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A study on the impact of digital financial inclusion on inclusive growth in China: The mediating effect of innovation

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Abstract

This study empirically explores the impact, regional variations and transmission mechanisms of digital financial inclusion on inclusive growth. A provincial panel dataset encompassing 31 Chinese provinces from 2011 to 2021 was collected from the wind database, the China statistical yearbook and the China regional financial operation report to analyze the relationship between digital financial inclusion and inclusive growth by using individual fixed effects and mediating effects. This study reveals that digital financial inclusion significantly influences the growth of China's east, central, west regions and economic growth, income distribution and opportunity equality. Moreover, digital financial inclusion can enhance inclusive growth through the transmission mechanism of innovation. Developing digital financial inclusion, comprising coverage breadth, usage depth and digital level will promote the level of inclusive growth in China. Meanwhile, the increasing level of innovation, especially the number of invention patents can support digital financial inclusion by fostering inclusive growth. The study focuses on Chinese provinces and reliance on a specific timeframe (from 2011 to 2021) might limit the generalizability of the findings. The implications for broader economic contexts need further exploration. Accelerating progress towards inclusive growth can be achieved by fostering the development of digital financial inclusion and elevating the level of innovation. This study contributes by highlighting the positive relationship between digital financial inclusion, regional disparities and its impact on inclusive growth, emphasizing the role of innovation in this relationship and suggesting policy directions for achieving inclusive growth.

Keywords: China, Digital financial inclusion, Inclusive growth, Innovation, Individual fixed effects, Mediating effect.

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Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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1. Introduction

Since the United Nations first introduced the concept of "financial inclusion" in 2005, the Chinese government has actively responded to international appeals by implementing measures to support and advance financial inclusion with a focus on addressing the financial service requirements of marginalized groups. Nevertheless, the coexistence of credit risk for underserved customers and technical risk for financial institutions has markedly impeded the progress of inclusive finance resulting in a lack of commercial sustainability. At the 2016 G20 Summit in Hangzhou, the GPFI (Global Partnership for Financial Inclusion) officially introduced the concept of "digital financial inclusion" and its advanced principles. This marked the recognized start of financial inclusion development in "the period of digital financial inclusion" in various nations. The use of big data credit assessment and financial technology innovation in the financial sector can effectively reduce the risks associated with the advancement of financial inclusion establishing a robust underpinning for the sustainable growth of financial inclusion [1]. Subsequently, the 26th APEC (Asia-Pacific Economic Cooperation) summit in 2018 introduced the theme "Embracing the Digital Future for Inclusive Opportunities." The rapidly evolving information and communication technology along with the flourishing expansion of digital financial services has created new ways and opportunities to establish an inclusive finance system and promote inclusive growth. These developments provided more people with equal opportunities to integrate into the economic system and promote a more inclusive and sustainable global economy.

Digital financial inclusion is an innovative way to improve financial inclusivity in the technological age. In the digital age, digital financial inclusion represents an innovative approach to enhance financial inclusivity. It combines inclusivity with notable advantages such as convenience and precision and can balance efficiency and fairness in economic development. Simultaneously, it promotes the fundamental tasks of increasing financial services for the economy and raising people's standard of living. This financial service model is crucial for implementing shared development and maintaining long-lasting and sustainable economic growth significantly impacting the promotion of inclusive growth in the Chinese economy [2]. In 2022, the Chinese government set forth the objective of "building a digital China, accelerating the digital growth of the economy, promoting the seamless fusion of the digital and physical economies and establishing globally competitive digital industrial hubs." This indicates the increasing prominence of the digital economy as the primary direction of economic progress in China. The new production factors brought about by the digital economy play a pivotal role in economic development. China has made high-quality progress in the full construction of a socialist modernized country since the report's proposal. It has shifted the focus from a single-dimensional perspective of economic growth to a coordinated development approach that encompasses economic development, income distribution and equitable access to opportunities. This goal reflects the essence and characteristics of stability, balance and fairness in inclusive development.

Academic research on digital financial inclusion and inclusive growth has primarily focused on stimulating economic expansion, reducing income disparities, alleviating financing constraints and improving consumption levels [3-8]. The impact of digital financial inclusion on inclusive growth has been studied and verified by several researchers [9-12]. These studies provide valuable theoretical and methodological support for this paper but they still have several limitations. First, most current research focuses on one or a few sub-dimensions of inclusive growth which may not fully reveal the essence of inclusive growth. Second, it is necessary to consider a structural examination of how digital financial inclusion affects inclusive growth given the widespread focus on its overall impact. Third, there is a need to fill the gap in the relevant research on how innovative factors operate between digital inclusive finance and inclusive growth. The Chinese government also emphasized the significance of enhancing the technology innovation system and expediting the implementation of a plan focused on innovation-driven development. Specifically, they highlight the importance of the mobility of elements that contribute to innovation. In this context, investigating the influence of digital financial inclusion on inclusive growth in the Chinese economy together with the effect of innovative elements is crucial for achieving high-quality economic development in this particular setting.

First, it analyzes how digital financial inclusion influences inclusive growth with a specific focus on interrelationships and development. Furthermore, this study explores the geographical variation in the influence of digital financial inclusion on inclusive growth by categorizing China into three distinct regions. Finally, this study examines how digital financial inclusion affects inclusive growth by analyzing the mechanism of impact through the innovation transmission channel. The objective is to offer both theoretical and empirical evidence for policy development.

2. Literature Review

2.1. Digital Financial Inclusion and Inclusive Growth

Digital financial inclusion assumes a pivotal role in enhancing inclusive growth levels primarily by promoting economic expansion, elevating income and mitigating wealth disparities. Digital financial inclusion promotes various elements of inclusive growth from a macroeconomic perspective. It can facilitate regional high-quality development and support the growth of the real economy [13, 14] thereby improving the industrial framework and modernizing [15]. Furthermore, the economic standards of less developed regions especially those in rural areas are significantly improved by digital financial inclusion which subsequently decreases the economic disparities between these regions and their more affluent counterparts [16]. Additionally, it substantially enhances the income levels in lower-income regions, helping to alleviate the imbalances in regional development [17]. Digital financial inclusion represents convenience, accessibility and inclusion from a microeconomic perspective. Research has uncovered that it stimulates entrepreneurial intentions and initiatives among low-income and rural populations [18, 19]. Moreover, it serves as a driving force behind increased innovation in enterprises ultimately boosting total factor productivity [20-22]. The advancement of digital inclusive finance

substantially enhances consumption within middle- and lower-income households [5] consequently reducing disparities between these income groups and their higher-income counterparts.

