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Analysis on the Effect of Digital financial inclusion in Promoting Inclusive Growth: Mechanism and Statistical Verification --Manuscript Draft--

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Analysis on the Effect of Digital financial inclusion in Promoting Inclusive Growth: Mechanism and Statistical Verification

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Abstract: As the main goal of economic development, inclusive growth 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 inclusive growth 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 paper first measures the inclusive growth index of China from three dimensions: sustainable economic growth, income distribution and social equity. Subsequently, the paper uses a series of mathematical statistical models to verify the transmission path and mechanism of the influence of digital inclusive finance on inclusive growth. The findings are as follows: (1) The level of inclusive growth in China shows a decreasing trend from east to middle to west, while the average annual growth rate of inclusive growth 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 inclusive growth, and digital inclusive finance in the central and western regions has a more obvious promotion effect on inclusive growth; (3) Digital inclusive finance can achieve inclusive growth 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

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 (Klasen, 2010; Zhou, 2022; Jiang et al., 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 (Ren et al., 2019; Kun et al., 2022; Wang et al., 2022; Ren et al., 2023). 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 (Mou et al., 2021; Liu, 2022; 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, with a view to providing 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. Rauniyar et al. and Fan et al. 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. and Ghouse et al. believe that IG has three meanings, namely, sharing the development achievements of the Sharing economy, giving basic development opportunities and cultivating basic development capabilities. This is 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 (Ma et al., 2022; Grigory et al., 2022), fuzzy comprehensive evaluation method (Zhu et al., 2017; Abimbola et al., 2021), dynamic factor analysis method (Peng et al., 2018; Zheng et al., 2022), and function derivation to calculate. Silber et al. and Fu et al. 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 et al. 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 et al. calculated China's IG level from four dimensions: economic development, social opportunity equity, green production and consumption, and ecological environment protection.

Second, research 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 (Sarma et al., 2011; Dollar et al., 2016). For example, Kapoor, Park, Zhang et al. and Li et al. 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, Further enhance 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. found that DFI and its sub dimensions will have different degrees of impact on IG, that is, DFI can promote IG, coverage and depth of use can promote equal access to opportunities, development achievements sharing can promote sustained economic growth, which has a certain role in promoting IG, but the role of digital degree is not significant. Khémiri et al. pointed out that DFI has a significant role in promoting the IG of China's economy, and the role is more obvious in regions where local governments are more efficient, there are strong innovation activities in cities, and the market is well developed. At the same time, DFI can achieve inclusive economic growth by easing the financing constraints of SMEs and promoting entrepreneurship of low-income families.

To sum up, the existing literature has conducted a lot of useful research on DFI and IG, providing ideas and experience for this paper to explore whether DFI can promote IG, but there is still marginal room for improvement. The potential innovations of the article are as follows: first, according to the connotation and purpose of IG, build an IG indicator system from multiple dimensions such as sustainable economic growth, income distribution and fair opportunity, comprehensively reflect China's IG level, and analyze the impact of DFI on the overall index and sub index of IG; Secondly, it reveals that China's IG level shows a decreasing trend from east to center to west, and analyzes the main reasons for regional heterogeneity; Thirdly, we explored the transmission mechanism of DFI affecting IG in depth and put forward corresponding suggestions, which provides theoretical reference for subsequent research on IG to promote the country's development towards a more balanced and adequate direction.

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 et al., 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 to cities, exacerbating the long-term "dual structure" of China's finance (Fan et al., 2022; Nómez 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 et al., 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; Xiong et al., 2022; Wang et al., 2023).

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 (Yu et al., 2021; Liu et al., 2023). 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 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; Orkun et al., 2022; Ling et al., 2023). 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 paper 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 et al., 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 to 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, etc.) tend to gather in areas with higher level of scientific and technological innovation ability, and the business activities of enterprises are also more active. Digital inclusive finance has improved the matching degree between financial support and the demand of enterprise funds through emerging technologies such as big data, especially alleviating the financing constraints of vulnerable groups such as small and medium-sized enterprises, which not only plays a good "catalyst" role in existing innovation and entrepreneurship activities, but also can increase the base of potential innovation and entrepreneurship groups limited by funds and provide a large number of employment opportunities, thus helping to achieve inclusive economic growth (Deng et al., 2019; Li et al., 2020).

3.2.2 Human capital

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 the 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 digital inclusive finance 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 human capital 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 human capital (Song et al., 2022). On the other hand, adult groups are facing the pressure from the elderly and their children's life investment while meeting their own human capital investment in later education, skills training and health, which directly affects the mental health of human capital investors and affects the quality of human capital to a certain extent (John et al., 2022). However, the low credit constraint in digital inclusive finance relieves the pressure of family capital shortage, especially the family residents in underdeveloped areas, weakens the pressure of caring for children and supporting the elderly, thus improving the quality and quantity of human capital (Li et al., 2022). Therefore, the development of digital inclusive finance has made it possible for residents in remote areas to obtain rich educational resources and improve the level of human capital, 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 paper 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 human capital.

