urban–rural income gap, taking into consideration the twin perspectives of economic growth and poverty alleviation in their research.

The GMM estimation principle of the system is as follows:

$$y_{it} = \alpha y_{i,t-1} + \beta x_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

Equation (1) is a dynamic panel model, where y_{it} is the explained variable and $y_{i,t-1}$ is the lag term of the explained variable; α is the coefficient of lag term; β is the $k \times 1$ order regression coefficient vector; x_{it} is the column vector of the $k \times 1$ order explanatory variable; μ_i is the individual fixed effect of non-observation section; ε_{it} is a random perturbation

term, where i represents the i th sample and t represents the year ($i = 1, 2, \dots, N$; $t = 1, 2, \dots, T$).

3.2. Empirical Specification

After conducting a prior study (in Section 3.1) of the poverty reduction mechanism and model selection of digital inclusive finance, this research employs system GMM to analyze and construct a dynamic panel model in the following ways:

$$IP_{it} = \alpha_0 + \beta_1 IP_{i,t-1} + \beta_2 DIFI_{it} + \beta_3 RGDP_{it} + \beta_4 GINI_{it} + \gamma X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (2)$$

where the subscript i denotes the province and the subscript t denotes the year, the following formula is used: The incidence of poverty (IP) is used to quantify the prevalence of poverty; the digital inclusive finance index (DIFI) is used to measure the amount of development of DIF; and RGDP estimates the level of regional economic development; GINI is the Gini coefficient, which is used to quantify the income disparity of a country or region's people; and X represents other control variables, such as the industrial structure (Is), the level of urban development (Urban), the level of financial support for agricultural production (Fs), the level of education (Edu), and the level of economic openness (Open); λ represents unknowable regional individual effects; μ represents an unknowable time effect; ε is the error term.

1. Incidence of poverty (IP)
This paper uses the incidence of poverty to measure the degree of poverty. The data on the incidence of poverty comes from the 2011–2020 China Rural Poverty Monitoring Report.
2. Digital inclusive finance index (DIFI)
There is a scarcity of scientific and authoritative index assessment systems as a result of the late introduction of DIF. The “Peking University digital inclusive finance index” was created by the Digital Finance Research Center at Peking University, based on massive data on digital inclusive finance provided by the Ant Group (The Ant Group is a leading global digital platform that enables consumers and businesses to connect and transact globally. Its goal is to promote digital upgrading of the service industry and bring about little changes in the world). The index calculates the digital inclusive finance index based on three dimensions: coverage; depth; and digitization of digital financial services and serves as a reference data source for relevant research in digital inclusive finance. When assessing the development level of DIF in China, this article uses province data from 2011 to 2020 to estimate the progress made.
3. Regional GDP (RGDP)
This paper picks the regional GDP growth rate as the indicator of a region's economic development level. Regional GDP refers to the ultimate output of all permanent inhabitants of a region's productive activities over a given time period. Economic growth may lead to the accumulation of wealth, the creation of new job possibilities, and an improvement in the welfare of disadvantaged populations. There is also a “trickle-down effect” in economic expansion, whereby the benefits produced by prosperity continue to permeate from developed regions to neighboring poor ones, so helping the poor. Theoretically, the larger the rate of economic growth, the better the effectiveness of poverty reduction in a region.
4. Gini coefficient (GINI)
Based on the Lorenz curve, the Gini index is an indication of the equality of income distribution. It is commonly utilized in economics studies. This paper employs the approach of Tian [44] for computing the Gini coefficient for 31 Chinese provinces, cities, and autonomous territories. The data comes from the China Statistics Yearbook and the statistical yearbooks of China's various provinces.
5. Other control variables
Other variables affecting poverty are selected as follows:

Industrial structure (Is): The optimization of the industrial structure is conducive to the coordinated development of various industries, promotes high-quality economic growth, and drives more labor employment [45]. Moreover, the continuous optimization of the industrial structure can promote poor areas to achieve industrial poverty alleviation, reduce the vulnerability of single agricultural production, and improve the income security of poor groups [46]. This paper selects the ratio of the total output value of the secondary and tertiary industries to RGDP to measure the industrial structure.