According to the perspective of transmission mechanisms, digital financial inclusion primarily exerts an indirect influence on inclusive growth through three key avenues. First, digital financial inclusion harnesses digital technologies to mitigate information asymmetry within the traditional financial sector, thereby reducing barriers to financial services and the associated costs by mitigating information constraints and capital mismatches. Consequently, it fosters the participation of middle- and low-income individuals in financial markets to obtain financial benefits while improving the level of human capital and technology, ultimately achieving wealth accumulation and narrowing the income gap [17]. Second, digital financial inclusion can encourage enterprises to participate in research and development as well as innovation endeavors through the increasing activities of innovation and entrepreneurship [13, 20] that enhance the entrepreneurial drive of both established businesses and aspiring entrepreneurs [23, 24]. Research demonstrates that the advancement of digital financial services might help ease financial limitations for small and medium-sized enterprises (SMEs) as well as low-income households particularly when these constraints are more pronounced [4, 25]. The alleviation of these constraints significantly increases the willingness to innovate and engage in entrepreneurship [26]. Digital financial inclusion drives high-quality economic development by influencing the willingness to innovate, increasing entrepreneurial activities and improving the total factor productivity of the entire society [27]. Third, through the improvement of human capital quality, people who live in economically weak regions and those with low incomes are more likely to invest in education as a result of digital financial inclusion. Furthermore, residents can enhance their financial literacy, improve their abilities to access and effectively use financial resources for investments and credit during the implementation of digital financial inclusion. As a result, this alleviates financial constraints on residents, thereby maximizing the impact of digital financial inclusion in reducing income disparities [28].

Inclusive growth is a concept aimed at achieving economic growth and narrowing income inequality emphasizing equality of opportunity throughout the economic process. It involves three key dimensions: economic growth, income distribution and opportunity equality. Digital financial inclusion, using digital technologies to lower the expenses of inclusive financial services, expand their reach and innovate service delivery, exerts a positive influence on these aspects. Moreover, the different regions in China exhibit developmental disparities. Thus, the following hypotheses are put forth by this study:

Hypothesis 1: Digital financial inclusion has a positive impact on overall inclusive growth in China.

Hypothesis 2: Digital financial inclusion has a positive impact on the three regions of China (eastern, central, and western) individually.

Hypothesis 3: The three dimensions of digital financial inclusion (coverage breadth, usage depth and digital level) each have a positive impact on the three regions of China (eastern, central and western) individually.

2.2. Digital Financial Inclusion and Innovation

SMEs are engaged in innovative activities and the establishment of new tech businesses primarily relies on two financing channels: equity financing and bond financing which are constrained by entry barriers and market limitations. Financial institutions have undergone favorable changes in providing financing to businesses involved in technology-based entrepreneurship and innovation, including an increase in the availability of credit funds and a decrease in the cost of capital supply with the evolution of digital technologies. Digital financial inclusion can lower the financial barriers, enhance accessibility and convenience, thereby addressing the credit needs of SMEs engaged in innovative technology ventures and lower-income residents. This promotes fairness in access to credit opportunities for enterprises and residents. Meanwhile, the digital economy helps reduce expenses related to searching, duplicating, transporting and verifying which enhances the vibrancy of retail markets and offers enterprises the opportunity to enter global supply chains. Digital payment methods also play a pivotal role in eliminating geographical constraints and expanding the market reach for goods and services. This results in significant commercial opportunities and provides a potential foundation for the emergence of innovative companies. In addition, small and micro-enterprises can secure their wealth appreciation by using internet-based insurance and wealth management products. Consequently, this stimulates the advancement of innovation and entrepreneurial endeavors. This means that the advancement of digital financial inclusion significantly promotes the enhancement of innovation levels. In a nutshell, the advancement of digital financial inclusion instills confidence among individuals and small businesses that were hitherto marginalized from the financial system. This motivates their participation in innovation activities leading to increased employment opportunities, reduced income inequality and fostering the growth of the economy.

As a result, the level of inclusive growth has also been improved through the transmission channel of innovation, which has occurred concurrently with the development of digital financial inclusion. Thus, the following hypotheses are put forth by this study:

Hypothesis 4: Digital financial inclusion can enhance the level of innovation.

Hypothesis 5: Innovation can increase the level of inclusive growth.

Hypothesis 6: Digital financial inclusion can promote inclusive growth by enhancing innovation levels.

3. Research Methods and Design

This study provides a detailed overview of the research background and outlines in chapter 1. A comprehensive review of pertinent literature and foundational theories is included in chapter 2 as well. This review establishes the hypotheses for

this study along with the exposition of foundational theories. This section will provide details about the selection of indicators and measurement methods expanding upon this groundwork.

The research framework and foundation have been constructed in preparation for the future investigation of the impact of digital financial inclusion on inclusive growth and the consequences of the innovation transmission channel.

3.1. Variables and Data

3.1.1. Dependent Variable: Inclusive Growth

This research has followed four principles taking into consideration the core concept of inclusive growth and the actual provincial development context in China: comprehensiveness, representativeness, scientific validity and operational feasibility. To measure inclusive growth in China, this study has constructed a comprehensive indicator system, as shown in Table 1 based primarily on the first three dimensions (economic growth, income inequality and opportunity equality) from the research results of Zhou and Wu [29].

Table 1.
Inclusive growth indicator system in China.

Dimensions	Classification	Index	Property
Economic growth	Economic output	GDP (Gross domestic product) per capita	+
		Proportion of secondary industry	-
		Proportion of tertiary industry	+
		Proportion of fiscal revenue	+
Income distribution	Income level	Net income of rural residents	+
		Per capita disposable income of urban residents	+
		urban-rural income ratio	-
Fair opportunity	Job opportunity	Employment rate in secondary and tertiary industries	+
		Registered urban unemployment rate	-
	Educational opportunities	Educational resources per 10,000 people	+
		Educational funding intensity	+
	Medical opportunities	Number of health technicians per 10,000 people	+
		Number of beds in medical and health institutions per 10,000 population	+
	Social security opportunities	Proportion of basic pension fund expenditures	+
		Proportion of basic medical insurance fund expenditure	+
	Infrastructure supply	Number of buses per 10,000 people	+
		Park green space per capita	+

Note: The employment rates in the secondary and tertiary industries are calculated as the number of employed individuals in the secondary and tertiary industries divided by the total number of employed individuals in the three major industries. The educational resources per ten thousand people are calculated as the total number of primary, junior high, senior high, higher education schools and special education schools divided by the total regional population.

