Research Article

Jingyi Yang, Xiaoyang Guo, and Xiuwu Zhang*

Analysis of the Effect of Digital Financial Inclusion in Promoting Inclusive Growth: Mechanism and Statistical Verification

https://doi.org/10.1515/econ-2022-0078
received November 02, 2023; accepted February 16, 2024

Abstract: As the main goal of economic development, inclusive growth (IG) is an important strategic measure to achieve common prosperity. Whether digital inclusive finance can make use of the advantages of scientific and technological innovation to promote IG is of great significance to promote the fairness, effectiveness, and inclusiveness of global development. Based on the panel data of 30 provinces in China from 2011 to 2021 (excluding Tibet, Hong Kong, Macao and Taiwan), this article first measures the IG index of China from three dimensions: sustainable economic growth, income distribution, and social equity. Subsequently, the article uses a series of mathematical statistical models to verify the transmission path and mechanism of the influence of digital inclusive finance on IG. The findings are as follows: (1) The level of IG in China shows a decreasing trend from east to middle to west, while the average annual growth rate of IG in the eastern region is obviously lower than that in the central and western regions; (2) digital inclusive finance has a significant promotion effect on IG, and digital inclusive finance in the central and western regions has a more obvious promotion effect on IG; (3) digital inclusive finance can achieve IG by increasing innovation activity and improving the level of human capital. Finally, based on the research conclusions, the article puts forward relevant policy suggestions, which provide reference value for formulating high-quality national development strategies and promoting high-quality economic development.

Keywords: digital financial inclusion, inclusive growth, sustainable economic growth, income distribution, fair opportunity

*** Corresponding author: Xiuwu Zhang,** School of Statistics, Institute of Quantitative Economics, Huaqiao University, Xiamen, China,
e-mail: zxwxz717@hqu.edu.cn
Jingyi Yang, Xiaoyang Guo: School of Statistics, Institute of Quantitative Economics, Huaqiao University, Xiamen, China

1 Introduction

Governing the country regularly and benefiting the people: In the first year of the "14th Five-Year Plan," China won a comprehensive victory in the fight against poverty, and the problem of absolute poverty was solved historically. The Sixth Plenary Session of the 19th Central Committee clearly pointed out that it is necessary to "unswervingly follow the road of common prosperity for all people and make substantial progress in promoting common prosperity in high-quality development." The 20th National Congress of the Communist Party of China further emphasized that the promotion of common prosperity should focus on enhancing balance and accessibility. However, poverty-stricken households and marginal households still face a high risk of returning to poverty due to the fragility of poverty alleviation foundation, limited coverage of assistance policies, and multidimensional poverty-causing factors. At the same time, income inequality, opportunity inequality, and social inequality between urban and rural areas, regions, and industries will make the problem of relative poverty persist for a long time (Hong et al., 2022). In addition, in the process of rapid evolution of China's economic and social development, agricultural and rural development lags behind, urban and rural factors mismatch, infrastructure construction gap is obvious, and ecological pollution caused by agricultural land overload has become a stumbling block on the road to achieving the goal of Common prosperity (Hao et al., 2023). To address this series of issues, inclusive growth (IG) has emerged. IG implies equal opportunities for growth, with a core emphasis on eliminating serious environmental inequalities to reduce inequality in outcomes, with a focus on creating productive employment opportunities and enabling equal access to opportunities for all (Jiang et al., 2022; Klasen, 2010; Zhou, 2022). Therefore, IG is not only a high-quality sustainable development path with healthy development as its core, but also an inherent requirement for enhancing people's sense of happiness and gain. It is of great significance for promoting regional

coordinated development and maintaining social harmony and stability.

With the acceleration of the process of building a digital society, digital financial inclusion (DFI) with big data, cloud computing, and blockchain technology as the core is regarded as one of the important keys to achieve IG (Kun et al., 2022; Ren & Li, 2019; Ren et al., 2023; Wang et al., 2022). In 2006, China introduced the concept of financial inclusion, and constantly carried out Chinese transformation. The Development Plan for Promoting Financial inclusion (2016–2020) issued by the State Council in 2016 has carefully defined the connotation and principles of financial inclusion, which has greatly promoted the prosperity and development of financial inclusion in China. Restricted by barriers such as scattered Human settlement, opaque information, and imperfect infrastructure in rural areas, traditional financial inclusion is bound by the dual shackles of physical outlets and extremely high promotion costs, so the "long tail group" is difficult to cover, and the "last mile" of financial supply is still a long way off. Based on the concept of "internal hematopoiesis" and sustainable development, DFI, which was born from the deep integration of modern digital technology and traditional Financial inclusion, has made up for the shortcomings of traditional Financial inclusion, such as high operating costs, difficult to promote financial coverage, and work efficiency cannot be guaranteed, giving full play to its "multiplier effect" of resource allocation, and achieving intelligent analysis and accurate delivery of financial services required by the poor and weak groups. We have expanded the funding supply channels for various industries such as agriculture, improved production efficiency, improved farmers' living conditions, continuously stimulated entrepreneurial potential, and developed characteristic industries on the spot, achieving truly "universal preferential" financial convenience (Liu, 2022; Mou et al., 2021; Tang et al., 2023). This is of great significance in alleviating the economic imbalance between urban and rural areas and fully demonstrates the core connotation of IG.

Based on this, the article will focus on the development and relationship between DFI and IG, explore the transmission path and mechanism of DFI's impact on IG from the theoretical and empirical levels, and verify whether DFI affects IG by increasing innovation activity and improving the level of human capital (HC), with a view to providing a useful reference for relevant theoretical research and policy practice.

2 Literature Review

Under the dual drive of financial resources and digital technology, how to fully release the DFI to boost IG, so that finance can better serve the people, has become a hot issue concerned by the government and scholars in recent years. By organizing existing literature, research related to the topic of this article can be roughly divided into the following aspects.

One is the interpretation of the connotation, measurement methods, and indicator system construction of IG. At present, the academic community has not yet formed a unified conclusion on the connotation of IG, all of which are summarized around dimensions such as sustainable economic growth, equal opportunities, and achievement sharing. The only difference lies in the different focus. Fan and Wu (2011) and Rauniyar and Kanbur (2010) define IG as "equal opportunity growth," with the core meaning of reducing or even eliminating the exclusion of the poor in terms of power and social experience, achieving the process of everyone having equal access to opportunities and being able to contribute to economic growth fairly, and being able to share the fruits of economic growth reasonably. Ge et al. (2022a,b) and Ghouse et al. (2022) believe that IG has three meanings, namely, sharing the development achievements of the Sharing economy, giving basic development opportunities and cultivating basic development capabilities. That is to say, IG no longer only focuses on the poor, but expands the investigation of inequality to all income classes, constantly removes obstacles for people to participate in economic development and share the national development dividend, and gradually establishes a social justice system with fairness in power, opportunity, rules and distribution as the main contents, so as to provide equal development opportunities for all. This is also similar to the implication of the EU 2020 strategy, that is, economic participants should be helped to predict and manage changes through high-level employment, investment skills, poverty reduction, and a modern labor market, coupled with a more complete training and social protection system, so as to build a cohesive society and enable the public to Sharing economy throughout the life cycle, including the outermost regions of society. For the scientific measurement of IG in China, most scholars use entropy method (Grigory & Simen, 2022; Ma et al., 2022), fuzzy comprehensive evaluation method (Abimbola & Adekunle, 2021; Zhu & Jiang, 2017), dynamic factor analysis method (Peng et al., 2018; Zheng & Su, 2022), and function derivation to calculate. Fu et al. (2021) and Silber and Son (2010) calculated China's IG level based on the generalized Bonferroni curve and characterized its spatiotemporal evolution and convergence, indicating that the IG level is showing an increasing trend year by year, and there are significant regional differences. Li and Bian (2021) constructed an identification and decomposition method for IG through NIGIC curves and FFL-OB decomposition techniques, thereby

constructing a multidimensional analysis index system for IG in China. Apart from differences in measurement methods, there are also slight differences in the indicator systems constructed for IG indices in existing literature. Most research still revolves around the two major aspects of growth process and growth outcomes, involving three specific dimensions: equal opportunities, income distribution, and economic growth. A few scholars define the extension of IG as a sustainable development approach that pursues economic growth, social equity, achievement sharing, resource conservation, and a good ecological environment, in order to construct an indicator system for IG. Based on the perspectives of social equity and environmental sustainability, Gu and Sun (2022) calculated China's IG level from four dimensions: economic development, social opportunity equity, green production and consumption, and ecological environment protection.

Second, research is on the mechanism and path innovation of DFI affecting IG. Because the concept of DFI and IG is proposed in a relatively short period, there are few literatures that have in-depth explored the relationship between DFI and IG, most of which focus on DFI to alleviate factor mismatch, promote economic growth, narrow the income gap between urban and rural areas, and promote the improvement of social security mechanisms (Dollar et al., 2016; Sarma & Pais, 2011). For example, Kapoor (2014), Li et al. (2020), Park (2015), and Zhang et al. (2019) all showed that DFI is conducive to enterprise innovation and regional entrepreneurship in backward and remote areas, and financial resources sink into the "tail" area, prompting financial service institutions to compete in the market and user groups to reduce their own transaction costs of financial services and meet capital needs. This further enhances the "hematopoietic" effect of financial resources to alleviate poverty and increase income, narrow the wealth gap, and achieve sustainable economic development, promoting high-quality development of the Chinese economy. Lambert et al. (2021) found that digital inclusive finance and its sub-dimensions will have different degrees of impact on IG. Specifically, the coverage and depth of use of DFI can promote the equality of access to opportunities and the sharing of development dividends, and thus promote the level of IG. But in this process, the degree of digitization is not significant. Khémiri et al. (2023) pointed out that DFI can promote IG in areas with high government efficiency, well-developed urban markets, and high innovation levels. At the same time, digital inclusive finance can achieve inclusive economic growth by easing the financing constraints of small- and medium-sized enterprises and promoting the entrepreneurship of low-income families.

