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# Digital Financial Inclusion and Inclusive Green Growth: Evidence from China's Green Growth Initiatives

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**Abstract:** The inclusive and environmentally sustainable transformation of economic growth is a crucial indicator for the high-quality development of urban areas. In this perspective, this paper explores the connection between digital inclusive finance and inclusive green growth in 270 Chinese cities from 2011 to 2021. The study used a panel dataset, individual fixed-effects models, and multiple mediation models to analyze the results. The study findings reveal that digital inclusive finance effectively stimulates regional inclusive green growth and enhances positive transmission mainly by improving green technology innovation, increasing entrepreneurship levels, and promoting industrial structure upgrading, of which environmental-friendly technology innovation channels constitute the main contributor. The effects of regions, administrative hierarchy of cities, financial marketization, policy support, and environmental regulation are analyzed in heterogeneity analysis. To ensure the robustness of baseline results, this study utilized two-stage least squares (2-SLS) and difference in difference (DID) approaches. Moreover, this study offers valuable insights into the environmental implications of digital financial inclusion in emerging economies.

**Keywords:** digital inclusive finance; inclusive green growth; sustainable development; heterogeneity analysis; China

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## 1. Introduction

As China, the world's second-largest economy, continues to perform economic miracles, the adverse impacts of sloppy development on the environment and the damage to social equity are often overlooked due to the "halo effect" of rapid economic growth (Q. Wang et al., 2019). China's Gini coefficient has been marked above the recognized international warning line of 0.4 for nearly two decades, and its carbon emissions are the highest in the world. Unequal income distribution, uneven development opportunities, inadequate regional development, and the deterioration and depletion of the environment and resources are major obstacles to China's economy's sustainable development. Traditional forms of growth lack inclusiveness and environmental friendliness, which are the root causes of inequality and environmental pollution (Zhou & Wu, 2018). The idea of inclusive green growth was first proposed in the UN conventional conference in 1992. This concept is dedicated to achieving the sustainable development goals of equality in economic development and green economic benefits. This aims to address social and environmental issues caused by traditional crude economic development. Under the framework of inclusive green growth issues, promoting an "inclusive" and "green" approach to sustainable

economic development has become a key initiative for China to achieve its dual-carbon goals and ensure social harmony and stability (Fan et al., 2023; Ren et al., 2022).

Studies suggest that financial development promotes economic growth (Levine, 2005; Öncel et al., 2024). The development of digital inclusive finance has similar inclusive characteristics as inclusive green growth that focuses our attention in the current study. With the emerging digital technologies of big data and cloud computing, digital inclusive finance has greatly enhanced the accessibility of financial services, effectively alleviated the traditional financial exclusion of low- and middle-income populations, and helped the real economy by providing more accessible financial services. As compared to developed economies, China faces a number of challenges, such as a large number of people living in poverty and unequal distribution of financial resources. Inclusive financial services provided by digital inclusive finance are better equipped to address these issues and have the potential to contribute to inclusive economic growth (X. Zhang et al., 2019). It is uncertain whether digital inclusive finance can help the economy become greener and support green growth. Research has revealed that digital inclusive finance is able to facilitate technological diversification, improve energy efficiency, and support low-carbon industrial transformation, which can ultimately reduce carbon emissions (Yi et al., 2022). Moreover, retail and leisure are two daily consumption areas where digital inclusive financing is commonly utilized. This greatly lowers carbon emissions, especially in the third sector (M. He & Yang, 2021). However, some authors have presented the opposite conclusion. The expansion of fiber optic cable increases the demand for devices that allow more users to connect to the Internet, leading to higher energy consumption (Nguyen et al., 2020; Ren et al., 2021). Utilizing ICT technologies for digital financial inclusion could potentially increase carbon emissions and harm environmental sustainability. Can digital inclusive finance contribute to inclusive green growth? What are the impact mechanisms and main pathways of action? Will it bring different benefits in different regions? There is a need for further research on these questions.