"+" represents a positive indicator, while "-" represents a negative indicator.

Sources: Zhou and Wu [29].

The object of this study is to use the fixed base extreme value entropy weighting method to assess the degree of inclusive growth. Since the concept of inclusive growth was formally put forward in 2005, data was collected from 2005 to 2021 from 31 Chinese provinces (based on the data availability, excluding the Hong Kong, Macau and Taiwan regions) to show the complete development process of inclusive growth in China. Macroeconomic data spanning 17 years was collected from the National Bureau of Statistics for these provincial regions leading to an assessment of China's provincial-level inclusive growth (see Table 2).

Table 2.
Inclusive growth levels of various provinces in China from 2005 to 2021.

Area	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	Mean	Rank
Beijing	1.700	1.670	1.661	1.608	1.564	1.566	1.430	1.387	1.333	1.302	1.241	1.148	1.145	1.053	1.029	1.014	0.904	1.338	1
Shanghai	1.806	1.754	1.722	1.647	1.580	1.524	1.447	1.288	1.228	1.187	1.134	1.070	1.053	0.978	0.971	0.926	0.876	1.305	2
Liaoning	1.521	1.504	1.475	1.377	1.261	1.265	1.190	1.088	1.014	0.942	0.860	0.803	0.723	0.701	0.610	0.592	0.590	1.030	3
Tianjin	1.364	1.330	1.316	1.306	1.240	1.239	1.117	1.055	1.012	0.956	0.910	0.849	0.818	0.772	0.718	0.716	0.679	1.023	4
Zhejiang	1.540	1.511	1.469	1.404	1.308	1.229	1.115	1.029	0.956	0.887	0.796	0.748	0.718	0.681	0.622	0.618	0.606	1.014	5
Heilongjiang	1.680	1.629	1.591	1.403	1.309	1.285	1.224	1.037	0.933	0.852	0.778	0.729	0.645	0.614	0.489	0.478	0.497	1.010	6
Jiangsu	1.446	1.410	1.369	1.338	1.210	1.115	1.039	0.984	0.930	0.866	0.773	0.708	0.674	0.654	0.576	0.550	0.553	0.953	7
Shandong	1.413	1.381	1.336	1.293	1.200	1.125	1.052	0.989	0.917	0.847	0.743	0.668	0.603	0.604	0.508	0.500	0.491	0.922	8
Sichuan	1.420	1.416	1.352	1.286	1.203	1.259	1.061	0.974	0.903	0.819	0.719	0.647	0.597	0.559	0.473	0.451	0.462	0.918	9
Guangdong	1.375	1.353	1.339	1.250	1.150	1.061	0.982	0.930	0.888	0.840	0.759	0.686	0.650	0.617	0.556	0.542	0.549	0.913	10
Xinjiang	1.181	1.188	1.192	1.116	1.109	1.233	0.980	0.883	0.831	0.774	0.719	0.661	0.615	0.592	0.527	0.510	0.533	0.861	11
Jilin	1.337	1.257	1.285	1.115	0.998	0.993	0.952	0.861	0.823	0.773	0.715	0.661	0.611	0.609	0.522	0.517	0.526	0.856	12
Qinghai	1.162	1.172	1.247	1.038	1.003	1.057	0.939	0.887	0.817	0.792	0.733	0.677	0.643	0.617	0.558	0.567	0.557	0.851	13
Hebei	1.232	1.233	1.282	1.194	1.050	1.009	0.909	0.830	0.783	0.723	0.641	0.593	0.544	0.539	0.456	0.456	0.456	0.819	14
Hainan	1.073	1.053	1.052	1.007	0.946	0.894	0.877	0.836	0.811	0.787	0.747	0.688	0.610	0.574	0.509	0.490	0.498	0.791	15
Hubei	1.197	1.166	1.160	1.108	1.054	0.935	0.889	0.822	0.759	0.681	0.606	0.566	0.542	0.550	0.474	0.473	0.463	0.791	16
Hunan	1.218	1.214	1.175	1.139	1.033	0.923	0.851	0.792	0.726	0.663	0.593	0.557	0.529	0.519	0.457	0.465	0.472	0.784	17
Shanxi	1.120	1.157	1.138	1.080	1.040	0.974	0.921	0.809	0.755	0.663	0.585	0.562	0.553	0.545	0.458	0.464	0.479	0.783	18
Henan	1.275	1.248	1.207	1.168	1.050	0.909	0.858	0.806	0.753	0.685	0.593	0.530	0.490	0.478	0.394	0.391	0.410	0.779	19
InnerMongolia	1.147	1.168	1.145	1.069	0.950	0.914	0.868	0.817	0.767	0.705	0.654	0.591	0.546	0.523	0.455	0.435	0.433	0.776	20
Chongqing	1.102	1.073	1.073	1.038	1.060	0.928	0.900	0.836	0.812	0.742	0.668	0.605	0.550	0.509	0.439	0.429	0.404	0.775	21
Ningxia	1.017	1.034	1.025	0.976	0.977	1.002	0.917	0.839	0.782	0.706	0.631	0.584	0.540	0.527	0.459	0.448	0.438	0.759	22
Tibet	1.111	1.091	1.118	1.052	1.018	0.873	0.795	0.731	0.668	0.650	0.616	0.579	0.531	0.489	0.465	0.451	0.433	0.745	23
Gansu	1.106	1.112	1.082	1.000	0.933	0.859	0.841	0.746	0.706	0.639	0.566	0.529	0.510	0.494	0.397	0.394	0.425	0.726	24

The inclusive growth levels of 31 Chinese provinces have shown a gradual increase with significant regional disparities in both levels and growth rates. In particular, the eastern region exhibits a relatively higher growth level whereas the other two regions fall behind the eastern region in terms of growth levels.

Table 3.
Descriptive statistics of inclusive growth index growth rate by region.