4 Research design and data sources

4.1 Variable selection

4.1.1 Explained variable

Inclusive growth (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., Fowowe et al., Ge et al. and Hu et al. combining the current situation of regional development in China, this paper 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. See Table 4.1 for specific indicators.

Table 4.1 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	Per capita disposable income of urban residents	Per capita disposable income of urban residents at constant prices in 2011	+
		Per capita disposable income of rural residents	Per capita disposable income 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 rate of secondary and tertiary industries	Proportion of employed persons in secondary and tertiary industries	+
	Employment opportunities	Registered urban unemployment rate	Registered urban unemployment rate	-
		Intensity of investment in education funds	The ratio of education expenditure to GDP	+
	Educational opportunities	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	+
		The number of doctors per 10,000 people	The ratio of practicing (assistant) doctors to total resident population	+
	Medical opportunity	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	+
		Forest coverage rate	Forest coverage rate	+
	Resource and environmental level	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 chemical oxygen demand (COD)	The ratio of chemical oxygen demand discharge in wastewater to resident population	-
		Urban-rural income ratio	The ratio of per capita disposable income of urban and rural residents	-
	Income equality	Degree of income equality	The ratio of disposable income of urban households to benchmark area in each province in that year.	+
		Regional income gap (town)	The ratio of disposable income of rural households to benchmark areas in each province in that year	+
		Industry income gap	Gini coefficient of industry	-

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 of residents' income is the starting point of the next round of consumption increase, which is conducive to enhancing the potential of 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., Ma et al., Xu et al., and Ying et al., using a mixed distance function with both radial and non-radial distance functions to measure the 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.

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 paper refers to the practice of Wang et al. and uses the formulas listed in the table to measure the market potential level. Where 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 in cities and towns 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 et al., 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

Digital Financial Inclusion (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; Ge et al., 2022; Chen et al., 2023). In view of this, this paper chooses this index to measure the development level of digital inclusive finance in China.

4.1.3 Mediator variable

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 paper selects the number of patent applications in various provinces (autonomous regions and municipalities) to represent the active situation of technological innovation.

Human Capital (HC). Compared with material capital, the improvement of human capital 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 of labor population. Therefore, this paper selects the average wage level of employees in various provinces (autonomous regions and municipalities) to measure the development level of human capital.

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 paper selects the following control variables according to the research perspective of existing literature. Specifically: (1) Per capita disposable income (PCDI). The reform of 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 paper uses the logarithm of regional per capita disposable income to measure per capita disposable income. (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 widening income gap among residents and insufficient living security for landless farmers, which hinder IG. Therefore, this paper 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, financial marketization can improve productivity by strengthening budget constraints and improving management level, and then affect the degree of economic and social inclusion. Therefore, this paper selects the regional financial marketization index to characterize financial marketization. (4) Unemployment rate (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 paper selects the ratio of unemployed population to working population to measure the unemployment rate. (5) Foreign direct investment (FDI). With the continuous improvement of China's opening to the outside world, foreign direct investment has become an important source of funds for China, which has played an important role in promoting economic growth and inclusive development. Therefore, this paper selects the proportion of foreign direct investment in GDP to measure.

4.2 Model setting

4.2.1 Fixed base range entropy weight method

This paper 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.

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

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.

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

If the specific gravity value $P_{ij}^t = 0$, $\lim_{Y_{ij}^t \rightarrow 0} P_{ij}^t \times \ln(P_{ij}^t) = 0$ 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 j -th index in the t -th 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 j -th 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 j -th 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 paper constructs the following panel econometric model:

$$IG_{it} = \alpha_0 + \alpha_1 DFI_{it} + \alpha_2 \sum_{j=1}^5 \gamma_j Control_{ijt} + \nu_t + \lambda_i + \varepsilon_{it}$$

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 and city fixed effect 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 paper.

Considering that there may be a nonlinear relationship between digital inclusive finance and green poverty reduction, this paper 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:

$$IG_{it} = \alpha_0 + \alpha_1 DFI_{it} + \alpha_2 DFI_{it}^2 + \alpha_3 \sum_{j=1}^5 \gamma_j Control_{ijt} + \nu_t + \lambda_i + \varepsilon_{it}$$

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 human capital in its process, combined with research hypothesis 2, this paper uses the form of recursive equations to test, and then constructs the following equations:

$$\begin{aligned} IAD_{it} &= \beta_0 + \theta_1 DFI_{it} + \gamma Control_{it} + \nu_t + \lambda_i + \varepsilon_{it} \\ IG_{it} &= \beta_0 + \beta_1' DFI_{it} + \sigma_1 IAD_{it} + \gamma Control_{it} + \nu_t + \lambda_i + \varepsilon_{it} \\ HC_{it} &= \beta_0 + \theta_2 DFI_{it} + \gamma Control_{it} + \nu_t + \lambda_i + \varepsilon_{it} \\ IG_{it} &= \beta_0 + \beta_1'' DFI_{it} + \sigma_2 HC_{it} + \gamma Control_{it} + \nu_t + \lambda_i + \varepsilon_{it} \end{aligned}$$

4.3 Data source

According to the principle of data availability, this paper 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 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 5.1 and 5.2.