To sum up, the existing literature has done a lot of useful research on DFI and IG, which provides ideas and experience enlightenment for this article. However, the existing literature lacks attention to the nonlinear relationship between DFI and IG. At the same time, there are few literature studies discussing the role of DFI in promoting IG from the perspectives of innovation activity and HC.

The contribution of this article is as follows: (1) According to the connotation and purpose of IG, this article constructs an IG index system from three dimensions: sustainable economic growth, income distribution, and fair opportunity, and quantitatively evaluates the level of IG in China from multiple dimensions, so as to reflect the influence of DFI on IG more comprehensively (2). Combining the channel mechanism of digital inclusive finance's influence on IG innovatively brings innovation activity and HC into the analytical framework, so as to identify the effective channels of DFI in China to promote IG at this stage and further enrich the relevant research content (3). This article clearly compares the differences in the influence of DFI on IG in different regions of China and expands the research depth in this field. This is also more conducive to finding the breakthrough point of DFI and speeding up the realization of more just resource allocation (4). Most of the existing studies focus on the static effect or spatial spillover effect of the development of DFI on IG, and there is little research on whether there is a dynamic effect between them. In this article, the quadratic term of DFI is included in the model analysis, and the relationship between the development of DFI and IG is discussed.

3 Mechanism Analysis and Research Hypotheses

3.1 Direct Impact of DFI on IG

3.1.1 Economic Growth Effect

The academic community has basically formed a consensus that financial development is conducive to economic growth, and the emergence of DFI will further strengthen the economic growth effect of traditional finance (Beck et al., 2000; Li & Jiang, 2006). The DFI developed by relying on the Internet and mobile communication technology can expand the coverage of rural financial services, identify potential and explicit soft information of lending farmers, effectively alleviate financial exclusion in rural areas, especially in remote and poor areas, and reduce the cost of poor

groups and marginal groups to access financial services (Xiong et al., 2023). Specifically, due to the lack of credit characteristics and risk preference of rural residents, the accuracy of financial poverty alleviation is seriously hindered, and the resource dividends that urban and rural residents can obtain are biased. With the Matthew effect, capital, labor, and other production factors will quickly converge in cities, exacerbating the long-term "dual structure" of China's finance (Fan & Chen, 2022; Náñez Alonso et al., 2022). DFI, by virtue of big data technology, collects the consumption and lending information of a large number of users, establishes a corresponding customer credit information database, reduces the impact of information asymmetry, alleviates the problem of "not daring to lend, not willing to lend" at the supply side, guides financial resources to serve the real economy more efficiently, and strengthens the effectiveness of finance in promoting economic growth. At the same time, due to the high cost of laying physical network points for traditional financial institutions, coupled with the "patchwork" distribution of "large scattered and small settlements" in rural areas, it is difficult to provide financial services to rural areas and there is insufficient effective supply (Ezzahid & Elouaourti, 2021). The "time-space penetration" of DFI itself can reduce the dependence of traditional finance on physical outlets, which can not only improve the accessibility of financial services, but also enable customers to easily access online financial services by virtue of intelligent terminals, save transaction costs, help promote the sinking of financial resources, meet the capital requirements for industrial development in the "tail" region, and enhance the "hematopoietic" effect of poverty alleviation and income increase (Mei et al., 2022; Wang et al., 2023; Xiong et al., 2022).

3.1.2 Income Distribution Effect

As the "best choice" for traditional financial institutions, a high interest rate level undoubtedly weakens the supply of microcredit, insurance, wealth management, and savings to low-income groups. In addition, the profit-seeking nature of financial capital itself makes most advanced production factors gather in various industrial sectors in cities and towns, exacerbating the phenomenon of resource scarcity in rural areas. The borderless feature of DFI has changed the "threshold effect" of marginal groups' access to financial services, corrected the discriminatory distribution of funds, guaranteed the economic security of low-income groups, and reduced the problems caused by the traditional urban-rural dual structure (Liu et al., 2023; Yu & Wang, 2021). Specifically, DFI, by establishing a big data sharing platform between developed and remote areas, enables different consumer groups to share decision-making information, solves the problems of low-income groups being excluded from financial coverage due to lack of collateral and imperfect credit information, and respects and protects the rights and interests of vulnerable groups in digital dividends, alleviating the current financial resource allocation problem of "heavy urban and light rural areas" in China (Liu et al., 2021). At the same time, the integration of digital technology into the financial sector has improved the speed of capital circulation, transfer, and effective distribution, improved the livelihood transformation ability of the poor and the sustainability of industrial development in underdevelopment, accumulated capital for regional development to promote rural economic development, and increased the disposable income of marginal groups, which is conducive to achieving IG between urban and rural areas.

3.1.3 Digital Divide Effect

With the continuous development of DFI, there will inevitably be "digital divide" and "knowledge gap hypothesis," which is not conducive to inclusive economic growth to a certain extent. Specifically, in the face of similar financial exclusion, different groups of users of financial services have significant differences in their ability to accept digital inclusive finance. The groups with higher financial literacy and digital literacy have a strong ability to apply digital technology, can understand the economic benefits that can be generated by using digital inclusive finance, take the initiative to accept emerging financial services, and allocate financial assets through peer-to-peer lending, investment, and insurance purchase, which is conducive to increasing their disposable income (Falak et al., 2022; Ling et al., 2023; Orkun et al., 2022). However, people with low digital literacy can't get in touch with and understand digital technology in time and lack the awareness of using digital inclusive finance to prevent risks and smooth their survival and consumption, so it is difficult to actively respond to digital inclusive finance services, resulting in "self-exclusion" and enjoying the dividend brought by digital inclusive finance (He et al., 2020; Liu et al., 2023). It can be seen that digital inclusive finance virtually reduces the rights of some groups who lack the ability to obtain and use digital information services to participate in social activities, resulting in relative deprivation and digital exclusion, and thus produces the "Matthew effect," which widens the gap between urban and rural residents and within rural society (Ozili, 2018).

Based on the above analysis, this article puts forward research hypothesis 1:

Hypothesis 1. Digital inclusive finance has an effect on IG, but the positive and negative effects are not clear.

3.2 Indirect Impact of Digital inclusive finance on IG

3.2.1 Innovation Activity

The application of financial technology has become the development trend of the financial industry, which has brought great influence on consumer identification, consumer participation, enterprise value delivery, and realization, and is an important driving force to realize the change of business model and promote the innovation of financial market (Sadok, 2021; Sun & You, 2023). For example, the introduction and application of virtual reality technology further promoted the innovation of inclusive finance's online business model and transferred the transaction negotiation and other links online, greatly reducing the transaction cost, transportation, and verification cost of financial services (Han et al., 2022). At the same time, more innovative subjects (universities, research institutes, and scientific and technological enterprises) tend to gather in areas with higher levels of scientific and technological innovation ability, and the business activities of enterprises are also more active. DFI improves the matching degree between financial support and the demand for enterprise funds through emerging technologies such as big data, especially easing the financing constraints of vulnerable groups such as small- and medium-sized enterprises. Specifically, the solutions that DFI can provide for SMEs include digital credit and equity products, such as supply chain finance, loans, guaranteed revolving credit lines, corporate accounts receivable financing market lending, and equity crowdfunding. In addition, digitalization of internal business processes and business-to-business (B2B) processes, such as electronic invoices and token assets using blockchain (distributed ledger) technology, will help solve the difficulties faced by small- and medium-sized enterprises in obtaining financing and significantly reduce financing costs (Chinoda & Kapingura, 2024; Suhrab et al., 2024). This will not only play a good "catalyst" role in existing innovation and entrepreneurship activities but also increase the base of potential innovation and entrepreneurship groups due to financial constraints and provide a large number of employment opportunities, thus contributing to the realization of IG (Deng et al., 2019; Li et al., 2020). According to the data of the fourth economic census, the number of employees in small- and medium-sized enterprises accounts for 80% of the total number of employees in enterprises. It can be seen that the improvement of innovation activity is helpful in promoting sustainable economic development, enhancing wealth, and maintaining social stability.

3.2.2 HC

The foundation of digital inclusive finance lies in inclusive finance, and the development of inclusive finance is devoted to solving the problem of financial exclusion for disadvantaged groups in modern financial services, including the financing constraints of family and individual education investment funds. On the one hand, the in-depth development of DFI can reduce the risks and costs of financial institutions in issuing education credit and lower the threshold for obtaining education credit, so that people who could not afford instant education consumption can invest in HC beyond their own consumption level through borrowing (Zhou et al., 2018). At the same time, the enhancement of financial availability and diversified financial products and services can not only promote the disadvantaged groups in traditional employment, such as low education level, to increase their educational opportunities, but also support high-tech talents to rebuild their skills and increase their educational opportunities at a higher level, thus promoting the upgrading of HC (Song et al., 2022). On the other hand, adult groups are facing pressure from the elderly and their children's life investment while meeting their own HC investment in later education, skills training, and health, which directly affects the mental health of HC investors and affects the quality of HC to a certain extent (John et al., 2022). However, the low credit constraint in DFI relieves the pressure of family capital shortage, especially the family residents in underdeveloped areas, and weakens the pressure of caring for children and supporting the elderly, thus improving the quality and quantity of HC (Li et al., 2022). With the spillover effect of HC flow and the increase of skills upgrading ways such as "learning by doing" and "re-education" of labor force, the structure of HC will continue to be optimized. In addition, the accumulation of HC contributes to the matching of supply and demand in the labor market, and the optimization of HC structure is conducive to stimulating the effect of technological progress, which will improve not only the labor productivity of society but also the efficiency of labor distribution in the market, thus effectively achieving IG (Abdulla, 2023). Therefore, the development of DFI has made it possible for residents in remote areas to obtain rich educational resources and improve the level of HC, so that they can apply for more jobs in the future, improve production methods, narrow the inherent gap with the rich, and thus promote inclusive economic and social growth.