Region	2005 mean	2021 mean	Annual average growth rate	Top 5 provinces (municipalities) with the highest annual average growth rates
Eastern region	0.608	1.406	0.055	Shandong, Hebei, Jiangsu, Liaoning and Zhejiang
Central region	0.458	1.252	0.065	Heilongjiang, Henan, Anhui, Jiangxi and Hubei
Western region	0.440	1.119	0.060	Sichuan, Guangxi, Chongqing, Guizhou and Inner Mongolia

There are significant variations in the level of development between the eastern and other areas when considering the top 10 provinces for inclusive growth. Eight provinces are in the eastern regions and one is in each of the other two regions. According to Table 3, the average annual growth rates in the eastern, central and western regions from 2005 to 2021 were 0.055, 0.065 and 0.060 respectively. The growth rate in the central region was the highest followed by the west and the slowest growth was in the east. However, the trend still aligns with the general pattern of regional development in China characterized by an increase from west to east due to the better economic foundation in the east and the weaker foundation in the central and west. It is necessary to declare that due to the temporal constraints associated with the independent variable of digital financial inclusion, the temporal scope of the inclusive growth index used in the benchmark regression analysis only covers the period from 2011 to 2021.

3.1.2. Other Variables

(1) Core independent variable: This study uses the "Peking University Digital Financial Inclusion Index," compiled by the Peking University Internet Finance Research Center and offers the overall data on digital inclusive finance of 31 provinces in China from 2011 to 2021. It also includes information on three sub-dimensions: coverage breadth, usage depth and digital level.

(2) Mediating Variable: Innovation plays a role as the mediating variable in this paper on the transmission channels of digital financial inclusion to inclusive growth. Currently, the main indicator to measure the level of innovation is the logarithm of patent applications. Patent applications are divided into three categories: inventions, utility models and designs. The logarithm of the three patent applications mentioned above is used separately as a mediating variable to measure innovation levels and conduct a robustness test of the innovation mediation effect.

(3) Control Variables: This paper selects five control variables which are traditional financial inclusion, foreign direct investment, price level, fiscal support for agriculture and foreign trade. First, the traditional inclusive financial indicator system is measured using a set of 15 indicators constructed from three dimensions: penetrability, utility and affordability. Secondly, foreign direct investment is quantified by logarithmically transforming the total foreign direct investment for each province. Third, price level is measured using the consumer price index for residents in each province. Fourth, fiscal support for agriculture is measured by the ratio of fiscal expenditures on agricultural support to the total fiscal expenditures in each province. Fifth, foreign trade is measured by the ratio of total foreign trade to GDP.

In practice, it cannot be ruled out that inclusive growth may promote the digital inclusive finance of China. This paper employs first-order lagged terms of the independent variables and the control variables during regression analysis to address the potential issue of reverse causality [4]. The statistical characteristics of the variables are displayed in Table 4.

Table 4.
Statistical characteristics of variables.

Symbol	Variable	Obs.	Mean	Std.	Min.	Max.
IG	Inclusive growth overall index	310	1.042	0.252	0.617	1.806
IG ⁽¹⁾	Inclusive growth economic growth sub-dimension index	310	0.207	0.083	0.101	0.557
IG ⁽²⁾	Inclusive growth income distribution sub-dimension index	310	0.226	0.090	0.092	0.582
IG ⁽³⁾	Inclusive growth opportunity equity sub-dimension index	310	0.609	0.156	0.292	1.257
DIFI	Digital inclusive financial index	310	216.235	97.030	16.220	431.928
DIFI ⁽¹⁾	Digital inclusive financial coverage breadth index	310	196.670	96.556	1.960	397.002
DIFI ⁽²⁾	Digital inclusive financial usage depth index	310	211.121	98.187	6.760	488.683
DIFI ⁽³⁾	Digital inclusive financial digital support service index	310	290.142	117.252	7.580	462.228
Inn	Logarithm of patent applications	310	10.573	1.590	5.136	13.782
Inn ⁽¹⁾	Logarithm of invention patent applications	310	9.429	1.587	4.394	12.285
Inn ⁽²⁾	Logarithm of utility model patent applications	310	9.839	1.621	3.714	13.100
Inn ⁽³⁾	Logarithm of design patent applications	310	8.641	1.709	3.332	12.547
IFI	Traditional financial inclusion index	310	0.133	0.118	0.039	0.614
FDI	Logarithm of total foreign direct investment	310	12.678	1.808	6.100	15.090
CPI	Consumer price index	310	102.512	1.172	100.567	106.338
FA	Financial support to agriculture ratio	310	11.311	3.403	4.110	20.380
Trade	Proportion of foreign trade	310	4.155	4.488	0.111	22.663

3.2. Econometric Model

This article theoretically analyzes the influence of digital inclusive finance on the country’s inclusive growth in chapter 2 as well as its effect on the three sub-dimensions of inclusive growth: economic growth, income distribution and opportunity equality and proposes the corresponding research framework diagram shown below (see Figure 1).

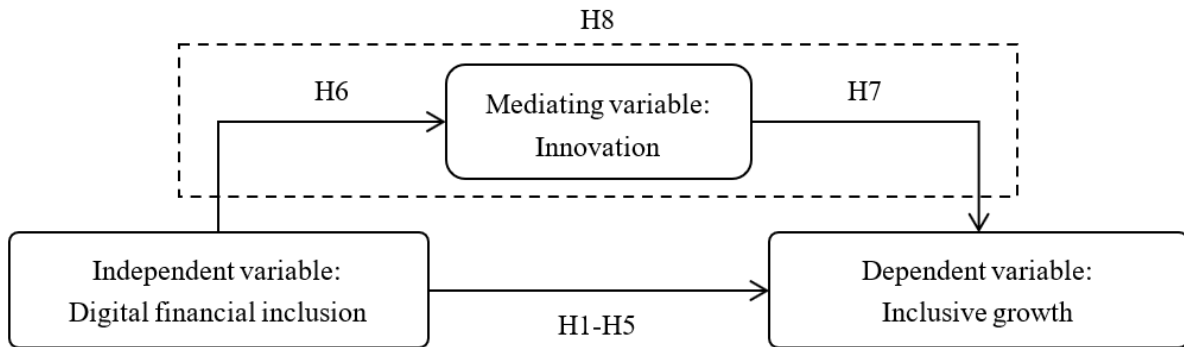


Figure 1. Research framework diagram.

3.2.1. Baseline Regression: Digital Financial Inclusion and Inclusive Growth

This paper will employ the individual fixed-effects method to explain the overall impacts of digital financial inclusion and its three dimensions on inclusive growth in China in order to avoid neglecting the impact of other provincial characteristic variables on the regression results. Therefore, this paper constructs the following benchmark econometric model:

$$IG_{i,t} = \beta_1 + \beta_2 DIFI_{i,t-1} + \beta_3 IFI_{i,t-1} + \beta_4 FDI_{i,t-1} + \beta_5 CPI_{i,t-1} + \beta_6 FA_{i,t-1} + \beta_7 TRADE_{i,t-1} + \mu_i + \varepsilon_{i,t} \tag{1}$$

Where i represents the i -th research subject (i.e., province), t represents the year, μ_i is the unobservable regional effect, $\varepsilon_{i,t}$ is the random disturbance term, and β_2 measures the impact of digital financial inclusion and its three dimensions on inclusive growth in China.