Compared to previous research, the following are this paper's contributions: (1) Much of the current research on digital financial inclusion focuses on its relationship with economic growth (W. Wang et al., 2023a), social welfare (Xie et al., 2020; C. He et al., 2022), and environmental impact (Lee & Wang, 2022; H. Wang & Guo, 2022). However, there is limited literature exploring digital inclusive finance and its connections from an urban perspective, especially within a comprehensive framework of inclusive green growth. Based on previous studies, this paper combines the theoretical and empirical aspects of digital inclusive finance and inclusive green growth based on panel data from 270 cities in China between 2011 and 2021 and explores the impacts of the benchmarking effect, mediating effect, heterogeneity analysis, and moderating effect, respectively. (2) Although the literature has examined the mediating role of digital financial inclusion indirectly influencing inclusive green growth (Li et al., 2024; Sun et al., 2024). Most of the studies have been conducted using a single mediator model and lack comparative results on the impact of each mediating variable. Compared with previous studies, the multi-intermediary model in this paper can obtain the comparative results of each mediating variable in the transmission channel. By identifying the most impactful mediating factors, it can effectively overcome the problems and obstacles in the mechanism of digital inclusive financial policies for inclusive green growth. This can assist in improving policy formulation and implementation in practice.

This is how this paper is organized: a detailed description of the literature review and research hypotheses is provided in Section 2; Section 3 discusses the research design; the empirical model testing results and discussion are reported in Section 4; the mechanism analysis findings are given in Section 5; the heterogeneity analysis results are given in Section 6; finally, Section 7 provides an overview of the conclusions and policy implications.

## 2. Literature Review and Hypotheses

### 2.1. Digital Inclusive Finance Impacts Inclusive Green Growth

Since financial development has an impact on economic growth, there is a relationship between inclusive green growth and digital inclusive finance. There is general consensus that financial development is beneficial to economic growth (Asteriou et al., 2024; Öncel et al., 2024). By reducing financial barriers and maximizing the distribution of available market resources, traditional financial services can stimulate economic growth (Levine, 2005). However, in the initial phases of financial development, traditional finance suffered from information asymmetry, and long-tail customers were excluded involuntarily. Long-tail customers refer to low-income individuals, small enterprises, and disadvantaged micro-entrepreneurs, often in remote or underserved areas, who traditionally lack access to formal financial services due to their low economic visibility, minimal credit history, and the high costs associated with serving them through conventional financial systems. Compared to traditional finance, inclusive finance aims to distribute financial resources equitably and provide more accessible financial services to people with low-income levels, small enterprises, and disadvantaged micro-entrepreneurs in remote areas. This plays a crucial role in addressing issues related to poverty and employment inequality. However, the advancement of inclusive finance has revealed a dilemma of endogenous and exogenous paths, challenging its sustainability. On the exogenous side, having the government as the sole program provider creates mismatches and inefficiencies in the provision of financial products and services due to limited access to information on the demand side, represented by long-tail customers. Due to the lack of proper regulation and a profit-seeking orientation toward capital on the endogenous side of the economy, microfinance institutions (MFIs) have become excessively focused on generating profits. This has resulted in a shift toward serving high-income groups and large-scale enterprises, leading to the market failure phenomenon referred to as mission drift. This shift is not beneficial to the inclusive development of small businesses and microenterprises, hindering their growth. The emergence of digital inclusive finance presents novel approaches to tackle the obstacles involved in the advancement of inclusive finance. By exploiting the unique information technology of the internet, greater physical area penetration and lower transaction costs can be obtained. This can help mitigate the information cocoon phenomenon, which has prevented small businesses and microenterprises from accessing accurate financial services in less developed areas (Fan et al., 2023). Consequently, digital inclusive finance can effectively promote inclusive economic growth. From a green perspective, Oanh (2024) argued that digital technology contributes to environmental responsibility in financial development. However, financing constraints can lead to underinvestment in green technologies (Bouchmel et al., 2024), further inhibiting the green economy's evolution. Micro-small and medium-sized enterprises (MSMEs) access to loans may be facilitated by digital inclusive finance in conducting research and development for internal green technology innovation purposes. This can also encourage enterprises to assume environmental, social, and governance (ESG) responsibility and shift production factors toward the implementation of clean energy and other low-energy, low-emission, and high-value-added industrial chains. This can promote green transformation growth for inclusive economic development. Technological advancements in digital inclusive finance enable the efficient collection of credit information on long-tail customers in remote areas, helping to reduce information asymmetry. This allows financial institutions to better understand the needs of these customers and provide tailored support. Additionally, it guides small-scale groups such as farmers and micro-entrepreneurs towards eco-friendly production and business practices, specifically in critical areas like industrial integration and pollution control. This approach fosters inclusive green growth by promoting the logical and market-driven allocation of resources