Based on the above analysis, this article puts forward research hypothesis 2:

Hypothesis 2. The development of digital inclusive finance can achieve IG by increasing innovation activity and improving the level of HC.

4 Research Design and Data Sources

4.1 Variable Selection

4.1.1 Explained Variable

4.1.1.1 IG

IG takes social opportunity equity as the core, which enables individuals to participate in economic development opportunities and share development achievements equally, and enables the society to widely mobilize production factors and distribute the achievements fairly. The macro-level performance is sustainable economic growth, increased social welfare and fairness, and the income gap tends to narrow. To measure the level of IG, we need to consider the multiple characteristics of its connotation. According to the definition of IG by academic circles and international organizations such as the World Bank, referring to the practices of Abor et al. (2018), Fowowe and Folarin (2019), Ge and Li (2020), and Hu et al. (2022, 2023), combining the current situation of regional development in China, this article constructs an IG index system from three dimensions: sustainable economic growth, income distribution, and fair opportunity. In the process of constructing the index system, it is considered that equality of opportunity belongs to a multidimensional comprehensive concept, including economic participation, employment, education, medical care, and other aspects. In order to avoid concept generalization, core indicators in all aspects are selected (Table 1 shows specific indicators).

Sustainable economic growth is the basis of IG. Only reasonable, high-speed, and sustainable economic growth can provide more opportunities for economic participation and enhance social welfare. Sustainable economic growth includes economic growth, income growth, and green production. The economic growth level reflects the efficiency, structure, and speed of growth. The level of income growth reflects the extent to which economic growth benefits residents' income. The increase in residents' income is the starting point of the next round of consumption increase, which is conducive to enhancing the potential for economic growth. The requirement of green production reflects that energy consumption and carbon emission are the constraints of economic growth, which is in line with the concept of green development. Among them, the total factor productivity refers to the practices of Guan et al. (2022), Ma and Zhang (2022), Xu and Zhao (2023), and Ying et al. (2023), using a mixed distance function with both radial and non-radial distance functions to measure production efficiency. In order to better describe the dynamic evolution of production efficiency, the Global Malmquist–Luenberger (GML) index is introduced to measure the total factor productivity. Input indicators include labor input, capital input, and energy input, which are characterized by the number of employees at the end of the year, capital stock, and total energy consumption, respectively. Output indicators include expected output and unexpected output, in which the expected output is expressed by the actual GDP of each province in the current year, and the unexpected output includes sulfur dioxide emissions and chemical oxygen demand (COD).

Social opportunity equity is a direct embodiment of the core connotation of IG, aiming at eliminating the inequality caused by the environment and ensuring the fairness of the growth process. It is beneficial to technological innovation, industrial upgrading, and social stability to improve the fairness of social opportunities and enable more individuals to have high quality, skills, and security. Social opportunity equity includes economic participation opportunities, employment opportunities, education opportunities, medical opportunities, social security level, and resources and environment level. Among them, the market potential has an important impact on industrial agglomeration and the evolution of spatial economic structure, which can reflect the differences in economic participation opportunities between regions. Therefore, this article refers to the practice of Wang and Xu (2018), and uses the formulas listed in the table to measure the market potential level. Here, Y_{jt} represents the actual GDP of j province in the period of t, D_{ij} represents the distance between the capital cities of i and j provinces, and D_{ii} represents the internal distance of i province. $D_{ii} = \frac{2}{3}\sqrt{s_i/\pi}$, s_i is the land area of i province.

Income equality is a positive result feedback to opportunity fairness and a measure of the equality of growth results. Based on the concept of sharing development achievements and the vision of common prosperity, the income distribution gap is reflected from multiple levels, including urban-rural income gap, regional income gap, and industry income gap. Among them, the urban-rural income gap is characterized by the urban-rural income ratio. The regional income gap is based on the ratio of per capita disposable income (PCDI) in cities and towns

Table 1: Index system of IG

Dimension layer	Domain layer	Index layer	Specific explanation	Attribute
Sustainable economic growth	Economic growth level	Total factor productivity	Calculation of EBM–GML index based on DEA	+
		Proportion of secondary and tertiary industries	The sum of the proportion of secondary industry and tertiary industry	+
		Per capita GDP growth rate	Per capita GDP growth rate	+
	Income growth level	PCDI of urban residents	PCDI of urban residents at constant prices in 2011	+
		PCDI of rural residents	PCDI of rural residents at constant prices in 2011	+
	Green production level	Carbon emission intensity	Ratio of total carbon dioxide emissions to GDP	−
		Energy consumption per unit GDP	Ratio of total energy consumption to GDP	−
Fair opportunity	Opportunities for economic participation	Market potential	$\sum_{i \neq j} Y_{jt}/D_{ij} + Y_{it}/D_{ii}$	+
		Total highway mileage per 10,000 people	The ratio of total highway mileage to permanent population	+
	Employment opportunities	Employment rate of secondary and tertiary industries	Proportion of employed persons in secondary and tertiary industries	+
		Registered urban urbanization rate	Registered urban urbanization rate	−
	Educational opportunities	Intensity of investment in education funds	The ratio of education expenditure to GDP	+
		The number of full-time teachers per 10,000 people	The sum of the number of full-time teachers in ordinary colleges and high schools	+
	Medical opportunity	The number of doctors per 10,000 people	The ratio of practicing (assistant) doctors to total resident population	+
		The number of beds per ten thousand people	The ratio of practicing (assistant) doctors to total resident population	+
	Social security opportunities	Number of basic old-age insurance per 10,000 people	The ratio of the number of participants in basic old-age insurance to the total resident population	+
		Number of basic old-age insurance per 10,000 people	The ratio of the number of participants in basic medical insurance to the total resident population	+
	Resource and environmental level	Forest coverage rate	Forest coverage rate	+
		Per capita output of general industrial solid waste	The ratio of general industrial solid waste output to permanent population	−
		Per capita sulfur dioxide emissions	The ratio of sulfur dioxide emission in waste gas to permanent population	−
		Per-capita discharge of COD	The ratio of COD discharge in wastewater to resident population	−
Income equality	Degree of income equality	Urban–rural income ratio	The ratio of PCDI of urban to rural residents	−
		Regional income gap (town)	The ratio of disposable income of urban households to benchmark area in each province in that year	+
		Regional income gap (rural)	The ratio of disposable income of rural households to benchmark areas in each province in that year	+
		Industry income gap	Gini coefficient of industry	−

or rural areas in each province to the benchmark area in that year, and the benchmark area is selected as Shanghai. The industry income gap is expressed by the Gini coefficient calculated by Chen and Gao (2012), and the calculation formula is $G = \frac{1}{2u}\sum_i\sum_j p_i p_j |y_i - y_j|$. Among them, u represents the average wage of the whole industry, y_i and y_j represent the average wages of the i and j industries, and p_i and p_j represent the employment share of the i and j industries.

4.1.2 Core Explanatory Variable

4.1.2.1 DFI

The Digital Finance Research Center of Peking University, together with Ant Financial Group, compiled the "Digital inclusive finance Index" by using the massive data of Ant Financial on digital inclusive finance. Starting from the three first-level dimensions of coverage, usage depth, and digital support service level, the index uses 24 specific indicators, such as the number of Fubao accounts per 10,000 people, the proportion of Alipay users and the average number of bank cards bound to each Alipay account, to reflect the development of digital inclusive finance. At present, the index has been widely used in academic circles (Cao et al., 2022; Chen et al., 2023; Ge et al., 2022a,b). In view of this, this article chooses this index to measure the development level of digital inclusive finance in China.

4.1.3 Mediator Variable

4.1.3.1 Innovation Activity Degree (IAD)

According to Solow's economic growth model, scientific and technological innovation plays an obvious role in boosting high-quality economic growth. Due to the long period of patent approval in China, which is generally 6–18 months, the number of patents granted is lagging behind and cannot reflect the current patent application. Therefore, this article refers to the idea of Feng et al. (2022) and selects the number of patent applications in each province (autonomous region and municipality) to represent the active situation of technological innovation.

4.1.3.2 HC

Compared with material capital, the improvement of HC level not only means the increase of labor quantity but also means the improvement of labor quality. According to Romer's economic growth model, the development of knowledge and technology is the source of economic growth, and the improvement of labor quality has a more positive effect on inclusive economic and social growth than the simple increase in labor population. Therefore, this article refers to the ideas of Duc et al. (2021) and selects the average wage level of employees in various provinces (autonomous regions and municipalities) to measure the development level of HC.