3.2.2. Transmission Mechanism: Digital Financial Inclusion and Innovation

The mediation effect model constructed in the baseline regression model is shown below to test how the transmission mechanism of digital financial inclusion promotes inclusive growth through enhancing innovation:

$$IG_{i,t} = \beta_1 + \beta_2 DIFI_{i,t-1} + \beta_3 IFI_{i,t-1} + \beta_4 FDI_{i,t-1} + \beta_5 CPI_{i,t-1} + \beta_6 FA_{i,t-1} + \beta_7 TRADE_{i,t-1} + \mu_i + \varepsilon_{i,t} \tag{2}$$

$$Inn_{i,t} = \delta_1 + \delta_2 DIFI_{i,t-1} + \delta_3 IFI_{i,t-1} + \delta_4 FDI_{i,t-1} + \delta_5 CPI_{i,t-1} + \delta_6 FA_{i,t-1} + \delta_7 TRADE_{i,t-1} + \mu_i + \varepsilon_{i,t} \tag{3}$$

$$IG_{i,t} = \alpha_1 + \alpha_2 DIFI_{i,t-1} + \alpha_3 Inn_{i,t-1} + \alpha_4 IFI_{i,t-1} + \alpha_5 FDI_{i,t-1} + \alpha_6 CPI_{i,t-1} + \alpha_7 FA_{i,t-1} + \alpha_8 TRADE_{i,t-1} + \mu_i + \varepsilon_{i,t} \tag{4}$$

Where β , δ and α are the estimated coefficients. Model 2 reflects the overall impact of China's digital financial inclusion on inclusive growth, with β_2 representing the degree of influence. Model 3 reflects the influence of digital inclusive finance on the mediating variable innovation with δ_2 representing the degree of influence. Model 4 reflects the combined impact of China's digital financial inclusion and the intermediate variable innovation on overall inclusive growth, with α_2 and α_3 representing the degrees of influence.

4. Analysis of Research Results

This chapter will proceed according to the following three steps: First, while controlling for other variables, evaluate the overall impact of digital financial inclusion on inclusive growth. The dependent variables are the inclusive growth composite index and its three sub-dimension indices and the independent variable is the Peking University Digital Financial Inclusion composite index. Additionally, it examines the effects of the three dimensions of digital financial inclusion on inclusive growth in terms of economic growth, income distribution and opportunity equality. Second, using the sub-indices of inclusive growth in three regions (east, central and west) as dependent variables and the Peking University Digital Financial Inclusion composite index and its three-dimension indices as independent variables while controlling for other variables examine the effects of digital financial inclusion on inclusive growth in these three regions. Third, using the inclusive growth composite index and three sub-dimension indices as dependent variables, the Peking University Digital Financial Inclusion composite index as the independent variable and introducing innovation as a mediator variable, examine whether digital inclusive finance affects inclusive growth through this channel and the extent of its impact.

4.1. Effect Models

4.1.1. Baseline Regression Results

The composite index of digital financial inclusion positively impacts the inclusive growth composite index and its three sub-dimension indices and the results of regression are all significant at the 1% level (see Table 5). This indicates that

the advancement of digital financial inclusion contributes to elevating the degree of inclusive growth across various Chinese provinces. In significance, a 1-unit rise in the digital financial inclusion composite index corresponds to a 0.0019-unit increase in the inclusive growth composite index. The economic growth index, income distribution index and opportunity equality index are 0.0003, 0.0006 and 0.0011 units respectively. The results demonstrate that digital financial inclusion promotes inclusive growth in its three dimensions. Particularly, it has a significant impact on the opportunity equality dimension, effectively supporting equal participation of all social strata in social and economic development. As a result, it confirms the validity of hypothesis 1 in the impact effect model.

Table 5.
Impact effect model of digital financial inclusion on inclusive growth.

Symbol	IG	IG ⁽¹⁾	IG ⁽²⁾	IG ⁽³⁾
	(1)	(2)	(3)	(4)
$DIFI_{i,t-1}$	0.0019*** (37.82)	0.0003*** (18.68)	0.0006*** (36.28)	0.0011*** (21.80)
$IFI_{i,t-1}$	0.6119*** (4.05)	0.0723* (1.75)	0.0552 (1.22)	0.4845*** (3.21)
$FDI_{i,t-1}$	-0.0112 (-1.55)	0.0056*** (2.84)	-0.0001 (-0.06)	-0.0167** (-2.31)
$CPI_{i,t-1}$	0.0113*** (3.29)	0.0049*** (5.16)	0.0129*** (12.51)	-0.0065* (-1.87)
$FA_{i,t-1}$	-0.0004 (-0.13)	-0.0033*** (-4.20)	-0.0007 (-0.84)	0.0037 (1.27)
$TRADE_{i,t-1}$	-0.0005 (-0.18)	-0.0079*** (-10.64)	-0.0087*** (-10.69)	0.0161*** (5.92)
Constant	-0.4642 (-1.20)	-0.3565*** (-3.38)	-1.1778*** (-10.19)	1.0701*** (2.77)
N	310	310	310	310
R ²	0.9142	0.7963	0.9176	0.7748

Note: ***, **, * represent significance levels at 1%, 5% and 10% respectively and the values in parentheses are t-values.

4.1.2. Robustness Checks

This study performed two additional robustness checks using the baseline regression model to further confirm the reliability of the research results (see Table 6).

(1) Calculating the inclusive growth composite index using a simple average weighting method. The columns 1, 3, 5 and 7 in Table 6 present the results of the robustness tests for the effects of the digital financial inclusion composite index on the recalculated inclusive growth composite index and its three sub-dimensions: economic growth, income distribution and opportunity equality respectively. In terms of significance, the digital financial inclusion composite index remains significant at the 1% level for the inclusive growth composite index and its three sub-dimension indices indicate that the robustness test is passed.

(2) Eliminate the four provinces with the highest inclusive growth levels (Beijing, Shanghai, Liaoning, and Tianjin). The columns 2, 4, 6 and 8 of Table 6 display the results of the robustness test regarding the influence of the digital financial inclusion composite index on the inclusive growth composite index and its three sub-dimensions following the exclusion of certain data. In terms of significance, the composite index of digital financial inclusion remains significant at the 1% level for the inclusive growth composite index and its three sub-dimension indices indicate that the robustness test is passed.