Urbanization level (Urban): The urbanization level can help rural communities receive their fair share of financial resources and reduce the rural surplus. However, it can also lead to excessive urbanization, which will affect rural economic development. Although urbanization can help improve the living conditions of rural communities, it can also lead to a rise in poverty. This paper aims to study the effects of urbanization on poverty using the proportion of urban residents in a region.

Financial support for agriculture (Fs): Improvement in financial support for farming is beneficial for rural areas as it promotes the construction of rural infrastructure and local industrial development. This paper shows that the proportion of the total financial support for agriculture that is allocated for local finance is relative to the total financial expenditure.

Education level (Edu): It is a factor that influences the accumulation of human capital. It can also help poor households improve their competitiveness and earn higher wages. This paper uses the mean years of schooling to measure the average level of education in different provinces.

Economic Openness (Open): Economic openness can promote the development of regions with comparative advantage industries so as to reduce poverty in such regions. However, for some regions without comparative advantage industries and lack of relevant resource endowment, economic openness may have a negative impact. This paper uses the proportion of regional net exports of goods and services to RGDP to measure the level of economic openness, in which the regional net exports of goods and services are converted into RMB by the weighted average exchange rate of that year.

The definition of each variable and the calculation method of indicators are shown in Table 2 below:

Table 2. Definition of each variable and index calculation method.

| Variables | Symbols | Index Calculation |
|-----------------------------------|---------|--|
| Incidence of poverty | IP | Number of poor people in the region/total population in the region |
| Digital Inclusive Finance | DIFI | Peking University Digital Inclusive Financial Index |
| Regional GDP | RGDP | Regional GDP |
| Gini coefficient | GINI | Gini coefficient |
| Industrial structure | IS | Total output value of secondary and tertiary industries/GDP |
| Urbanization level | URBAN | Regional urban population/total regional population |
| Financial support for agriculture | FS | Financial expenditure for agriculture/total financial expenditure |
| Education level | EDU | Mean years of schooling |
| Economic Openness | OPEN | Regional Net Exports of Goods and Services/RGDP |

3.3. Data

The China Statistical Yearbook, the China Rural Poverty Monitoring Report, and the Peking University Digital Financial Inclusion Index of China from 2012 to 2021 were the primary sources for the data utilized in this paper. As for the dependent variable, the incidence rate of poverty, this variable varies significantly among China's provinces. As China's economy as a whole has developed, the prevalence of poverty in various regions has reduced dramatically. Figure 2 depicts the incidence of poverty in China's various provinces from 2011 to 2020.