4.1.4 Control Variable

Because there are many macro and micro factors affecting IG, in order to minimize the error caused by the omission of important variables in causal inference of the model, this article selects the following control variables according to the research perspective of existing literature (Afolabi et al., 2023; Borice et al., 2023; Katuka et al., 2024): Specifically, (1) PCDI: The reform of the income distribution mechanism is an important channel to achieve IG, and how to correctly handle the problems of efficiency and fairness in primary distribution and how to play the role of the adjustment mechanism of secondary distribution is an important issue to achieve economic and social inclusion at present. Therefore, this article uses the logarithm of regional PCDI to measure PCDI; (2) Urbanization rate (UR): On the one hand, urbanization stimulates regional economic growth and promotes the formation of inclusive ideas by expanding market scope; on the other hand, in the process of urban expansion, there may be problems such as a widening income gap among residents and insufficient living security for landless farmers, which hinder IG. Therefore, this article uses the ratio of urban population to total population to measure the urbanization rate; (3) Financial marketization (FM): Because in the process of institutional change to achieve IG, it often means that the original pattern of interest distribution has been broken. However, FM can improve productivity by strengthening budget constraints and improving management level and then affect the degree of economic and social inclusion. Therefore, this article selects the regional FM index to characterize FM; (4) UR: In the traditional Cobb Douglas production function, labor is input as an important factor of economic growth. Similarly, the labor force is also one of the important factors affecting IG, so this article selects the ratio of the unemployed population to the working population to measure the UR; (5) Foreign direct investment (FDI): With the continuous improvement of China's opening to the outside world, FDI has become an important source of funds for China, which has played an important role in promoting economic growth and inclusive development. Therefore, this article selects the proportion of FDI in GDP to measure.

4.2 Model Setting

4.2.1 Fixed Base Range Entropy Weight Method

This article takes 30 provinces in China from 2011 to 2021 (excluding Tibet, Hong Kong, Macao, and Taiwan) as the research object, and uses the entropy weight method of fixed-base range to measure and analyze their IG level. This method is a combination of entropy weight method and fixed-base range method, which can not only avoid the subjectivity of weight setting but also make the global universal reference system through fixed-base, thus reflecting the changing trend in both space and time dimensions. In addition, this method can also deal with positive and negative indicators and form three sub-dimension indexes. The specific calculation steps are as follows:

Step 1: Dimensionless processing of index data.

$$Y_{ij}^t = \begin{cases} \dfrac{X_{ij}^t - \min(X_{ij}^t)}{\max(X_{ij}^t) - \min(X_{ij}^t)}, & X_{ij}^t \text{ is a positive indicator} \\ \dfrac{\max(X_{ij}^t) - X_{ij}^t}{\max(X_{ij}^t) - \min(X_{ij}^t)}, & X_{ij}^t \text{ is a negative indicator.} \end{cases}$$

where X_{ij}^t represents the original data of the j index of the i province in the t year, and Y_{ij}^t is the data after dimensionless processing by using the range method.

Step 2: Calculate the specific gravity of indicators.

$$P_{ij}^t = \frac{Y_{ij}^t}{\sum_{i=1}^n Y_{ij}^t}, \quad i \in [1, n], j \in [1, m].$$

If the specific gravity value $P_{ij}^t = 0, \lim_{Y_{ij}^t \to 0} P_{ij}^t \times \ln(P_{ij}^t) = 0$ is defined.

Step 3: Calculate the index information entropy.

$$E_j^t = -[\ln(n)]^{-1} \times \sum_{i=1}^n [P_{ij}^t \times \ln(P_{ij}^t)].$$

Among them, E_j^t represents the information entropy of the jth index in the tth year. $E_j^t \in [0, 1]$. The smaller the index information entropy, the greater the degree of data dispersion, the greater the amount of information it provides, and the greater the index weight; on the contrary, the smaller the index weight.

Step 4: Calculate the index weight.

$$W_j^t = \frac{(1 - E_j^t)}{\sum_{j=1}^m (1 - E_j^t)},$$

where W_j is the weight of the j-th index.

Step 5: Use the fixed base range method to process the original data.

$$Z_j^t = \frac{X_j^t - \min(X_{j,\min}^{2011})}{\max(X_{j,\max}^{2011}) - \min(X_{j,\min}^{2011})}.$$

Among them, Z_j^t represents the dimensionless index value of the jth index after being processed by the fixed-base range method in the t year, and X_j^t is the original data. $X_{j,\min}^t$ and $X_{j,\max}^t$, respectively, represent the minimum and maximum values of the jth index in the original data of all cities in the base year. The article takes 2011, the initial year of the sample, as the base year.

Step 6: Calculate the comprehensive index. Weighting the index weight determined by the entropy weight method and the dimensionless index value processed by the fixed base range method to obtain the comprehensive index:

$$S_j^t = \sum_{j=1}^m (W_j^t \times Z_j^t).$$

4.2.2 Econometric Model

In order to verify the comprehensive effect of digital inclusive finance on IG, combined with research hypothesis 1, this article constructs the following panel econometric model:

$$\mathrm{IG}_{it} = \alpha_0 + \alpha_1 \mathrm{DFI}_{it} + \alpha_2 \sum_{i=1}^5 \gamma_j \mathrm{Control}_{ijt} + \nu_t + \lambda_i + \varepsilon_{it}.$$

Among them, subscripts i and t represent the city and year respectively; α_0 represents a constant term, α_1 and α_2 represent the regression coefficients of the core explanatory variables and control variables respectively; ν_t and λ_i represent year fixed effect (FE) and city FE respectively; ε_{it} represents the random disturbance term that obeys the white noise process. In the actual fitting calculation process, in order to slow down the influence of heteroscedasticity and reduce the data level of variables, all variables are logarithmically transformed in this article.

Considering that there may be a nonlinear relationship between digital inclusive finance and green poverty reduction, this article puts the square term of digital inclusive finance (DFI^2) into the model framework, and in order to avoid collinearity, the DFI is decentralized and then multiplied by square, and the following econometric model is established:

$$\mathrm{IG}_{it} = \alpha_0 + \alpha_1 \mathrm{DFI}_{it} + \alpha_2 \mathrm{DFI}_{it}^2 + \alpha_3 \sum_{i=1}^5 \gamma_j \mathrm{Control}_{ijt} + \nu_t + \lambda_i + \varepsilon_{it}.$$

In addition, in order to test the channel of digital inclusive finance's influence on IG, that is, to verify the channel

effect played by innovation activity and HC in its process, combined with research hypothesis 2, this article uses the form of recursive equations to test and then constructs the following equations:

$$\mathrm{IAD}_{it} = \beta_0 + \theta_1 \mathrm{DFI}_{it} + \gamma \mathrm{Control}_{it} + \nu_t + \lambda_i + \varepsilon_{it},$$

$$\mathrm{IG}_{it} = \beta_0 + \beta_1' \mathrm{DFI}_{it} + \sigma_1 \mathrm{IAD}_{it} + \gamma \mathrm{Control}_{it} + \nu_t + \lambda_i + \varepsilon_{it},$$

$$\mathrm{HC}_{it} = \beta_0 + \theta_2 \mathrm{DFI}_{it} + \gamma \mathrm{Control}_{it} + \nu_t + \lambda_i + \varepsilon_{it},$$

$$\mathrm{IG}_{it} = \beta_0 + \beta_1'' \mathrm{DFI}_{it} + \sigma_2 \mathrm{HC}_{it} + \gamma \mathrm{Control}_{it} + \nu_t + \lambda_i + \varepsilon_{it}.$$

4.3 Data Source

According to the principle of data availability, this article selects the panel data of 30 provinces in China from 2011 to 2021 (except Tibet, Hong Kong, Macao, and Taiwan) as the research sample. The original data of all variables mainly come from the China Economic Net database, EPS data platform, website of National Bureau of Statistics, China Statistical Yearbook, China Energy Statistical Yearbook, China Labor Statistical Yearbook, China Population and Employment Statistical Yearbook, China Education Expenditure Statistical Yearbook, China Education Statistical Yearbook, China Environment Statistical Yearbook, Peking University Digital inclusive finance Index (Phase III), and Chinese people. For a few missing values, LaGrange interpolation polynomial is used to complete them.

5 Analysis of empirical results

5.1 Measurement Results of IG Level

According to the above-mentioned IG index system, the total index and sub-index of IG of 30 provinces in China (excluding Tibet, Hong Kong, Macao, and Taiwan) from 2011 to 2021 are calculated by using the fixed-base range entropy weight method, and the specific results are shown in Tables 2 and 3.

It is not difficult to see from Table 2 that from 2011 to 2021, the total index of IG in China showed an obvious upward trend, with an average of 0.291. Taking 2021 as an example, Shanghai and Beijing are the leading cities in China, with IG levels of 0.546 and 0.539, respectively. In terms of increment and growth rate, Shanghai, Beijing, and Tianjin have higher starting point, slower growth rate and smaller increment, while Jiangsu, Zhejiang, Guangdong, and Shandong have lower starting point, faster growth rate, and larger increment. The reason behind this phenomenon may be the difference in regional economic development levels (Zeng et al., 2022). The core indicators such as per-capita GDP and PCDI in the region where the former is located are relatively high, which leads to a slower growth rate. From this point of view, although there are regional differences in IG among provinces in China, this difference is narrowing with the passage of time. This conclusion can also be seen from Table 3 that there are great differences in the total index and fractal index of IG in different regions of China, among which the eastern regions are in the leading position, showing a decreasing trend of "East-Middle-West" in turn. However, the average annual growth rate of the total IG index and fractal dimension index in the eastern region is obviously lower than that in the central and western regions.

5.2 Benchmark Regression Result

Common statistical models used in panel data include pool least square method (POLS), random effect model, and FE model. Which method is most suitable for the sample data of this article needs further testing. The test results show that the P values of houseman test and likelihood ratio test both reject the original hypothesis at a 1% level. Based on this, this article uses the FE model as the benchmark regression model for subsequent empirical tests. At the same time, in order to eliminate the interference of heteroscedasticity, sequence correlation, and cross-section correlation on regression results, Driscoll–Kraay standard error is mainly used to deal with it. The estimation results of specific parameters are shown in Table 4.