through capital allocation, technology, and talent. While ICT technologies increase energy demand, advancements in green technology facilitated by digital inclusive finance can also improve energy efficiency and mitigate adverse environmental impacts. In light of the analysis above, we presume hypothesis H1 as follows;

**Hypothesis 1:** *Digital inclusive finance can promote inclusive green growth.*

### *2.2. Analysis of the Mechanisms by Which Digital Financial Inclusion Affects Inclusive Green Growth*

Digital financial inclusion fosters green technology innovation, which has an impact on inclusive green growth. The neoclassical economic growth model of Solow indicates that technological progress can effectively promote economic growth (Solow, 1956). Enterprises face significant challenges in funding technological research and development due to financing constraints. These limitations inhibit innovation practices because of the high risks, substantial investments, and long payback period (King & Levine, 1993). Regarding the demand side, digital inclusive finance exhibits the potential to efficiently integrate small-scale investors into the market by accurately profiling users, implementing risk pricing, and utilizing intensive processes. This can increase the likelihood of financing through a transparent platform application without favoring wealthy investors as traditional finance often does. By accurately reaching the tail group that matches the risks and returns, small- and medium-sized enterprises (SMEs) may experience fewer financial restraints if they adopt digital inclusive finance. Enterprises with strong financing constraints will have to devote their energy and focus to finding sources of corporate working capital and neglect ESG practices. Only when SMEs are able to obtain sufficient financial support to cover the initial costs of ESG practices will they use part of their capital to improve ESG performance. This way, more and more investors tend to invest in enterprises with good ESG performance (Wu, 2023). When the financing constraints faced by SMEs are alleviated, then SMEs are more likely to allocate additional funds toward Environmental, Social, and Governance (ESG) practices to attract greater investor interest. This encourages SMEs to make purchases in green technology, thereby promoting inclusive and sustainable economic growth. On the production side, expanding digitalization in industry can improve energy efficiency and reduce carbon emissions (J. Huang et al., 2023). A novel approach to development is digital inclusive financing, which promotes open-source and cost-saving practices. It aims to help enterprises overcome liquidity constraints and conduct research and development as well as apply green technology. The ultimate goal is to transform and upgrade low-energy-consumption and low-pollution production chains. As a result, this approach can result in carbon emission reduction, leading to a mutually beneficial arrangement for the environment and economy. This can help foster inclusive and green growth.

In light of the study above, hypothesis H2 is put forth;

**Hypothesis 2:** *The impact of digital inclusive finance on inclusive green growth is driven by promoting green technology innovation.*