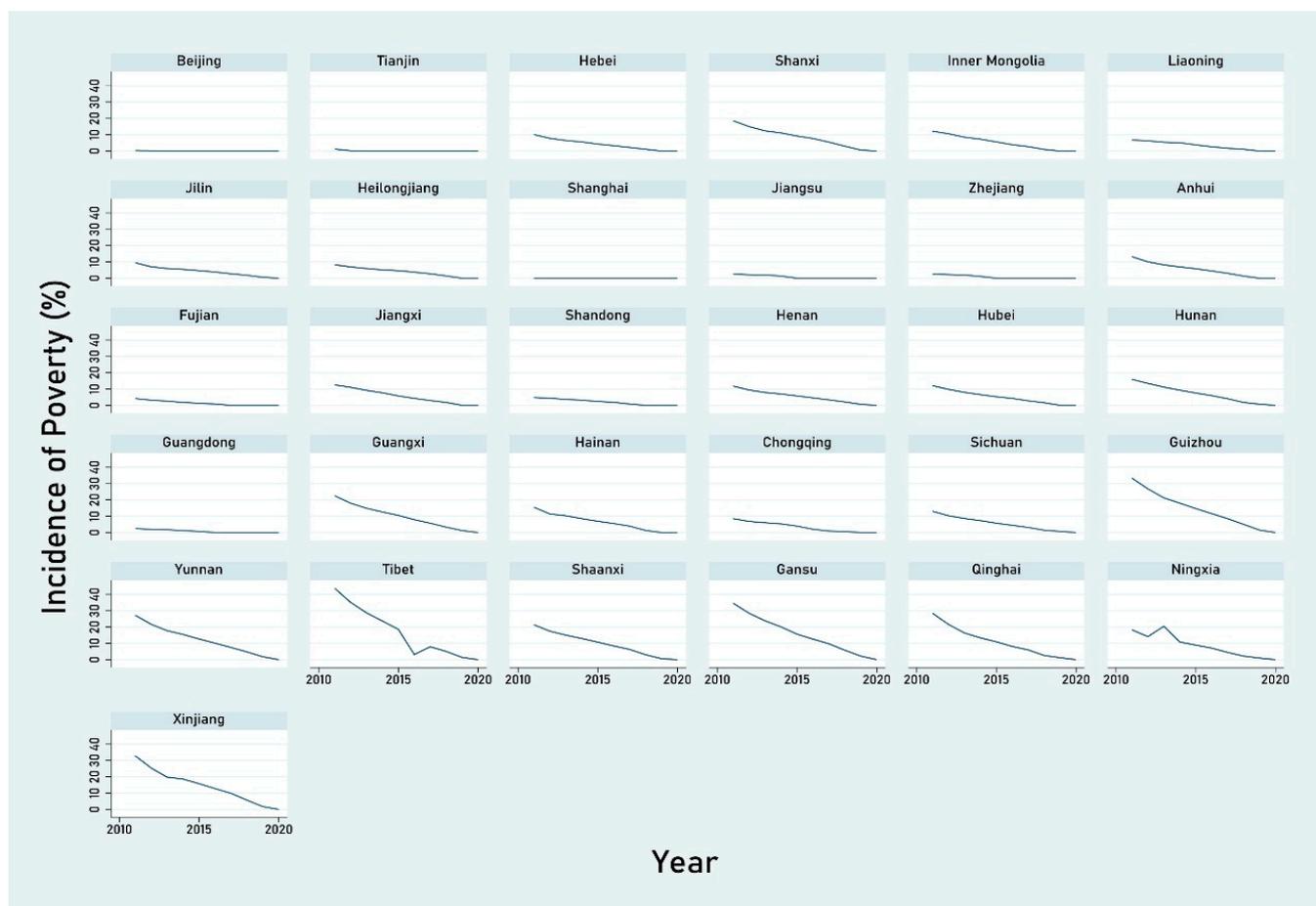


Figure 2. The incidence of poverty in China’s various provinces from 2011 to 2020.

Table 3 displays the numerical characteristics of the dependent variable, independent variables, and control variables. The figures in the table indicate the mean values of each variable throughout many years, while the values in brackets represent each variable’s standard deviation.

In order to avoid “pseudo-regression” and to ensure the validity of the estimation results, it is often necessary to analyze the panel data for cross-sectional dependence and non-stationarity. In this paper, Pesaran’s cross-sectional dependence (CD) [47] test was used: This test checks for cross-sectional dependence in the panel, which is an important prerequisite step for more advanced unit root and cointegration tests. After the CD test, it was found that the null hypothesis was significantly rejected for all variables except the GINI variable, implying that there is dependence between cross-sectional units.

Because cross-sectional dependence may affect the validity and consistency of the traditional unit root test, this paper used Pesaran’s CADF (Cross-Sectionally Augmented Dickey-Fuller) test [48] and CIPS (Cross-sectional Im, Pesaran and Shin) test [49] for non-stationarity analysis of panel data. Both Pesaran’s CADF and CIPS tests take into account the effect of cross-sectional dependence. The CADF test provides results for each individual cross-section, while the CIPS test provides results for the overall cross-section. The CADF test provides more specific information for each individual, while the CIPS test provides a broader overall view. Theoretically, the CIPS test is based on the CADF test, and both share the same logic for dealing with cross-sectional dependence. Table 4 shows the results of the unit root test.