The results show that digital inclusive finance can obviously promote the total index of IG, the sub-index of sustainable economic growth, the sub-index of opportunity fairness, and the sub-index of income equality, and all of them have passed the significance level test of at least 10%. At the same time, digital inclusive finance has the highest contribution to income distribution, with a regression coefficient of 0.1671. The possible reason behind it is that digital inclusive finance, because of its natural ubiquity, uses information technologies such as remote account opening and capital exchange to realize the zero marginal cost effect of the network, break through the barriers of traditional financial physical outlets, effectively improve the efficiency of information exchange, greatly improve the availability of financial services for marginal groups, and guide the inclined allocation of capital to remote rural areas, thus promoting the "grassroots" people to innovate and start businesses, broadening their income channels,

Table 2: Total index of IG of provinces in China from 2011 to 2020

Province	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Shanghai	0.453	0.460	0.478	0.486	0.509	0.511	0.530	0.540	0.540	0.523	0.546	0.507
Beijing	0.491	0.478	0.510	0.487	0.492	0.485	0.507	0.501	0.504	0.482	0.539	0.498
Jiangsu	0.277	0.329	0.332	0.366	0.391	0.402	0.443	0.472	0.490	0.494	0.511	0.410
Zhejiang	0.276	0.316	0.331	0.352	0.382	0.395	0.427	0.452	0.472	0.468	0.514	0.399
Guangdong	0.268	0.312	0.301	0.346	0.369	0.379	0.413	0.444	0.467	0.512	0.543	0.396
Shandong	0.227	0.274	0.288	0.319	0.344	0.406	0.448	0.457	0.489	0.501	0.512	0.388
Tianjin	0.314	0.335	0.322	0.341	0.357	0.349	0.336	0.329	0.364	0.365	0.378	0.345
Sichuan	0.165	0.204	0.263	0.280	0.307	0.357	0.370	0.385	0.407	0.429	0.435	0.327
Shanxi	0.180	0.216	0.244	0.253	0.298	0.294	0.353	0.362	0.383	0.384	0.387	0.305
Chongqing	0.190	0.244	0.242	0.262	0.276	0.271	0.298	0.303	0.305	0.294	0.343	0.275
Fujian	0.193	0.231	0.226	0.246	0.261	0.262	0.289	0.315	0.329	0.328	0.337	0.274
Hubei	0.169	0.213	0.243	0.260	0.277	0.286	0.314	0.321	0.347	0.329	0.240	0.273
Liaoning	0.225	0.244	0.258	0.256	0.248	0.267	0.278	0.288	0.309	0.305	0.313	0.272
Shanxi	0.165	0.197	0.238	0.233	0.236	0.253	0.268	0.289	0.310	0.326	0.354	0.261
Xinjiang	0.203	0.218	0.250	0.244	0.259	0.284	0.273	0.272	0.281	0.275	0.299	0.260
Anhui	0.140	0.192	0.210	0.220	0.240	0.245	0.273	0.305	0.303	0.327	0.349	0.255
Ningxia	0.157	0.200	0.237	0.241	0.252	0.261	0.274	0.281	0.285	0.281	0.321	0.254
Henan	0.133	0.178	0.197	0.211	0.228	0.235	0.277	0.299	0.318	0.328	0.337	0.249
Gansu	0.141	0.182	0.235	0.225	0.243	0.253	0.271	0.268	0.276	0.284	0.301	0.244
Jiangxi	0.147	0.195	0.204	0.208	0.224	0.228	0.265	0.279	0.293	0.312	0.330	0.244
Hainan	0.205	0.247	0.231	0.232	0.240	0.231	0.237	0.247	0.256	0.266	0.270	0.242
Neimenggu	0.159	0.184	0.221	0.216	0.225	0.240	0.254	0.268	0.290	0.300	0.304	0.242
Hunan	0.141	0.164	0.198	0.197	0.215	0.224	0.253	0.278	0.303	0.323	0.338	0.239
Heilongjiang	0.171	0.200	0.217	0.206	0.214	0.235	0.240	0.238	0.292	0.296	0.301	0.237
Qinghai	0.170	0.202	0.224	0.205	0.220	0.234	0.229	0.233	0.270	0.287	0.330	0.237
Yunnan	0.144	0.170	0.209	0.210	0.221	0.239	0.274	0.277	0.277	0.278	0.283	0.235
Hebei	0.145	0.177	0.184	0.191	0.210	0.233	0.248	0.270	0.296	0.305	0.313	0.234
Jilin	0.167	0.190	0.195	0.201	0.213	0.219	0.228	0.239	0.284	0.284	0.294	0.229
Guizhou	0.118	0.163	0.195	0.192	0.206	0.216	0.229	0.256	0.253	0.251	0.269	0.213
Guangxi	0.120	0.156	0.185	0.177	0.191	0.199	0.226	0.234	0.246	0.256	0.267	0.205
Average	0.202	0.236	0.256	0.262	0.278	0.290	0.311	0.323	0.341	0.346	0.361	0.291

Table 3: IG and Its Sub-dimension changes in different regions of China

Dimension	Region	2011	2021	Average	Average annual growth rate (%)
Total index of IG	Whole country	0.202	0.361	0.291	6.090
	Eastern	0.285	0.446	0.369	4.620
	Middle	0.149	0.325	0.254	8.320
	Western	0.159	0.322	0.254	7.510
Economic sustainable growth index	Whole country	0.264	0.384	0.334	3.540
	Eastern	0.388	0.529	0.470	2.905
	Middle	0.203	0.345	0.300	5.110
	Western	0.188	0.289	0.242	3.932
Income equality index	Whole country	0.172	0.386	0.314	8.956
	Eastern	0.276	0.493	0.440	6.302
	Middle	0.151	0.339	0.293	8.669
	Western	0.084	0.333	0.222	16.566
Opportunity equity index	Whole country	0.176	0.339	0.259	6.943
	Eastern	0.231	0.371	0.295	4.915
	Middle	0.120	0.307	0.218	10.504
	Western	0.164	0.346	0.265	8.007

and sharing financial digital dividends (Tan et al., 2022). At the same time, the strengthening of the supply of financial resources in rural areas is conducive to further improving infrastructure construction, optimizing the business environment, enhancing the siphon effect to attract high-quality talents and production enterprises, thereby improving the soft power of production in rural areas and narrowing the huge gap between urban and rural areas. Judging from the square term of digital inclusive finance, its fitting coefficient to the total index of IG is 0.0832, which is significant at the level of 1%. This conclusion shows that with the continuous improvement of the level of digital inclusive finance, its marginal utility in promoting the IG of the economy and society is slightly weakened. With China entering a new stage of relative poverty control characterized by transformational secondary poverty, the production and living conditions of residents have been significantly improved, and the dependence of industries on resources and environment has been reduced, which has promoted the upgrading and transformation adjustment of industrial structure. However, for remote areas in the west or a few deep poverty-stricken areas, the possibility of poverty and the income gap between urban and rural areas are more obvious, which makes the promotion effect of digital inclusive finance on IG show an invisible slowdown.

5.3 Robustness Test

In order to verify the robustness and reliability of the benchmark regression estimation results, this article uses the following three methods to demonstrate:

First, replace the model: When there is an intra-group correlation, inter-group correlation, and same-period correlation in the random disturbance term, the estimation results of the two-way FE model may produce certain bias, and Driscoll–Kraay standard error is used to solve the possible heteroscedasticity, autocorrelation and cross-section correlation problems in the above benchmark regression analysis. However, in addition to using this standard error, the feasible generalized least squares (FGLS) can also deal with the three threats faced by short panel data. Due to the small number of sections, this article allows each individual to have the same autoregressive coefficient in the estimation process and uses the unique AR (1) autocorrelation structure of panel data.

Second, tail-shrinking treatment: In order to prevent extreme value interference, such as economic shocks or major natural disasters in various industries in China during the epidemic period, this article makes a 1% truncated treatment for all continuous variables and then uses the two-way FE model to re-estimate.

Third, change the core explanatory variables: The development of digital inclusive finance has improved the coverage, availability, and convenience of financial services, which is an important way to achieve business transformation and upgrading in the financial industry and gain competitive advantages. For example, compared with the traditional financial model, the convenient and fast characteristics of online payment overcome the geographical restrictions and the dual division between urban and rural areas, so that the majority of long-tail users can enjoy basic financial services. Therefore, this article replaces the digital inclusive finance total index with the coverage index. The index is mainly reflected by the number of electronic accounts (such as Internet payment accounts and the number of bank accounts bound to them), which mainly reflects the coverage of digital inclusive finance services.

As can be seen from the robustness test results in Table 5, the fitting results of the three methods all show that digital inclusive finance has a significant promotion effect on IG, and

Table 4: Benchmark regression results

Variable	IG	IGe	IGi	IGo	IG	IGe	IGi	IGo
DFI	0.1593***	0.0501**	0.1671***	0.0259*	0.1588***	0.0438*	0.1592***	0.0277*
	(4.33)	(3.95)	(5.89)	(2.17)	(4.33)	(3.05)	(4.50)	(2.21)
DFI^2					0.0832***	0.0217***	0.1184**	0.0164**
					(1.18)	(0.97)	(2.23)	(0.75)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
*R*Square	0.7328	0.7012	0.8305	0.8214	0.8317	0.7023	0.6724	0.8072

Note: ***, **, and * indicate significant at the level of 1%, 5%, and 10%, respectively, and t statistics are reported in brackets.

the significance level has not changed significantly, which fully shows that the benchmark regression results are reliable and robust.