Inclusive green growth is influenced by digital inclusion finance through enhancing entrepreneurship. Financial development can incentivize entrepreneurial behaviors by alleviating entrepreneurial credit constraints through its resource allocation function (Bianchi, 2010). Digital inclusive finance is a more accessible and widespread form of finance than traditional finance, which often provides limited availability. Financial services become more accessible through digital inclusive finance, which improves the financing environment in underdeveloped and remote areas. It also reduces the difficulty of obtaining start-up capital for entrepreneurial financing projects and reduces the thresholds for entrepreneur-

ship's cash limitations, boosting entrepreneurship (Lam, 2010). Digital financial inclusion has also given rise to several new industrial businesses, providing robust platforms for entrepreneurial activities such as e-commerce, rural Taobao, online car rental, and other online-to-offline (O2O) areas. This has not only reduced the cost of searching for information but also created many opportunities for entrepreneurs and jobs. The promotion of digital inclusive finance for rural SMEs or labor-intensive entrepreneurship can not only effectively diminish the disparity in wealth between rural and urban areas (B. Zhang & Wu, 2021), which favors equitable economic growth, but also provide greening guidelines for farmers to engage in energy-saving and eco-friendly entrepreneurial activities. For instance, the Yu Nong Tong digital inclusive financial product offered by the China Construction Bank focuses on investing in environmentally friendly targets, which helps reduce carbon emissions resulting from economic development. This supports inclusive green growth. According to the greening guidelines for investment and financing support for entrepreneurial capital, the interlocking resource integration effect of digital inclusive finance further aids in shifting the production mode from extensive to intensive based on entrepreneurial level promotion, which contributes to effectively realizing the benefits of inclusive green growth.

In regard to the study above, hypothesis H3 is put forth;

**Hypothesis 3:** *Digital inclusive finance enhances entrepreneurship levels, which benefits inclusive green growth.*

Digital inclusive finance contributes to inclusive green growth by promoting the structural upgrading of industries. Financial development continues to catalyze technological innovation and the growth of emerging sectors, enhance the efficiency of the flow of production factors in conventional sectors, and promote the interactive and integrated industry development, thus facilitating industrial structure upgrading (Aghion et al., 2005). Industrial development involves the participation of multiple classes, while industrial structure upgrading can result in a reasonable flow of labor and capital factors. This can lead to economic growth that benefits all social groups, ensuring an inclusive process. Modernizing the internal industrial framework is reflected in the evolution of the economic structure toward a service-oriented mode (Gan et al., 2011). Moreover, the growth of the third sector facilitates the control of the pollution intensity (Z. Khan et al., 2019), which in turn reflects the potential mode of green transformation of economic growth. To reduce search costs, digital inclusive finance is guided by digital technology. It addresses the issue of asymmetric traditional financial information by accurately matching the supply and demand limits of the industrial chain. Digital inclusive finance provides both financial and technical support for industrial growth while facilitating resource allocation to promote the green transformation of resource-based urban industrial structures. Digital financial inclusion is characterized by low costs, extensive coverage, and rapid processing speeds, allowing it to reach a broader audience, provide a diverse range of financial products and services, and accommodate various usage scenarios. This promotes the demand for environmentally friendly products and helps residents allocate their assets in favor of such products. Furthermore, digital inclusive finance encourages the upgrading and restructuring of the industrial structure to satisfy consumer demand for environmentally friendly goods. The continuous advancement of industrial structures facilitates the influx of resources into low-pollution, low-energy-consumption industries. This shift improves energy efficiency and strengthens environmental governance, ultimately contributing to inclusive green growth. The analysis above leads to the proposal of a fourth hypothesis;

**Hypothesis 4:** *Digital inclusive finance affects inclusive green growth by promoting industrial structure upgrading.*