Table 3. The mean value and standard deviation of variables.

| Year | IP | DIFI | RGDP | GINI | IS | URBAN | FS | EDU | OPEN |
|------|------------------|-------------------|-----------------|-----------------|-----------------|------------------|-----------------|-----------------|-------------------|
| 2011 | 14.48 (11.40) | 40.00 (18.61) | 12.53 (1.99) | 43.58 (4.99) | 89.39 (5.29) | 52.20 (14.46) | 10.88 (2.88) | 8.85 (3.35) | −9.58 (15.24) |
| 2012 | 11.58 (9.08) | 99.68 (22.34) | 12.05 (3.11) | 43.79 (4.61) | 89.49 (5.20) | 53.35 (14.25) | 11.22 (2.81) | 8.94 (2.98) | −12.85 (18.30) |
| 2013 | 9.82 (7.59) | 155.35 (26.18) | 10.44 (3.44) | 43.26 (4.92) | 89.54 (5.14) | 54.65 (13.96) | 11.24 (2.69) | 9.05 (3.24) | −15.75 (21.66) |
| 2014 | 8.15 (6.29) | 179.75 (23.46) | 8.16 (2.71) | 42.63 (4.94) | 90.07 (4.98) | 55.91 (13.45) | 11.13 (2.82) | 9.04 (3.22) | −16.69 (24.42) |
| 2015 | 6.51 (5.20) | 220.01 (22.94) | 5.30 (3.53) | 42.20 (4.58) | 90.09 (5.06) | 57.40 (12.85) | 11.77 (3.10) | 9.08 (2.81) | −18.63 (28.75) |
| 2016 | 4.68 (3.79) | 230.41 (21.19) | 7.59 (6.36) | 43.21 (4.48) | 90.23 (5.09) | 58.89 (12.34) | 12.05 (3.58) | 9.09 (2.55) | −18.99 (28.41) |
| 2017 | 3.50 (3.01) | 271.98 (24.06) | 8.15 (5.48) | 41.97 (4.31) | 91.07 (4.93) | 60.27 (11.87) | 11.58 (3.33) | 9.21 (2.54) | −17.94 (30.28) |
| 2018 | 1.90 (1.80) | 300.21 (29.77) | 8.18 (2.87) | 42.43 (3.99) | 91.34 (4.76) | 61.48 (11.58) | 11.93 (3.77) | 10.06 (2.43) | −0.42 (9.22) |
| 2019 | 0.51 (0.67) | 323.73 (33.29) | 6.83 (12.29) | 42.45 (4.53) | 91.08 (5.13) | 62.62 (11.34) | 12.12 (4.22) | 10.05 (2.41) | −0.55 (9.71) |
| 2020 | 0 (0) | 341.22 (34.72) | 3.15 (2.79) | 43.32 (5.18) | 90.44 (5.43) | 63.73 (11.06) | 12.20 (4.19) | 10.70 (2.38) | −0.17 (9.71) |

Table 4. The unit root test.

| Variables | CD-Test | CADF | CIPS |
|-----------|-----------|------------|------------|
| DIFI | 68.05 *** | −2.585 *** | −1.334 |
| RGDP | 26.79 *** | −2.193 ** | −2.899 *** |
| GINI | −0.86 | −1.745 | −2.509 *** |
| IS | 31.91 *** | −1.699 | −1.748 |
| URBAN | 62.35 *** | −2.956 *** | −2.598 *** |
| FS | 3.37 *** | −1.464 | −1.722 |
| EDU | 27.76 *** | −1.877 | −2.071 * |
| OPEN | 23.36 *** | −2.024 * | −2.424 *** |

Note: *, **, *** indicate the significant level at 10%, 5%, and 1% level, respectively.