5.4 Endogenous Treatment

Although this article selects a series of control variables to avoid the endogenous problems caused by omitting important variables as much as possible, the model still faces the endogenous threat of omitting important variables because some confusing factors are difficult to quantify, such as residents' perception of financial risks, lending preferences, and other factors. At the same time, there may be a two-way causal relationship between digital inclusive finance and IG. On the one hand, digital inclusive finance can effectively improve the efficiency of information exchange, reduce the cost of information transaction, improve the efficiency of regional industrial production organization, and guide the balanced allocation of capital, labor, and other factors, which is conducive to improving the existing economic structure, promoting high-quality industrial development, narrowing the income gap between urban and rural areas, and completely getting rid of the "resource curse" poverty trap. On the other hand, only when the inclusive level of economy and society is steadily improved, the relationship between financial lenders and borrowers can develop steadily and continuously, thus further promoting the development of digital inclusive finance. In view of this, in order to eliminate the deep endogenous relationship between them, this article adopts two-stage least square method (2SLS) and double difference method (DID) to deal with the potential endogenous problems of the model. Specifically:

Tool variable method: The precondition of the 2SLS model is to select one or more tool variables with strict exclusiveness. Considering that the development level of digital inclusive finance is closely related to the Internet carrier, and digital inclusive finance aims to provide financial products and services to the public by taking advantage of scientific and technological innovation, it is difficult to influence the IG level through the penetration rate of mobile phones. Therefore, this article chooses the mobile phone penetration rate (PRMT) as a tool variable for two-stage least square estimation. In addition, in order to avoid the influence of weak instrumental variables, this article refers to the practices of Nunn and Nancy (2014), Qian et al. (2020) and selects the per-capita postal business volume as the second instrumental variable. The development and application of digital technology began with the post and telecommunications business, and digital finance often develops rapidly in areas with high post and telecommunications business, which shows that there is a high correlation between the per capita post and telecommunications business and the level of digital inclusive finance. Moreover, compared with the development speed of digital technology and the change in information technology, the influence of post and telecommunications services on IG can be ignored, so this tool variable also meets the assumptions of relevance and exclusivity.

Double difference method: The underlying logic of digital inclusive finance is still the traditional inclusive finance, but it breaks through the time and space restrictions with the help of modern information technology, which is more conducive to giving play to the "general" and "benefit" attributes of finance. "Promoting the Development Plan of inclusive finance (2016–2020)" and "Advanced Principles of G20 Digital inclusive finance" provide a good "quasi-natural experiment" for this article. Compared with the eastern coastal areas, the development of the western region is still relatively backward, and the degree of financial development is generally low. Digital inclusive finance, which is based on modern information technology, inherits the inclusive and

Table 5: Results of robustness test and endogenous treatment

Variable	Robustness test			Endogenous treatment	
	FGLS	Tail shrinking treatment	Replace the core explanatory variable	2SLS	DID
DFI	0.0868***	0.1075***	0.0972***	0.1158***	0.1047***
	(2.65)	(3.10)	(2.91)	(3.77)	(3.38)
Control variable	Control	Control	Control	Control	Control
Unidentifiable test				83.447***	
Weak instrumental variable test				251.733	
Over-identification test				0.209	
Individual effect	Control	Control	Control	Control	Control
Time effect	Control	Control	Control	Control	Control

Note: *** indicates significant at the level of 1%.

inclusive characteristics of traditional inclusive finance. With the help of the natural "ubiquitous" characteristics of the Internet, its marginal promotion cost opportunity is zero, and the promulgation of two major policies provides a realistic opportunity for backward areas to develop digital inclusive finance and improve the financial system. Therefore, using the practices of Guo and Ma (2023) and Shen et al. (2021), this article sets 2016 as the exogenous policy impact node, the western region as the experimental group, and the eastern and central regions as the control group, and uses the DID model to verify the policy effect of the development of digital inclusive finance.

It can be seen from the results of endogenous treatment in Table 5 that the 2SLS method has passed the unidentifiable test, the weak tool variable test, and the over-identification test, and it is considered that the tool variable is exogenous and has nothing to do with the disturbance term. From the specific numerical point of view, the effectiveness of digital inclusive finance in promoting IG is 0.1158 and 0.1047, respectively, and both of them have passed the significance test of 1%. The result is similar to that of benchmark regression, and the sign direction and significance have not changed significantly. Therefore, the conclusion that digital inclusive finance can promote IG is still valid after eliminating possible endogenous problems.

6 Analysis of Path Mechanism

6.1 Heterogeneity Analysis

According to the above, the overall development of the eastern, central, and western regions of China is extremely uneven due to the influence of resource endowment, human ecology, economic development, financial development level, and HC, which will inevitably lead to regional differences in the influence of digital inclusive finance on IG. Therefore, this article divides the sample into three regions: the east, the middle, and the west, and analyzes the heterogeneity of the relationship between them by using the FE model. The specific results are shown in Table 6.

As can be seen from the table, digital inclusive finance has a significant role in promoting IG nationwide and passed the significance level test of 1%. The only difference is that the size of the promotion effect is slightly different between regions; that is, the marginal effect of digital inclusive finance on IG in the western region is 0.1002, which is higher than that in the central and eastern regions. The reason is that the infrastructure construction in the western region is relatively slow, the level of economic development is relatively backward, and the degree of FM is relatively low. In recent years, with the gradual strengthening of China's policy inclination for the development of the western region, the idle funds of online investors are loaned to vulnerable groups, small- and micro enterprises, and other long-tail users in remote western regions by using scientific and technological innovation technologies such as big data and cloud computing, thus expanding the financial coverage and lowering the financial transaction cost and financial service threshold, thus effectively alleviating the phenomenon of financial service exclusion in the western region, narrowing the income gap between regions, and promoting.

Table 6: Path Mechanism Analysis Results

Variable	Heterogeneity analysis			Mediation effect analysis	
	Eastern	Middle	Western	IAD	HC
DFI	0.0767***	0.0850***	0.1002***	0.0325**	0.0491*
	(2.32)	(2.47)	(2.98)	(0.94)	(1.03)
Control variable	Control	Control	Control	Control	Control
Individual effect	Control	Control	Control	Control	Control
Time effect	Control	Control	Control	Control	Control
Sobel (Z)				6.58	4.46
Sobel (boot Z)				5.79	4.95

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

6.2 Mediation Effect Analysis

In order to reveal whether digital inclusive finance can affect IG through the intermediary channels of innovation and HC, according to the above-mentioned intermediary effect test procedure and related principles, this article uses the Sobel intermediary factor test model to fit and calculate the panel data, and the specific results are shown in Table 6.

It is not difficult to see that the Z statistics of the Sobel test are all greater than the critical value of 0.96, which indicates that Digital inclusive finance can promote IG through the intermediary channels of improving innovation activity and HC level, in which the average estimation coefficients of innovation activity and HC are 0.325 and 0.0491, respectively, and pass the significance test of 5%

and 10%. This result shows that Digital inclusive finance uses big data, blockchain, artificial intelligence, and other digital technologies to accurately support small and micro enterprises and residents in remote areas to solve financing constraints in a low-cost, convenient, and fast way, realize the redistribution of funds, and stimulate regional innovation vitality, thus promoting sustainable economic development and IG. At the same time, by improving the efficiency of the use of funds, using idle funds to develop education and strengthen vocational skills training, and cultivating and introducing high-level and compound talents, China will develop in a more balanced and sufficient direction.

7 Research Conclusions and Policy Recommendations

7.1 Research Conclusions

On the basis of combining the relevant theoretical support and intermediary transmission mechanism of the influence of digital inclusive finance on IG, this article combines the panel data of 30 provinces in China (excluding Tibet, Hong Kong, Macao, and Taiwan) from 2011 to 2021, first measures the total index and fractal index of IG in China by using the fixed-base range entropy weight method, and then comprehensively uses the fixed-effect model, instrumental variable method, DID and Sobel intermediary factor method to verify the influence of digital inclusive finance on IG and whether digital inclusive finance can improve innovation. The results show that (1) the level of IG in China is gradually decreasing, while the average annual growth rate of IG in the eastern region is obviously lower than that in the central and western regions; (2) Digital inclusive finance can significantly improve the level of IG, and its contribution to income distribution is the highest. This conclusion still holds after a series of robustness tests and endogenous treatment. At the same time, with the continuous improvement of the level of digital inclusive finance, its promotion effect on the level of IG shows a hidden slowdown; (3) heterogeneity analysis shows that digital inclusive finance plays a more significant role in promoting the level of IG in the western region. The analysis of the mediating effect shows that innovation activity and HC level play a positive mediating role in the process of digital inclusive finance promoting IG, but there are differences in the effect.

7.2 Policy Recommendations

In order to give full play to the positive role of digital inclusive finance in IG, combined with the conclusion of the article, the following policy suggestions are put forward:

First, attach great importance to the construction of a digital inclusive financial system and improve the inclusiveness, coverage, and accuracy of financial services. Considering that the marginal effect of digital inclusive finance in the western region on IG is 0.1002, the government should increase the degree of digital support in the western region and remote areas, constantly improve the digital inclusive financial system and infrastructure construction, and fully release the promotion effect of digital inclusive finance on IG. Specifically, by optimizing digital functions such as personal payment, micro-credit and internet insurance, Digital inclusive finance realizes the accurate delivery of financial products, such as guiding Internet companies such as “JD Finance,” “Ant Financial Service,” and “Du-xiaoman” to sink the market, developing and designing digital financial products and services that benefit the people and facilitate the people according to local conditions, and ensuring the rights of economic entities such as deeply poor individuals, farmers, small- and medium-sized enterprises to obtain financial services, which will help alleviate financial exclusion in rural areas, reduce the incidence of regional multi-dimensional poverty, and improve the quality of life of residents.