### 2.3. Heterogeneity Analysis of the Impact of Digital Inclusive Finance on Inclusive Green Growth

Influence of location factors and administrative hierarchy: The objective of digital financial inclusion is to provide equitable access to financial services for financially vulnerable groups in underdeveloped regions without discrimination. The influence of digital financial inclusion on inclusive green growth may differ based on the degree of resource endowment and economic development of cities. The allocation of urban resources is influenced not only by the market economy but also by the regional level. With increasing administrative level, the ability to allocate city resources increases accordingly (Peng et al., 2016). Within developed areas, the level of management authority granted to them tends to impose fewer restrictions that further promote the efficiency of government-led, market-oriented initiatives, allowing for smoother implementation of digital financial inclusion policies. The Chinese green initiatives characterize a comprehensive framework aimed at achieving sustainable economic development while mitigating environmental impact (Amin et al., 2024). The green initiatives include ambitious policies such as the "Dual Carbon Goals" of achieving peak carbon emissions by 2030 and carbon neutrality by 2060, alongside efforts to promote renewable energy, green urbanization, and eco-friendly industrial practices (Y. Jiang et al., 2023). By integrating these initiatives with digital financial inclusion policies, China seeks to enhance resource allocation efficiency, stimulate green entrepreneurship, and promote equitable growth across regions, particularly in developed areas where streamlined management facilitates effective policy implementation.

More advanced regions can leverage their administrative advantages to draw resources from lower-tier cities, effectively channeling these resources to drive differentiation in development strategies. This process promotes higher-quality urban growth and fosters inclusive green growth, as more developed cities employ advanced technologies and sustainable practices to lead regional development. The degree of financial marketization's influence: Advancing financial marketization effectively minimizes distortions caused by dual-track interest rates, thereby fostering healthy competition within the financial sector. This also motivates traditional financial market players to innovate and ultimately contributes to the development of digital inclusive finance through the deep integration of finance and technology. In addition, the financial marketization process fulfills a significant role in enhancing the advancement of financial infrastructure and minimizing information asymmetry, such as issues related to selection bias and ethical hazard. This, in turn, improves the efficiency of digital inclusive finance services and exerts varying impacts on promoting inclusive green growth across different regions.

Impact of the policy intensity: The advancement of inclusive digital finance is intimately linked to the continuous advancement in digital technology and is heavily influenced by policies. The Action Plan for Fostering Big Data Development was issued by the State Council on 31 August 2015 (X. Jiang, 2022). And it launched the construction of a national big data comprehensive pilot zone in September of the same year. The creation of an extensive national big data pilot program enables the open sharing of regional data, creates favorable conditions for developing digitally inclusive financial service platforms, and lays a solid foundation for establishing intelligent data risk control and management mechanisms. Various policy intensities can affect the interaction between digital financial inclusion and inclusive green growth.

Impact of environmental regulations: The detrimental environmental issues due to economic advancement have caused the government to create numerous regulations to produce a circular economy that still produces pollutants. Implementing ecological reg-

ulations has emerged as a key strategy to address the market failures associated with environmental challenges and to promote green growth. Environmental regulations can potentially increase the cost of ecological governance for businesses. However, digital inclusive finance's financial non-exclusion component can ease external financing restrictions while giving businesses internal incentives. Securing start-up capital through this approach incentivizes enterprises to adopt green technological innovations, enhancing their competitiveness and fostering green development. The process of survival of the fittest and innovation compensation can incentivize industries to shift toward low-pollution and low-energy-consumption technologies (Porter & van der Linde, 1995). This, in turn, can encourage the development of clean industries in the service sector, yielding a more environmentally sustainable industrial structure (Cai & Zhou, 2017) and promoting inclusive green growth. Under varying levels of environmental regulation, digital financial inclusion imposes different effects on promoting inclusive green growth.

In regard to the study above, hypothesis H5 is put forth;

**Hypothesis 5:** *Differences in regional, urban administrative levels, financial marketization degree, policy intensity, and environmental regulation can allow financial inclusion to exert varying degrees of impact on inclusive green growth.*

The theoretical framework of this paper is shown in Figure 1.