Table 5.1 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

It is not difficult to see from Table 5.1 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 of regional economic development level (Zeng et al., 2022). The core indicators such as per capita GDP and per capita disposable income 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 5.2 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.

Table 5.2 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

5.2 Benchmark regression result

Common statistical models used in panel data include pool least square method (POLS), random effect model (RE) and fixed effect model (FE). Which method is most suitable for the sample data of this paper needs further testing. The test results show that the P values of houseman test and likelihood ratio test both reject the original hypothesis at 1% level. Based on this, this paper uses the fixed effect 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 5.3.

Table 5.3 Benchmark Regression Results

Variable	IG	IGe	IGi	IGo	IG	IGe	IGi	IGo
<i>DFI</i>	0.1593*** (4.33)	0.0501** (3.95)	0.1671*** (5.89)	0.0259* (2.17)	0.1588*** (4.33)	0.0438* (3.05)	0.1592*** (4.50)	0.0277* (2.21)
<i>DFI</i> ²					0.0832*** (1.18)	0.0217*** (0.97)	0.1184** (2.23)	0.0164** (0.75)
<i>Control variable</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>Individual effect</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>Time effect</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>R Square</i>	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 results show that the 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 and sharing financial digital dividends (Tan et al., 2022). At the same time, with the strengthening of the supply of financial resources in rural areas, it 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 IG of 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 paper uses the following three methods to demonstrate:

First, replace the model. When there is intra-group correlation, inter-group correlation and

same-period correlation in the random disturbance term, the estimation results of the two-way fixed effect 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 paper 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 paper makes a 1% truncated treatment for all continuous variables, and then uses the two-way fixed effect 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 paper 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.

Table 5.4 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*** (2.65)	0.1075*** (3.10)	0.0972*** (2.91)	0.1158*** (3.77)	0.1047*** (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

As can be seen from the robustness test results in Table 5.4, the fitting results of the three methods all show that digital inclusive finance has a significant promotion effect on IG, and 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 paper 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 can the relationship between financial lenders and borrowers 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 paper adopts two-stage least square method (2SLS) and double difference method (DID) to deal with the potential endogenous problems of the model. Specifically:

1. Tool variable method. The precondition of 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 paper 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 paper refers to the practices of Nunn et al., Huang et al. and Qian et al., 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 of 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.

2. 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 paper. 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 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 Shen et al. and Guo et al., this paper 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 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 5.4 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 human capital, which will inevitably lead to regional differences in the influence of digital inclusive finance on IG. Therefore, this paper 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 fixed effect model. The specific results are shown in Table 6.1.

Table 6.1 Path Mechanism Analysis Results

Variable	Heterogeneity analysis			Mediation effect analysis	
	Eastern	Middle	Western	Innovation activity degree	Human capital
DFI	0.0767*** (2.32)	0.0850*** (2.47)	0.1002*** (2.98)	0.0325** (0.94)	0.0491* (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

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 financial marketization 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 the 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.

6.2 Mediation effect analysis

In order to reveal whether digital inclusive finance can affect IG through the intermediary channels of innovation and human capital, according to the above-mentioned intermediary effect test procedure and related principles, this paper uses Sobel intermediary factor test model to fit and calculate the panel data, and the specific results are shown in Table 6.1.

It is not difficult to see that the Z statistics of 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 human capital level, in which the average estimation coefficients of innovation activity and human capital 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 combing the relevant theoretical support and intermediary transmission mechanism of the influence of digital inclusive finance on IG, this paper 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 mediating effect shows that innovation activity and human capital 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. 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 realize the accurate delivery of financial products by optimizing digital functions such as personal payment, micro-credit and internet insurance, such as guiding Internet companies such as JD Finance, Ant Financial and Du-xiaoman to sink the market and develop and design digital financial products and services that benefit the people and facilitate the people according to local conditions. Safeguarding the rights of economic entities such as individuals in deep poverty, farmers, small and medium-sized enterprises to obtain financial services will help alleviate financial exclusion in rural areas, reduce the incidence of regional multidimensional poverty and improve the quality of life of residents, thus promoting sustainable economic development and IG.

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 human capital 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 human capital 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.

8 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.

9 Author Contributions

Conceptualization, X.Z.; Methodology, J. Y., X.G., and Y.S.; Software, J.Y., X.G., and Y.S.; Formal analysis, J.Y., X.G., and Y.S.; Investigation, X.Z; Resources, X.G.; Writing—original draft, J.Y.; Writing—review & editing, J.Y.; Supervision, J.Y.; Project administration, X.Z. All authors have read and agreed to the published version of the manuscript.

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11 Data Availability Statement

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

12 Publisher's Note

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