Second, while developing digital inclusive finance, we should dredge innovation channels, deepen the “streamline administration, delegate power, strengthen regulation and improve services” reform, strengthen fair supervision, create a fair, convenient and efficient business environment, coordinate the designation of digital inclusive finance and innovation and entrepreneurship support policies, guide the optimal allocation of technology, capital and talents, and cultivate more dynamic, sustainable and stable innovation subjects, so as to enhance the regional innovation activity and enable low-income people to better enjoy the inclusive and inclusive economic growth brought by digital inclusive finance. At the same time, strengthen the “cluster effect” of developed economic regions in the eastern region, build relevant policy demonstration areas and pilot areas, fully stimulate the development momentum, and create a strong regional synergy effect.

Third, when developing digital financial products or services, financial institutions or financial technology companies should fully consider the HC level of residents in rural areas and remote areas, and try their best to increase the convenience of using digital finance in remote areas by

increasing voice assistants and reduce the constraints of low HC level in developing digital financial services in such areas. At the same time, we should attach importance to consumer education, continuously increase residents' knowledge reserves, and further improve the financial literacy level of residents in low-income groups and underdeveloped areas through flexible online and offline training, so as to better play the role of digital inclusive finance in promoting IG.

Funding information: This work was financially supported by the Natural Science Foundation of Fujian Province (grant number: 2022J01320) and supported by the Fundamental Research Funds for the Central Universities in Huaqiao University.

Author contributions: Conceptualization, X.Z.; methodology, J. Y., and X.G.; software, J.Y., and X.G.; formal analysis, J.Y., and X.G.; investigation, X.Z; resources, X.G.; writing – original draft, J.Y.; writing – review and editing, J.Y.; supervision, J.Y.; project administration, X.Z. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Article note: As part of the open assessment, reviews and the original submission are available as supplementary files on our website.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors, and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Data availability statement: The datasets used during the current study are available from the corresponding author on reasonable request.

References

Abdulla, K. (2023). New evidence on the role of human capital in economic development. *Applied Economics*, *55*(10), 1062–1073.

Abimbola, M. O., & Adekunle, A. A. (2021). Tax structure, human capital, and inclusive growth: A sub-Saharan Africa perspective. *Journal of Public Affairs*, *22*(4), e2670.

Abor, Y. J., Amidu, M., & Lssahaku, H. (2018). Mobile telephony, financial inclusion and inclusive growth. *Journal of African Business*, *2*, 430–453.

Afolabi, L. J., Uzoechina, B. L., Olasehinde, W. G., & Bekun, F. V. (2023). External financing for inclusive growth in lower - middle income West African countries: Foreign direct investment versus official development assistance. *International Journal of Public Administration*, *46*(16), 1166–1176.

Beck, T., Levine. R., & Loayza. N. (2000). Finance and the sources of growth. *Journal of Financial Economics*, *1*, 261–300.

Borice, A. N., Honoré, T. O., Bruno, E. O. N., & Edmond, N. D. (2023). Inclusive growth in the face of increasing urbanization: What experience for African countries? *Review of Development Economics*, *28*(1), 34–70.

Cao, J. H., Law, S. H., Wu, D. S., Tang, X. H., & Yang, X. D. (2022). Effect of digital financial inclusion on dredging the path of green growth—New evidence from front-end and back-end perspectives. *Frontiers in Environmental Science*, *10*, 2296–665X.

Chen, J. D., & Gao, Y. (2012). Analysis of income gap among industries in China — Based on the perspective of gini coefficient decomposition. *Financial Research*, *4*, 25–30.

Chen, M., Chu, Q., Zhang, T., Li, Q., Liu, J., & Yamaka, W. (2023). The structural causes and trend evolution of imbalance and insufficiency of development of digital inclusive finance in China. *Sustainability*, *15*, 10286.

Chinoda, T., & Kapingura, F. M. (2024). Digital financial inclusion and economic growth in Sub-Saharan Africa: The role of institutions and governance. *African Journal of Economic and Management Studies*, *15*(1), 15–30.

Deng, X. N., Yang, J. F., & Wang, W. (2019). Inclusive finance's entrepreneurial effect: Theoretical mechanism and empirical test. *Journal of Research on Financial Supervision*, *7*(1), 53–68.

Dollar, D., Kleineberg, T., & Kraay, A. (2016). Growth still is good for the poor. *European Economic Review*, *81*, 68–85.

Duc, H. V., Ngov, P. T., & Ha, M. N. (2021). Does financial development improve human capital accumulation in the Southeast Asian countries? *Cogent Business & Management*, *8*, 1.

Ezzahid, E., & Elouaourti, Z. (2021). Financial inclusion, mobile banking, informal finance and financial exclusion: Micro-level evidence from Morocco. *International Journal of Social Economics*, *48*(7), 1060–1086.

Falak, K., Ayub, M. S., & Salma, I. (2022). Role of financial literacy in achieving financial inclusion: A review, synthesis and research agenda. *Cogent Business & Management*, *9*(1).

Fan, Y. J., & Chen, S. T. (2022). Research on the effects of digital inclusive finance on the efficiency of financial resource allocation. *Frontiers in Environmental Science*, *10*.

Fan, Y. L., & Wu, X. B. (2011). Review on the research of inclusive growth. *Journal of Economic Management*, *33*(9), 180–184.

Feng, S. L., Chong, Y., Li, G. X., & Zhang, S. B. (2022). Digital finance and innovation inequality: Evidence from green technological innovation in China. *Environmental Science and Pollution Research*, *29*(58), 87884–87900.

Fowowe, B., & Folarin, E. O. (2019). The effects of fragility and financial inequalities on inclusive growth in African countries. *Review of Development Economics*, *23*, 1141–76.

Fu, L. F., Li, J. N., Fang, X., & Wei, H. Y. (2021). The mechanism and effectiveness test of digital inclusive finance promoting inclusive growth. *Journal of Statistical Study*, *38*(10), 62–75.

Ge, H., Li, B., Tang, D., Xu, H., & Boamah, V. (2022a). Research on digital inclusive finance promoting the integration of rural three-industry.

International Journal of Environmental Research and Public Health, *19*, 3363.

Ge, T, Ding, Z. Q., Lin, S. W., Yang, Y. M., & Ji, J. H. (2022b). Does environmental regulation dividends inequality impact inclusive growth? Evidence from China. *Frontiers in Public Health*, *10*, 2296–2565.

Ge, T., & Li, J. (2020). The effect of environmental regulation intensity deviation on China's inclusive growth. *Environmental Science and Pollution Research*, *27*, 34158–71.

Ghouse, G., Aslam, A., & Bhatti, M. I. (2022). The impact of the environment, digital–social inclusion, and institutions on inclusive growth: A conceptual and empirical analysis. *Energies*, *15*, 7098.

Grigory, A., & Simen, C. K. B. (2022). Environmental entrepreneurship and inclusive growth: A three-fold approach to analysis. *International Journal of Technological Learning, Innovation and Development*, *10*, 153–191.

Gu, K. Y., & Sun, H. (2022). Measurement and analysis of urban inclusive green growth index in China. *Journal of Statistics and Decision*, *38*(8), 100–104.

Guan, Y. P., Wang, H. J., Guan, R., & Ding, L. (2022). Measuring inclusive green total factor productivity from urban level in China. *Frontiers in Environmental Science*, *10*, 2296–665X.

Guo, Q. Q., & Ma, X. Y. (2023). Research on the influence of digital finance on economic growth and its effect. *Journal of Statistics and Decision*, *39*(14), 147–151.

Han, W., Wang, P., Jiang, Y., & Han, H. (2022). Nonlinear influence of financial technology on regional innovation capability: Based on the threshold effect analysis of human capital. *Sustainability*, *14*, 1007.

Hao, D., Yang, Z., & Chen, T. Q. (2023). A study on farmers' participation in environmental protection in the context of rural revitalization: The moderating role of policy environment. *International Journal of Environmental Research and Public Health*, *20*(3), 1768.

He, Z. Y., Zhang, X., & Wan, G. H. (2020). Digital finance, digital divide and multidimensional poverty. *Journal of Statistical Study*, *37*(10), 79–89.

Hong, M. Y., Lou, L., & Gong, L. J. (2022). Governance of characteristic poverty in China: Institutional basis and theoretical interpretation. *Journal of Shandong University (Philosophy and Social Sciences Edition)*, *2*, 23–37.

Hu, J. L., Wang, Y. Z., Lv, Y. B., & Duan, D. D. (2023). Can digital inclusive finance promote inclusive growth? *Journal of Forum on Statistics and Information*, *38*(2), 47–60.

Hu, R., Shahzad, F., Abbas, A., & Xu, N. (2022). Empirical analysis of the impact of industrial internet development environment on open green innovation of manufacturing enterprises. *Frontiers in Environmental Science*, *2022*, 10.

Jiang, A. C., Chen, C., Ao, Y. B., & Zhou, W. M. (2022). Measuring the inclusive growth of rural areas in China. *Applied Economics*, *54*(32), 3695–3708.

John, J., Alejandro, L. A. L., & David, O. G. M. (2022). The link between financial education and financial literacy: A cross-national analysis. *The Journal of Economic Education*, *53*(4), 307–324.

Kapoor, A. (2014). Financial inclusion and the future of the Indian economy. *Futures*, *56*(2), 35–42.

Katuka, B., Mudzingiri, C., & Ozili, P. K. (2024). Fiscal space, governance quality and inclusive growth: evidence from Africa. *Journal of Financial Economic Policy*, *16*(1), 80–101.

Khémiri, W., Chafai, A., & Alsulami, F. (2023). Financial inclusion and sustainable growth in North African firms: A dynamic-panel-threshold approach. *Risks*, *11*, 132.

Klasen, S. (2010). Measuring and monitoring inclusive growth. *ADB Sustainable Development Working Paper Series*, *8*, 7–12.