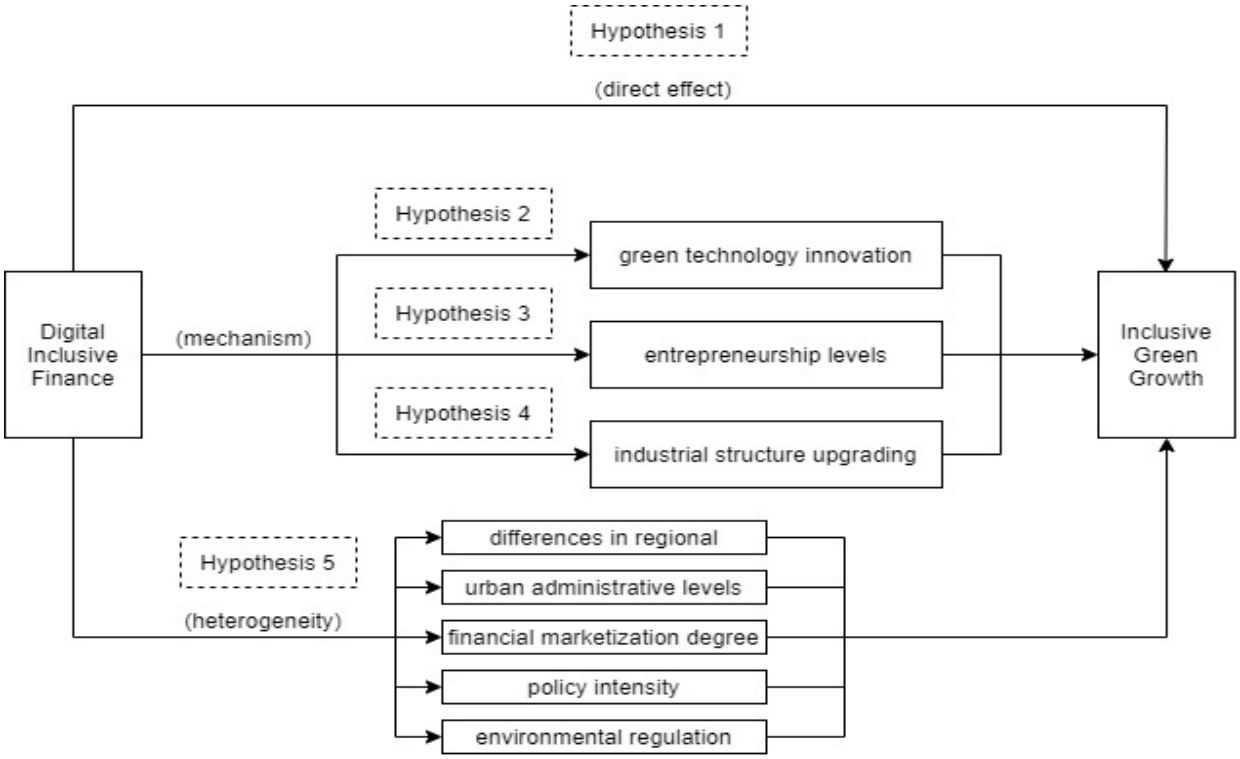



**Figure 1.** The theoretical framework of digital inclusive finance on inclusive green growth.

## 3. Methodology

### *3.1. Benchmark Model*

This study has employed an individual fixed effect approach for addressing unobserved heterogeneity across cities that may influence both digital financial inclusion and inclusive green growth. By controlling for time-invariant factors such as geographical location, institutional quality, and historical development patterns, the fixed effect model minimizes bias from unobserved characteristics (F. U. Khan et al., 2024a). Moreover, the

fixed effect approach provides a more robust evaluation of the actual effect of digital financial inclusion on inclusive green growth by isolating the effect from potential unobserved variables unique to each city. This study employs the following model for analysis:

$$Igg_{it} = \alpha_0 + \alpha_1 dfii_{it} + \alpha_2 gpatent_{it} + \alpha_3 business_{it} + \alpha_4 ts_{it} + \sum_{i=1}^{n} a_n F_Control_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (1)$$

where $i$ represents the city, $t$ symbolizes the year, the dependent variable $Igg$ denotes inclusive green growth, and the main explanatory variable $dfii$ denotes the logarithm of the total index of digital inclusive finance. In addition, the equation also reports the mediating variables, which are green technology innovation (gpatent), entrepreneurship (business), and industrial structure upgrading (ts). Moreover, F_Control represents $loan$, $urban$, $gdp$, and $tech$ that are the set of control variables. These variables represent the financial development level, urbanization rate, logarithm of the regional per capita gross domestic product (GDP), and scientific and technological input level, respectively. Finally, $\mu_i$ denotes the elements that remain constant over time in each city to control for regional fixed effects, $\tau_t$ denotes the elements that remain constant over time in each year to control for time fixed effects, and $\varepsilon_{it}$ is the error term.