From the results of the CADF test, it is clear that the variables DIFI, RGDP, URBAN, and OPEN series were smooth in the panel data. While the test results of other variables were not significant, implying that the series are non-stationary. From the results of the CIPS test, the test results of variables DIFI, IS, and FS in the panel data did not significantly imply that the series are non-stationary.

Therefore, it is reasonable to use system GMM as a tool for dynamic panel data analysis in this paper. System GMM is particularly suitable for dealing with non-stationary data and endogenous explanatory variables, while it is able to deal with datasets that are relatively small in both cross-section and time dimensions, and it can deal with potential endogeneity issues with instrumental variable methods.

4. Results

This section presents the estimated findings of the dynamic panel model using the system GMM method. The results indicate that the influence of digital financial inclusion on regional incidence of poverty in dynamic panel data is significantly negative, and the effect of incidence of poverty in the preceding period on regional poverty in dynamic panel data is significantly positive.

In order to properly examine the dynamic impact of digital financial inclusion on poverty reduction in China's provinces, this paper established models (1) and (2) in Table 5 using the system GMM method. In model (1), the only independent variables were the first lag of incidence of poverty, the digital inclusive finance index, and the economic growth

rate; a number of control variables were introduced to model (2). The coefficients in models (1) and (2) were those after controlling heteroscedasticity. The OLS regression approach was utilized in model (3), and the results of that model were compared with the findings of model (2).

Table 5. System GMM and OLS model estimation results.

| Variables | (1) GMM | (2) GMM | (3) OLS |
|-----------|-------------------------|-------------------------|-------------------------|
| L. IP | 0.7774 *** (0.0041) | 0.8019 *** (0.0096) | 0.7961 *** (0.0185) |
| DIFI | −0.0056 *** (0.0004) | −0.0036 *** (0.0007) | −0.0043 *** (0.0013) |
| RGDP | −0.0161 *** (0.0029) | −0.0210 *** (0.0042) | −0.0208 (0.0131) |
| GINI | | 0.0109 *** (0.0039) | 0.0125 (0.0157) |
| IS | | −0.0546 *** (0.0202) | −0.0249 (0.0208) |
| URBAN | | 0.0038 (0.0046) | 0.0077 (0.0118) |
| FS | | −0.1477 *** (0.0319) | −0.0938 *** (0.0358) |
| EDU | | −0.0245 ** (0.0022) | −0.0167 (0.0335) |
| OPEN | | −0.0050 *** (0.0011) | −0.0056 (0.0043) |
| Constant | 1.3539 *** (0.1317) | 6.7396 ** (2.9067) | 2.7134 (2.4084) |
| AR(1) | 0.152 | 0.145 | |
| AR(2) | 0.284 | 0.299 | |
| Sargan P | 0.000 | 0.000 | |
| Hansen P | 1.000 | 1.000 | |
| R-squared | | | 0.9734 |

Note: L. IP indicates the variable with the first lag period of incidence of poverty. **, *** indicates the significant level at 5% and 1% level, respectively. The numbers in brackets represent standard errors.

The incidence of poverty in the previous period will have a significant positive effect on the incidence of poverty in the present period, as shown by model (1). Furthermore, this demonstrates the dynamic transmission features of poverty. Model (1) demonstrates that DIFI has an important role in alleviating regional poverty. The coefficient is -0.0056 , which indicates that each unit increase in DIFI reduces regional poverty incidence by 0.0056 percent. The economic growth rate plays a significant influence in lowering the prevalence of poverty in a region, as demonstrated by model (1). The incidence of poverty can be reduced by 0.0161% for each one percent rise in economic growth.

There are several causes of poverty, and poverty is a complicated issue. To further examine the factors that influence the incidence of poverty, more control variables were included in model (2). After introducing a series of control variables, the significance of the original explanatory variables is maintained, showing that the original explanatory variables have a substantial influence on the incidence of regional poverty. In model (2), the L.IP coefficient is 0.8019 and is statistically significant at the 1% level. Compared to model (1), the incidence of poverty in the last period has a larger influence on the incidence of poverty in the current period. It continues to have a substantial effect in lowering the incidence of regional poverty, with coefficients of -0.0036 and -0.0210 for the variables digital inclusive finance index and growth rate of RGDP, respectively.