Kun, S., Tang, Y., Zang, D. G., & Gao, H. (2022). Does digital finance increase relatively large-scale farmers' agricultural income through the allocation of production factors? Evidence from China. *Agriculture*, *12*(11), 1915.

Lambert, C. N., Fulbert, T. T., & Albert, G. Z. (2021). Housing finance and inclusive growth in Africa: Benchmarking, determinants and effects. *International Economic Journal*, *35*(2), 259–287.

Li, H. J., Zhuge, R. Y., Han, J., Zhao, P., & Gong, M. G. (2022). Research on the impact of digital inclusive finance on rural human capital accumulation: A case study of China. *Frontiers in Environmental Science*, *10*.

Li, J. J., Peng, Y. C., & Ma, S. C. (2020). Economic Development of inclusive finance and China: Multi-dimensional connotation and empirical analysis. *Journal of Economic Research*, *55*(4), 37–52.

Li, L. X., & Bian, S. (2021). Economic growth, income distribution and poverty: Identification and decomposition of inclusive growth. *Journal of Economic Research*, *56*(2), 54–70.

Li, Y. F., & Jiang, Y. (2006). Economic structure, banking structure and economic development: An empirical analysis based on provincial panel data. *Journal of Financial Research*, *48*(1), 7–22.

Ling, X., Wang, L., Pan, Y., & Feng, Y. (2023). The impact of financial literacy on household health investment: Empirical evidence from China. *International Journal of Environmental Research and Public Health*, *20*, 2229.

Liu, L. H., Wang, Y. X., Li, B., & Peng, Y., 2023. Digital inclusive finance and residents' consumption level: Analysis based on mediating effect test. *Academic Journal of Business & Management*, 2023, *5*(15), 23–30.

Liu, Q. T. (2022). Determinants of financial poverty alleviation efficiency: Evidence from Henan, China. *PloS ONE*, *17*(11), e0277354.

Liu, W. Z., Wang, B., Wang, C. Y., & Han, K. F. (2023). The effect of financial literacy on rural households' insurance participation: Evidence from farmers in southwest China. *Asia-Pacific Journal of Accounting & Economics*, *30*(1), 139–155.

Liu, Y., Liu, C. Y., & Zhou, M. (2021). Does digital inclusive finance promote agricultural production for rural households in China? Research based on the Chinese family database (CFD). *China Agricultural Economic Review*, *13*(2), 1756–137X.

Ma, J. M., Gao, D., & Sun, J. (2022). Does ESG performance promote total factor productivity? Evidence from China. *Frontiers in Ecology and Evolution*, *10*, 2296–701X.

Ma, X. Y., & Zhang, Y. (2022). Evaluation of inter-provincial inclusive growth in China — Based on entropy method. *Journal of Technology and Industry*, *22*(2), 113–118.

Mei, B., Khan, A. A., Khan, S. U., Ali, M. A. S., & Luo, J. (2022). Complementarity or substitution: A study of the impacts of internet finance and rural financial development on agricultural economic growth. *Agriculture*, *12*, 1786.

Mou, T. Q., Diao, L., & Huo, P. (2021). Digital economy and inclusive growth in urban and rural areas: From the perspective of digital skills. *Journal of Chinese Review of Financial Studies*, *13*(4), 36–57 + 124–125.

Náñez Alonso, S. L., Jorge-Vazquez, J., Reier Forradellas, R. F., & Ahijado Dochado, E. (2022). Solutions to financial exclusion in rural and depopulated areas: Evidence based in castilla y León (Spain). *Land*, *11*, 74.

Nunn, N., & Nancy, Q. (2014). US Food Aid and Civil Conflict. *American Economic Review*, *104*(6), 1630–1666.

Orkun, S., Barry, E., & Giray, C. A. (2022). Epidemic exposure, financial technology, and the digital divide. *Journal of Money, Credit and Banking*, *54*(7), 1913–1940.

Ozili, P. K. (2018). Impact of digital finance on financial inclusion and stability. *Borsa Istanbul Review*, *18*(4), 329–340.

Park, C.Y. (2015). Financial inclusion, poverty, and income inequality in developing Asia. *Social Science Electronic Publishing*, *20*(5), 419–435.

Peng, D. Y., Zhou, T. F., & Yan, M. J. (2018). Research on measurement of inclusive growth level and spatial correlation analysis — Based on panel data from 2009 to 2016. *Journal of Finance and Economy*, *4*, 52–58.

Qian, H. Z., Tao, Y. Q., Cao, S. W., & Cao, Y. Y. (2020). Theory and demonstration of digital finance development and economic growth in China. *Journal of Quantitative & Technical Economics*, *37*(6), 26–46.

Rauniyar, G. P., & Kanbur, R. (2010). Inclusive development: Two papers on conceptualization, application, and the ADB perspective. *Working Papers*, *72*(72), 523–530

Ren, B. Y., & Li, L. Y. (2019). Does digital inclusive finance promote inclusive growth in rural areas — Based on the survey data of 2114 rural residents in Beijing, Tianjin and Hebei. *Modern Finance and Economics (Journal of Tianjin University of Finance and Economics)*, *39*(4), 3–14.

Ren, X. H., Zeng, G. D., & Gozgor, G. (2023). How does digital finance affect industrial structure upgrading? Evidence from Chinese prefecture-level cities. *Journal of Environmental Management*, *330*, 117125.

Sadok H. (2021). How can inclusive growth be enabled from financial technology? *International Journal of Business Performance Management*, *22*(2–3), 159–179.

Sarma, M., & Pais, J. (2011). Financial inclusion and development. *Journal of International Development*, *23*(5), 613–628.

Shen, Y., You, Y. H., & Zhou, P. F. (2021). The influence of digital inclusive finance on new urbanization. *Journal of Finance and Economy*, *11*, 46–53.

Silber, J., & Son, H. (2010). On the link between the Bonferroni index and the measurement of inclusive growth. *Economics Bulletin*, *30*(1), 421–428.

Song, J., Zhou, H., Gao, Y., & Guan, Y. (2022). Digital inclusive finance, human capital and inclusive green development—Evidence from China. *Sustainability*, *14*, 9922.

Suhrab, M., Chen, P. L., & Ullah, A. (2024). Digital financial inclusion and income inequality nexus: Can technology innovation and infrastructure development help in achieving sustainable development goals? *Technology in Society*, *76*, 102411.

Sun, Y. N., & You, X. T. (2023). Do digital inclusive finance, innovation, and entrepreneurship activities stimulate vitality of the urban economy? Empirical evidence from the Yangtze River Delta, China. *Technology in Society*, *72*, 0160–791X.

Tan, L. Z., Zhang, Y. Z., Tian, N. L., & Sun, K. L. (2022). The influence and explanation of digital inclusive finance on that income of rural return labor force. *Journal of Southern Population*, *37*(6), 37–51.

Tang, Y., Wang, H., & Lin, Z. (2023). Spatial heterogeneity effects of green finance on absolute and relative poverty. *Sustainability*, *15*, 6206.

Wang, H. H., & Xu, J. J. (2018). Market potential, spatial spillover and manufacturing agglomeration. *Journal of Geographical Research*, *37*(9), 1736–1750.

Wang, L., Chen, Y., & Ding, S. (2022). Examining the impact of digital finance on farmer consumption inequality in China. *Sustainability*, *14*, 13575.

Wang, Y., Weng, F., & Huo, X. (2023). Can digital finance promote professional farmers' income growth in China? — An examination based on the perspective of income structure. *Agriculture*, *13*, 1103.

Xiong, M., Li, W., Jenny, C., & Wang, P. (2023). Financial inclusion through digitalization: Improving emerging drivers of industrial pollution—Evidence from China. *Sustainability*, *15*, 10203.

Xiong, M., Li, W., Teo, B. S. X., & Othman, J. (2022). Can China's digital inclusive finance alleviate rural poverty? An empirical analysis from the perspective of regional economic development and an income gap. *Sustainability*, *14*, 16984.

Xu, K., & Zhao, P. (2023). Does green finance promote green total factor productivity? Empirical evidence from China. *Sustainability*, *15*, 11204.

Ying, Y., Cui, X., & Jin, S. (2023). Artificial intelligence and green total factor productivity: The moderating effect of slack resources. *Systems*, *11*, 356.

Yu, N., & Wang, Y. (2021). Can digital inclusive finance narrow the Chinese urban–rural income gap? The perspective of the regional urban–rural income structure. *Sustainability*, *13*, 6427.

Zeng, W. H., Wang, C., Qiao, Q., & Liu, Z. S. (2022). Research on measurement, differential decomposition and convergence of inclusive green growth of urban agglomerations — A case study of Yangtze River Delta and Pearl River Delta urban agglomerations. *Journal of Financial Education Research*, *35*(1), 57–70.

Zhang, X., Wan, G. H., Zhang, J. J., & He, Z. Y. (2019). Digital economy, inclusive finance and inclusive growth. *Journal of Economic Research*, *54*(8), 71–86.

Zheng, L. L., & Su, Y. (2022). Inclusive insurance, income distribution, and inclusive growth. *Frontiers in Public Health*, *10*, 2296–2565.

Zhou, G., Gong, K., Luo, S., & Xu, G. (2018). Inclusive finance, human capital and regional economic growth in China. *Sustainability*, *10*, 1194.

Zhou, R. (2022). Measurement and spatial-temporal characteristics of inclusive green growth in China. *Land*, *11*, 1131.

Zhu, J. H., & Jiang, P. P. (2017). Measurement and evaluation of inclusive growth level in Xinjiang based on fuzzy comprehensive evaluation method. *Journal of Qinghai Ethnic Studies*, *28*(2), 193–199.