Table 6.
Robustness test for the impact effects model.

Symbol	IG		IG ⁽¹⁾		IG ⁽²⁾		IG ⁽³⁾	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$DIFI_{i,t-1}$	0.0019*** (59.43)	0.0019*** (34.95)	0.0010*** (30.18)	0.0003*** (21.42)	0.0045*** (48.72)	0.0006*** (40.79)	0.0014*** (30.47)	0.0011*** (20.29)
$IFI_{i,t-1}$	0.4003*** (4.30)	0.6441*** (4.05)	0.1868* (1.95)	0.1359*** (3.68)	0.0011 (0.00)	0.1188*** (2.93)	0.6055*** (4.33)	0.3894** (2.54)
$FDI_{i,t-1}$	-0.0028 (-0.63)	-0.0067 (-0.80)	0.0204*** (4.44)	0.0035* (1.80)	0.0019 (0.15)	-0.0029 (-1.35)	-0.0135** (-2.01)	-0.0073 (-0.91)
$CPI_{i,t-1}$	0.0166*** (7.84)	0.0107*** (2.98)	0.0044** (2.03)	0.0040*** (4.77)	0.0616*** (9.89)	0.0115*** (12.58)	0.0081** (2.53)	-0.0048 (-1.39)
$FA_{i,t-1}$	0.0037** (2.05)	0.0004 (0.13)	-0.0094*** (-5.08)	-0.0041*** (-5.97)	-0.0064 (-1.22)	-0.0019** (-2.44)	0.0119*** (4.43)	0.0064** (2.22)
$TRADE_{i,t-1}$	-0.0052*** (-3.11)	-0.0077* (-1.77)	-0.0133*** (-7.71)	-0.0050*** (-4.95)	0.0574*** (-11.69)	-0.0055*** (-4.99)	0.0137*** (5.44)	0.0028 (0.68)
Constant	-1.0795*** (-4.54)	-0.4715 (-1.17)	0.0050 (0.02)	-0.2716*** (-2.90)	-5.1241*** (-7.35)	-1.0276*** (-9.97)	-0.2999 (-0.84)	0.8277** (2.13)
N	310	270	310	270	310	270	310	270
R ²	0.9647	0.9146	0.8959	0.8001	0.9551	0.9295	0.8628	0.8027

Note: ***, **, * represent significance levels at 1%, 5%, 10% respectively, and the values in parentheses are t-values.

4.2. Regional Heterogeneity

Panels A, B, C and D in Table 7 reflect the digital financial inclusion composite index and the indexes of its three sub-dimensions: coverage breadth, usage depth and digital level. In each panel, the dependent variables are divided into three groups representing the inclusiveness growth levels in the regions of east, central and west. All four sets of independent factors have a positive effect on inclusiveness growth levels in various regions and they are all significant at the 1% level based on the results of regional-level tests. This means that improving the level of digital financial inclusion, whether at the composite index level or at the dimension index level can promote inclusive growth in the respective regions.

In addition, through the examination of the central region in column 2 of Table 7, it can be found that: With each 1-unit increase in the digital financial inclusion composite index, the inclusive growth composite index experiences a growth of 0.0021 units, for every 1 unit increase in the coverage breadth index, the inclusive growth composite index increases by 0.0003 units, a 1-unit increase in the usage depth index corresponds to a 0.0005 unit increase in the inclusive growth composite index; and a 1-unit increase in the digital level index leads to a 0.0013 unit increase in the inclusive growth composite index. The marginal effects in the central region are clearly larger than those in the eastern and western regions when one compares the four panels of the central region with those of the two other regions. This implies that the progress of digital financial inclusion has a more pronounced promoting effect on the inclusiveness growth level in the central region compared to the other two regions. This phenomenon may be attributed to the relatively weaker foundation in the central region, resulting in a more pronounced catch-up effect. As a result, it confirms the validity of hypothesis 3 in the impact effect model.

Table 7.
Heterogeneous impact of digital financial inclusion on inclusive growth: differences between regions.

Panel	Symbol	IG-East	IG-Central	IG-West
		(1)	(2)	(3)
Panel A	$DIFI_{i,t-1}$	0.0018*** (16.27)	0.0021*** (23.12)	0.0017*** (23.56)
	$IFI_{i,t-1}$	0.2505 (0.76)	0.3303 (0.89)	0.7477*** (4.72)
	$FDI_{i,t-1}$	-0.0082(-0.62)	-0.0472*** (-2.73)	-0.0064 (-0.73)
	$CPI_{i,t-1}$	0.0149** (2.25)	0.0122* (1.73)	0.0022 (0.51)
	$FA_{i,t-1}$	-0.0155** (-2.02)	0.0043 (0.61)	-0.0024 (-0.71)
	$TRADE_{i,t-1}$	-0.0019 (-0.48)	-0.0499** (-2.43)	-0.0116* (-1.67)
	<i>Constant</i>	-0.5559 (-0.72)	-0.0471 (-0.06)	0.4008 (0.86)
	R^2	0.9254	0.9384	0.9311
Panel B	$DIFI_{i,t-1}^{(1)}$	0.0003*** (7.27)	0.0003*** (16.40)	0.0002*** (11.72)
	$IFI_{i,t-1}$	-0.2015* (-1.88)	0.2855*** (3.75)	0.1373*** (3.32)
	$FDI_{i,t-1}$	0.0095** (2.20)	-0.0056 (-1.58)	0.0029 (1.24)
	$CPI_{i,t-1}$	0.0080*** (3.71)	0.0008 (0.56)	0.0036*** (3.22)
	$FA_{i,t-1}$	-0.0030 (-1.22)	0.0004 (0.25)	-0.0019** (-2.10)
	$TRADE_{i,t-1}$	-0.0088*** (-6.88)	0.0087** (2.05)	0.0004 (0.22)
	<i>Constant</i>	-0.6057** (-2.41)	0.0417 (0.24)	-0.2642** (-2.17)
	R^2	0.8650	0.8508	0.6637
Panel C	$DIFI_{i,t-1}^{(2)}$	0.0006*** (12.25)	0.0005*** (26.39)	0.0005*** (30.37)
	$IFI_{i,t-1}$	-0.1535 (-1.13)	0.1664** (2.07)	0.0796** (2.04)
	$FDI_{i,t-1}$	0.0055 (1.01)	0.0035 (0.93)	-0.0027 (-1.25)
	$CPI_{i,t-1}$	0.0197*** (7.27)	0.0108*** (7.08)	0.0099*** (9.34)
	$FA_{i,t-1}$	-0.0000 (-0.01)	-0.0002 (-0.16)	-0.0001 (-0.11)
	$TRADE_{i,t-1}$	-0.0096*** (-5.90)	-0.0017 (-0.38)	-0.0083*** (-4.78)
	<i>Constant</i>	-1.8348*** (-5.77)	-1.0729*** (-5.93)	-0.9111*** (-7.90)
	R^2	0.9090	0.9414	0.9520
Panel D	$DIFI_{i,t-1}^{(3)}$	0.0010*** (9.20)	0.0013*** (14.53)	0.0009*** (12.81)
	$IFI_{i,t-1}$	0.6055* (1.89)	-0.1216 (-0.34)	0.5309*** (3.31)
	$FDI_{i,t-1}$	-0.0231* (-1.81)	-0.0450*** (-2.70)	-0.0066 (-0.74)
	$CPI_{i,t-1}$	-0.0128** (-2.01)	0.0005 (0.08)	-0.0113** (-2.60)
	$FA_{i,t-1}$	-0.0124* (-1.67)	0.0042 (0.61)	-0.0005 (-0.13)
	$TRADE_{i,t-1}$	0.0165*** (4.32)	-0.0568*** (-2.86)	-0.0038 (-0.54)
	<i>Constant</i>	1.8845** (2.51)	0.9841 (1.22)	1.5761*** (3.33)
	R^2	0.7336	0.8798	0.8337
	<i>N</i>	110	80	120