### 3.2. Variables and Data

#### 3.2.1. Dependent Variable

The dependent variable used in this study is inclusive green growth ($igg$). At present, index measurement of inclusive green growth is the comprehensive evaluation method (Jia et al., 2023; Li et al., 2023). The present research adopts the index system comprehensive evaluation method, as it is more suitable for measuring inclusive green growth in Chinese cities, using the subjective and objective empowerment methods outlined by T. Zhang and Li (2023). Using this method, an index system was developed based on four key dimensions: (a) economic development; (b) equitable income distribution; (c) inclusive social welfare; and (d) and environmental sustainability through pollution reduction. Economic development was measured by the GDP per capita and the GDP growth rate. Income distribution was determined by examining the ratio between the per capita disposable income of urban residents, rural residents, and the combined per capita disposable income of both urban and rural populations. Inclusive social welfare was assessed using the ratio of urban basic medical insurance, urban workers' basic old-age insurance, and unemployment insurance to the total population at the end of the year, along with the number of public library books per 10,000 people and the number of hospitals and health centers. The reduction in environmental pollution was determined by the discharge of the three industrial wastes per 10,000 people, the overall utilization rate of general industrial solid waste, the sewage treatment plants' centralized processing rate, and the safe disposal rate of household waste. These indicators were mapped to the 0–10 range to highlight differences in the levels of inclusive green growth. This approach, commonly employed in constructing composite indices, was implemented under the guidance of experts in environmental and economic sustainability, ensuring that the methodology adhered to rigorous academic and statistical standards.

#### 3.2.2. Core Independent Variable

Digital inclusive finance ($dfii$). The main independent variable is digital inclusive finance, which was measured by the total index of digital financial inclusion for Chinese cities published annually by the China Digital Finance Research Center of Peking University[1]. This index captures various aspects of digital financial inclusion and provides a robust measure for assessing its impact. To enhance data stability and reduce potential skewness, the index underwent logarithmic transformation. Additionally, the compre-

hensive index encompasses three sub-indices that reflect different dimensions of digital financial inclusion: (1) the coverage breadth sub-index (*breadth*), which evaluates the extent of access to digital financial services across different populations and regions; (2) the usage depth sub-index (*depth*), which assesses the intensity of digital financial services usage, such as the frequency and diversity of financial activities conducted digitally; and (3) the digitization degree sub-index (*digitization*), which measures the extent to which financial services have been digitized and integrated into the broader economy. While these sub-indices provide important insights into specific dimensions of digital finance, the study utilized the sub-indices and the total digital financial inclusion index as a consolidated measure in the regression analysis to ensure a holistic and valid representation of digital inclusive finance.

#### 3.2.3. Mediating Variables

(1) Green technology innovation (*gpatent*): The number of green patent applications was utilized to assess the extent of green technology innovation in each city. Only promising innovations at the forefront of technology associated with patent applications were considered (Furman et al., 2002).

(2) Entrepreneurship (*business*): In this paper, the number of newly registered enterprises in various cities was obtained through crawler grasping. The ratio of private firms to total employment has been used in previous studies to measure entrepreneurship. Nevertheless, this measure largely reflects retained business activity rather than entrepreneurial activity. The use of the number of newly listed firms to measure the entrepreneurship level can more clearly reveal the start-up of the entrepreneurial level from scratch.