The coefficient of the variable GINI in model (2) is 0.0109 and is significant at the 1% level, which implies that assuming other factors stay constant, a 1% rise in the Gini coefficient will result in a 0.0109% increase in the incidence of regional poverty. This

finding also confirms that the occurrence of poverty is proportional to the degree of income disparity. The industrial structure has a negative influence on the incidence of poverty, as indicated by a coefficient of -0.0546 , which is significant at the 1% level in model (2). The value of the variable industrial structure (IS) was calculated by dividing the regional gross value of secondary and tertiary industries by the regional GDP. The result indicates that the decrease in regional poverty incidence is more effective the greater the gross value of the region's secondary and tertiary sectors, and the coefficient for the variable industrial structure is -0.1477 , which is significant at the 1% level.

In model (2), the coefficient of urbanization degree (URBAN) is 0.0038 , although this coefficient is not statistically significant. The non-significance of the coefficient may be due to the fact that China has been improving the urbanization level in different regions over the past few years. However, given the actual situation in China's various provinces, the improvement in urbanization level may not necessarily reduce the incidence of regional poverty. As urbanization improves, more people migrate to urban regions, whereas the rural poverty problem may not be able to be resolved owing to population loss.

The findings of model (2) indicate that financial assistance for agriculture has significantly reduced the incidence of regional poverty, with a coefficient of -0.1477 , which is significant at the 1% level. Simultaneously, financial assistance for education reduces the prevalence of regional poverty (the coefficient is -0.0045 , which is significant at the 10% level). The coefficient of -0.0050 for the variable "economic openness" is significant at the 1% level, indicating that it has played a substantial effect in lowering the prevalence of regional poverty.

Other control factors, except the variable URBAN, have had a substantial effect on the incidence of regional poverty, as shown by the previous results. If a region can reduce the inequality of income distribution, increase the proportion of gross output value of regional secondary and tertiary industries, increase financial support for agriculture, increase financial support for education, and improve the degree of regional economic openness, it can significantly reduce the incidence of poverty in the region, assuming all other conditions remain unchanged.

From the practical results of this research, it can be confirmed that the development of digital inclusive finance has a significant role in reducing the incidence of regional poverty. This conclusion validates the hypothesis previously proposed in this article, and even when adding a series of control variables or using different models for validation, this effect is still significant. The implications of this finding are profound, highlighting the power of digital financial tools in enabling access to essential services for marginalized communities. By fostering economic inclusivity, digital finance has the potential to serve as a vital lever for poverty reduction. These insights add value to the ongoing discussions on poverty alleviation strategies, emphasizing the need to integrate technological advancements into holistic solutions.

5. Discussion

Model (1) unveils the persistently dynamic character of poverty by demonstrating that the incidence of poverty from a preceding period carries a positive influence on the current phase. This not only underscores the enduring nature of poverty but also sheds light on its complex temporal dimensions.

The research provides compelling evidence that an uptick in the digital inclusive finance index is inversely correlated with the incidence of regional poverty. With every unit increase in DIFI, there is a notable 0.0056 percent reduction in poverty. This discovery reinforces the indispensable role of digital finance in expanding access to financial resources, acting as a catalyst for poverty reduction. It resonates with the global momentum aimed at harnessing technological advancements to foster financial inclusiveness.

Furthermore, the findings clearly depict that economic growth is inversely proportional to poverty, marking a 0.0161% decrease in poverty for each percentage increase in

growth. This relationship accentuates the intrinsic connection between broad economic advancement and targeted poverty mitigation strategies.