Note: ***, **, * represent significance levels at 1%, 5% and 10% respectively, and the values in parentheses are t-values.

4.3. The Transmission Mechanism Model

4.3.1. Baseline Regression Results

The specific indicator for the innovation mediation variable in this study was patent applications rather than issued patents. The reason for this choice is that the approval process for patent grants in China typically takes a relatively long time, usually requiring a waiting period of 6-18 months. On the other hand, the number of patent applications can more accurately reflect the current level of innovation activity.

Table 8 presents the outcomes of the mediation effect examination. Columns 1 and 2 show that digital financial inclusion has a positive impact on inclusive growth at the 1% significance level as well as on innovation. It indicates that the development of digital inclusive finance helps promote inclusive growth and innovation. The results in the third column present that digital financial inclusion have a positive impact on inclusive growth at a 1% significance level while innovation exerts an adverse effect of the inclusive growth at a 10% significance level. This suggests that innovation serves as a mediator and digital financial inclusion influences inclusive growth through this pathway.

Additionally, Table 7 shows that when the patent applications from the previous year are included as a mediation variable, the coefficient for the impact of digital financial inclusion on inclusive growth changes from 0.0019 in column 1 to 0.0021 in column 3 remaining significant at the 1% level. Meanwhile, the coefficient for the mediation effect of innovation on inclusive growth changed from 0.0053 to -0.0269. This indicates that the innovation mediation channel has a partial mediation effect, which confirms the validity of hypothesis 4 in the innovation mediation effect model hold.

Table 8.
The mediation effect of innovation in the transmission mechanism of digital financial inclusion on inclusive growth.

Symbol	IG	$Inn_{i,t-1}$	IG
	(1)	(2)	(3)
$DIFI_{i,t-1}$	0.0019*** (42.22)	0.0053*** (22.68)	0.0021*** (23.99)
$Inn_{i,t-1}$	/	/	-0.0269* (-1.91)
$IFI_{i,t-1}$	0.6119*** (4.12)	1.8024*** (2.73)	0.6605*** (4.59)
$FDI_{i,t-1}$	-0.0112 (-1.14)	0.0053*** (0.14)	-0.0111 (-1.16)
$CPI_{i,t-1}$	0.0113*** (3.01)	0.0013 (0.08)	0.0113*** (3.05)
$FA_{i,t-1}$	-0.0004 (-0.11)	0.0267 (1.59)	0.0003 (0.10)
$TRADE_{i,t-1}$	-0.0005 (-0.18)	0.0274** (2.28)	0.0002 (0.08)
Constant	-0.1993 (-0.48)	8.7995*** (4.39)	0.0378 (0.09)
N	310	310	310
R ²	0.9584	0.9783	0.9590

Note: ***, **, * represent significance levels at 1%, 5% and 10% respectively and the values in parentheses are t-values.

4.3.2. Robustness Checks

In the previous section of benchmark regression, it was found that using the logarithm of the patent applications as the innovation mediation variable led to a negative effect on inclusive growth which contradicts the theoretical analysis. In this section, we will conduct a robustness test to examine the reasons behind this discrepancy. Since patent applications consist of three categories: invention patents, utility model patents and design patents. The applicants for each type of patent are different which makes the characteristics and beneficiary groups of innovation reflected in each type of patent application different.

This paper uses the logarithm of invention patent applications, utility model patent applications and design patent applications separately as proxies to measure the level of innovation analyze their effects to test the robustness of the innovation mediation effect (see Table 9).

The results presented in Table 9 are the regressions of the three patent applications explained above as measures of innovation level in China. The first column indicates a substantial positive influence of digital financial inclusion on inclusive growth at the 1% significance level. In columns 2 to 4, digital financial inclusion has a marked positive impact on the innovation level at the 1% significance level indicating that the development of digital financial inclusion contributes to a higher level of innovation.

Columns 5 to 7 demonstrate that digital inclusive finance positively impacts inclusive growth at the 1% significance level. Additionally, invention patents have a beneficial effect on inclusive growth at the 10% significance level whereas utility model and design patents show a negative effect at the 5% significance level. These results demonstrate the robustness of the innovation mediation mechanism model, indicating the presence of partial mediation effects on inclusive growth.

Therefore, it confirms the validity of hypotheses 5 and 6 in the innovation mediation mechanism model especially the transmission channel of the invention patent.

Table 9.
Robustness test of the innovation mediation mechanism model.

Symbol	IG	Inn _{i,t-1}			IG		
		Inn ⁽¹⁾	Inn ⁽²⁾	Inn ⁽³⁾	Inn ⁽¹⁾	Inn ⁽²⁾	Inn ⁽³⁾
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$DIFI_{i,t-1}$	0.0019*** (42.22)	0.0044*** (17.61)	0.0069*** (27.31)	0.0023*** (5.88)	0.0018*** (28.49)	0.0021*** (21.77)	0.0020*** (38.47)
$Inn_{i,t-1}$	/	/	/	/	0.0194* (1.79)	-0.0244** (-1.96)	-0.0184** (-2.01)
$IFI_{i,t-1}$	0.6119*** (4.12)	1.9294*** (3.01)	1.9443** (2.51)	0.8799 (0.91)	0.5745*** (3.78)	0.6594*** (4.65)	0.6281*** (4.25)
$FDI_{i,t-1}$	-0.0112 (-1.14)	0.0562 (1.42)	-0.0514 (-1.05)	0.0918* (1.78)	-0.0123 (-1.23)	-0.0125 (-1.30)	-0.0095 (-0.98)
$CPI_{i,t-1}$	0.0113*** (3.01)	-0.0815*** (-4.26)	0.0568*** (3.03)	0.0124 (0.43)	0.0129*** (3.24)	0.0127*** (3.33)	0.0115*** (3.11)
$FA_{i,t-1}$	-0.0004 (-0.11)	-0.0108 (-0.78)	0.0448** (2.15)	0.0193 (0.68)	-0.0002 (-0.05)	0.0007 (0.20)	-0.0000 (-0.01)
$TRADE_{i,t-1}$	-0.0005 (-0.18)	0.0294** (2.35)	0.0284** (2.00)	-0.0188 (-1.04)	-0.0011 (-0.39)	0.0002 (0.07)	-0.0008 (-0.30)
Constant	-0.1993 (-0.48)	16.0978*** (7.38)	2.4784 (1.09)	6.3110** (1.98)	-0.5113 (-1.09)	-0.1388 (-0.34)	-0.0833 (-0.20)
N	310	310	310	310	310	310	310
R ²	0.9584	0.9768	0.9706	0.9488	0.9587	0.9591	0.9592

Note: ***, **, * represent significance levels at 1%, 5% and 10% respectively, and the values in parentheses are t-values.

Furthermore, it is evident that invention patents as the primary drivers of transforming innovative technological achievements have a more significant effect on promoting the socialization, commercialization and professionalization of technological outcomes when compared with the other types of patent applications according to the results of this research [30].

5. Conclusion and Discussion

5.1. Research Conclusion

The following conclusion can be drawn based on the analysis of empirical results: First, the China inclusive growth index shows an upward trend year by year. Although the central region exhibits the fastest growth, there is still a general trend of increasing from west to east. Second, digital financial inclusion along with its three sub-dimensions, namely economic growth, income distribution and opportunity equality has a positive impact on inclusive growth. Additionally, it is notable that digital financial inclusion has a more substantial effect on equal opportunities signifying its ability to facilitate the equitable participation of various social strata in social and economic development. Third, the development of digital financial inclusion has a more substantial impact on the level of inclusive growth in the central region than in the eastern and western regions. Because of the relatively weaker infrastructure and resources, the central region is better positioned to use capital and total factor productivity effectively, creating more value and experiencing a noticeable catch-up impact. Fourth, in terms of transmission mechanisms, digital financial inclusion elevates inclusive growth levels by enhancing innovation. Invention patents play a pivotal role in transforming technological achievements within the realm of innovation. Digital financial inclusion can effectively foster the enhancement of inclusive growth levels through this channel.

The innovations of this study mainly lie in three aspects. First, the comprehensiveness of the research objects, timeliness of the study and completeness of the indicator system constructions. Second, a specific distinction was made regarding the impact of digital financial inclusion and its three sub-dimensions in the examination of regional heterogeneity. Last but not least, the study selectively identified the transmission channel within the innovation system that is truly conducive to digital financial inclusion in promoting inclusive growth, specifically through the precise enhancement of the number of invention patents in the examination of mediating effects, compared to the general concept of innovation.

5.2. Suggestions

This paper puts forth the following policy recommendations based on the aforementioned research findings:

Firstly, stimulate the new vitality of digital financial inclusion and closely follow the endogenous factors of common prosperity. Local governments should commit to advancing the development of digital inclusive finance by harnessing its potential to drive shared prosperity. On one hand, continuous efforts should be made to strengthen basic network infrastructure support research and funding in technologies, expand application scenarios for digital financial inclusion, and promote the penetration of digital financial inclusion as well. On the other hand, there is a need to deepen reforms in digital inclusive finance, encourage collaboration between financial institutions and tech-innovative enterprises, foster ongoing innovation in financial products and services and narrow the gap in accessibility and availability of digital financial inclusion services across regions.

Secondly, creating a new pattern of innovative element mobility for inclusive prosperity. Establishing a new pattern of innovative element mobility can help to balance income growth among urban and rural residents and ensure equal participation in social and economic development. On one hand, financial capital and advanced technology can be promoted within regions, harnessing the innovative elements to drive income growth and opportunity equality by exploring cross-regional collaboration models centered on technology parks, innovative mobility of factors such as tech talents. On the other hand, to address the digital divide among urban and rural residents and advance shared prosperity, innovative elements should be used to empower modern industrial systems and guide digital technology and infrastructure towards less-developed regions.

Thirdly, create a new scenario of regionally coordinated development for inclusive prosperity. On one hand, it is essential to foster collaboration among the eastern, central and western regions. This collaboration should harness the broad scope of digital financial inclusion and the unrestricted exchange of innovative elements to establish cooperative mechanisms and share implementation experiences that promote shared prosperity. On the other hand, it is essential to explore the integration of digital financial inclusion and innovative elements with constructing a regional coordinated development network, and driving shared prosperity in neighboring cities from existing city clusters.

These policy recommendations are intended to use digital financial inclusion, innovative elements and regional cooperation as the primary drivers of inclusive prosperity in China. Their objective is to ensure that the benefits of economic growth are distributed more equitably among various regions and populations [31].

5.3. Limitations and Prospects

In China, the digital economy is experiencing rapid growth and the pursuit of high-quality economic development has become a central national strategy. The present phase of high-quality economic development is most appropriate for inclusive growth which goes beyond simple economic expansion and considers elements like income distribution and opportunity equality. The emerging financial paradigm of digital financial inclusion, combining digital technology and inclusive financial services is of significant research and practical importance. It is of great research and practical significance to study whether digital financial inclusion can promote inclusive growth and understand the underlying mechanisms between them. The limitations of this study and the potential directions for future research primarily revolve around two key aspects. One is that the inclusive growth indicator system should be further enriched and improved. The other one is that the characterization of innovation level can be further deepened to achieve in-depth research on the impact mechanisms of digital financial inclusion and inclusive growth.

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