The analysis also sheds light on other nuanced factors affecting poverty. The GINI coefficient, indicative of income inequality, manifests a direct proportionality with the incidence of poverty, where a 1% elevation in GINI corresponds to a 0.0109% increment in poverty. This relationship is pivotal in understanding the interconnectedness between wealth distribution and poverty levels. Concurrently, the research emphasizes the value of a diversified industrial structure, particularly in the secondary and tertiary sectors, as a key driver in alleviating poverty. Special attention is given to the significant role of financial support in agriculture and education, calling for specialized policy interventions. Interestingly, the study unravels the complex interplay between urbanization and poverty in China, suggesting that increased urbanization may not unequivocally translate into poverty reduction.

The comparative approach, employing OLS regression in model (3) alongside model (2), adds a layer of depth and validation to the findings, offering a nuanced perspective on the complex relationships under study.

Taken collectively, the results unequivocally affirm that digital inclusive finance serves as a potent instrument in the fight against regional poverty, reiterating the imperative to weave technological innovations into comprehensive poverty alleviation frameworks.

In summation, this study stands as a significant contribution to the contemporary discourse on poverty, meticulously unraveling its multifaceted and intricate nature. By leveraging sophisticated analytical techniques and an array of variables, it not only deepens the understanding of poverty dynamics within China but also lays the groundwork for informed policy-making and implementation in analogous contexts around the world.

Comparing the results of models (2) and (3) reveals that the OLS regression coefficients are not statistically significant for the majority of variables. In addition, RDGDP, the primary explanatory variable, is no longer significant in the OLS model. Comparing the system GMM technique to the OLS regression method reveals that the system GMM method is more successful at identifying the dynamic relationship between explanatory variables and explained variables when analyzing the factors impacting the incidence of regional poverty. When looking into the results of models (1) and (2), the coefficients of all variables in model (1) remain significant after adding a set of control variables. So, it can be believed that model (2) can better describe the actual relationship between the incidence of poverty and the explanatory variables.

The results of model (2) clearly demonstrate that poverty is a complicated and long-term issue and that the incidence of poverty in the current era is significantly influenced by the incidence of poverty in the preceding period. Moreover, the data reveal conclusively that the growth of digitally inclusive finance and regional economic development may effectively (substantially) reduce the prevalence of poverty. Similarly, the optimization of industrial institutions, the growth in agriculture financial expenditures, the enhancement of the average number of years of schooling, and the enhancement of economic openness can significantly lower the incidence of regional poverty. The differentiation in income distribution (a rise in the Gini coefficient) will increase the prevalence of poverty. This result also supports the view of the first category of scholars [20–23] that financial development will provide a positive impetus for solving the poverty problem.

In model (2), the coefficients corresponding to URBAN variables are not significant. The reason for this result may be that there are significant differences in the level of urbanization in different provinces of China during the period 2011–2020. The incidence of poverty in economically developed coastal provinces is very low, regardless of whether the level of urbanization is high or low. For provinces located in the west, although some provinces have a high level of urbanization, the poverty problem in rural areas still exists. A variable that distinguishes different provinces by geographical location can be added to future research to address this deficiency.

6. Conclusions

The present research marks a significant contribution to understanding the role of digitally inclusive finance in reducing regional poverty across China's provinces from 2011 to 2020, utilizing a robust system GMM methodology and panel data from 31 provinces, municipalities, and autonomous regions. The research findings reveal the considerable impact of digitally inclusive finance in poverty alleviation, coupled with the influence of economic growth.

First, this paper has identified and emphasized the intergenerational continuity of poverty, a finding that is substantial for policymakers and practitioners aiming to eradicate poverty. This highlights the importance of considering historical factors in current poverty interventions.

Second, the study has quantitatively established a significant negative correlation between the digital inclusive financial index and the incidence of poverty. The robustness of the regression results provides a credible basis for policy intervention, thus contributing to existing literature in both economics and financial studies.

Lastly, the analysis of the evolution of China's digital inclusive finance between 2011 and 2020, as evidenced by the rapid growth in the index value, showcases the effectiveness of this approach in reaching marginalized populations, offering a model that other countries might follow.

The innovative approach of the present research has illuminated how digital inclusive finance has become a tool to mitigate regional poverty, especially for those with low incomes. By presenting novel insights and concrete policy recommendations, this study not only builds on the existing body of knowledge but also lays the groundwork for future research and practical applications in the field of digital finance and poverty reduction. The exploration of these findings and their policy implications demonstrates the rich potential for further studies to capitalize on this work, enriching both the academic field and real-world interventions.

This paper proposes policy recommendations for the study of financial poverty reduction based on the link between poverty and digital finance that it uncovers.

1. The development of finance must support the growth of actual industry and society. The goal of inclusive finance is to guarantee that every member of society has equal access to the benefits of financial services.
2. For low-income and impoverished individuals, it is vital to increase education and training in financial-related information and to ensure that the link between risk and income is appropriately understood. Effectively enhancing the ability of the poor to confront risks through prudent use of financial instruments is possible, but the current level of financial literacy among the poor is insufficient for them to make reasonable decisions in a complicated market environment.
3. It is vital to increase the administration and oversight of digital financial goods and services, particularly those that are inclusive and assist the agricultural sector. Owing to a lack of corresponding financial expertise, it is challenging for the poor to appropriately assess the risks associated with complicated financial instruments. Hence, financial items offered to the poor must be supervised and managed by the appropriate departments.

Future research in the domain of poverty reduction through digitally inclusive finance presents a plethora of opportunities to explore multifaceted dimensions. The following details the promising areas that might be explored further:

1. Exploring Economic Development Growth Rates Across Different Regions: Economic development growth rates across various regions interact intricately with poverty reduction strategies. Understanding this interaction is pivotal as different regions might possess unique economic characteristics, and a uniform poverty reduction strategy might not yield the desired results everywhere;

- The Effect on Poverty Reduction: Understanding how growth rates affect poverty can help in tailoring specific economic policies. A region experiencing rapid growth might require different strategies than a stagnating area;
 - The Role of Government and Policy: How local governments respond to different growth rates in terms of policy interventions can be a vital area of study. This can help in understanding whether local conditions are considered in policy formulation;
 - Intersection with Digital Inclusion: Future research could also delve into how digital inclusion strategies fit into regions with different economic growth rates. This could lead to insights into what types of digital interventions are most effective in various economic contexts;
2. Examining Specific Digital Financial Inclusion Products: Digital financial inclusion products play a significant role in addressing regional poverty, and a deeper examination of specific products and their effectiveness is an exciting prospect;
 - Effectiveness in Poverty Alleviation: Understanding which products have been most effective, why, and in what contexts could lead to more targeted interventions;
 - Barriers and Opportunities: Identifying barriers to accessing these products and ways to overcome them can be vital for making digital financial inclusion a reality for all, especially in underprivileged areas;
 - Innovation and Development: Research into developing new or improving existing products that are tailored to the needs of those in poverty could spark innovation in the field;
 3. Comparing Different Digital Financial Inclusion Products: Beyond examining individual products, there is a wealth of knowledge to be gained from comparing different digital financial inclusion products;
 - Understanding Diverse Impacts: Different products may have varying impacts on poverty alleviation. Comparative studies could lead to a more nuanced understanding of what works best, where, and why;
 - Tailoring Products to Needs: A comparative study could also help in tailoring products to the specific needs of different populations or regions. This could help in creating more effective, targeted poverty reduction strategies;
 4. Poverty as a Multifaceted Problem: This study also opens avenues for recognizing poverty not merely as an economic challenge but as a multifaceted problem that requires a comprehensive approach;
 - Sociocultural Aspects: Understanding the cultural and social dynamics that contribute to poverty can lead to more humane and effective interventions;
 - Environmental Factors: Researching how environmental factors intersect with poverty could open doors to sustainable development strategies;
 - Education and Awareness: Delving into the role of education in both understanding financial products and lifting individuals out of poverty could be a crucial aspect of a more comprehensive approach.

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