(3) Industrial structure upgrading (*ts*): The upgrading of the industrial structure is reflected in the evolution of the economic structure toward a more service-oriented mode (Gan et al., 2011). To measure industrial structure upgrading can effectively reflect the improvement in the service level of the economy by using the proportion of the secondary and tertiary industries' added values.

#### 3.2.4. Control Variables

(1) Financial development level (*loan*): Several investigations have demonstrated that financial development facilitates capital accumulation to promote local economic growth and alleviate poverty. In this paper, the proportion of local financial institutions' outstanding loans to GDP was used for measurement.

(2) Urbanization rate (*urban*): The continuous evolution of urbanization promotes the flow of population input and capital factors to ensure urban economic growth. In contrast, in the expansion process, the income gap of residents increases, and overdevelopment of the surrounding environment can influence inclusive green growth. The ratio of the population living in cities to the overall population was used to measure this variable.

(3) Economic development level (*gdp*): The foundation of inclusive green growth is economic growth, but economic growth promotion can also cause environmental and equity issues, adversely affecting the social Pareto optimality of inclusive green growth. The regional GDP per capita was measured and logarithmically processed.

(4) Investment level in science and technology (*tech*): The traditional Cochrane production function suggests that continuous investment in science and technology is crucial for overcoming the current bottleneck of economic development and achieving progress. The greater the level of investment in technology and science is, the more favorable the conditions for cities to attain technological progress and undergo green transformation and upgrading, which positively impacts inclusive green growth. The amount of science and technology expenditure was logarithmically measured and processed.

### 3.3. Data Sources

The study focused on 270 prefecture-level cities in China. Prefecture-level cities in China have generally achieved an apparent growth in inclusive green development during the 12th and 13th Five-Year Plans. In terms of time, inclusive green development has maintained steady growth during the 12th Five-Year Plan Period (2011–2015).Sample data spanning 2011 to 2021 were collected, and 2970 sets of sample data were obtained after sorting. To ensure data integrity, missing information was supplemented using each city's statistical yearbook or through linear interpolation. Digital inclusive finance data were obtained from the Digital Finance Research Center of Peking University, data on green patents were collected from the CIRD database, and remaining data originated from the China City Statistical Yearbook and CSMAR database. Table 1 provides details about the selection and definition of the variables. Table 2 and Figure 2 present the variables' descriptive statistics. The descriptive statistical results showed that digital inclusive finance, inclusive green growth, green technology innovation, entrepreneurship, and industrial structure vary among the selected sample of study.

**Table 1.** Variables selection and definitions.

| Variables | Variable Sign | Variable Name | Description |
|---|---|---|---|
| Dependent variable | *igg* | Inclusive green growth | A comprehensive evaluation index system is established in four dimensions: economic growth, income distribution, and universal benefits of environmental protection and pollution reduction |
| Core independent variable | *dfii* | Digital financial inclusion | The logarithm of the total index of digital financial inclusion is obtained |
| | *breadth* | Breadth of digital financial inclusion coverage | Digital financial inclusion coverage sub-index logarithm |
| | *depth* | Depth of use of digital financial inclusion | Digital financial inclusion use depth sub-index logarithm |
| | *digitization* | Degree of digitalization of digital financial inclusion | Logarithm of the digital financial inclusion degree sub-index |
| Mediating variable | *gpatent* | Green technology innovation | Green patent applications |
| | *business* | Entrepreneurship | Number of newly registered enterprises by city |
| | *ts* | Upgrading of the industrial structure | Ratio of the value added of the tertiary industry to that of the secondary industry |
| Control variable | *loan* | Financial development level | Ratio of the outstanding loans of local financial institutions to the GDP |
| | *urban* | Urbanization rate | Proportion of the urban population in the total population |
| | *gdp* | Economic development level | The logarithm of the regional gross domestic product per capita is determined |
| | *tech* | Investment level of science and technology | The logarithm of the amount spent on science and technology is obtained |

**Table 2.** Descriptive statistics of the variables.

| Variable Name | Observations | Mean Value | Standard Deviation | Minimum Value | Maximum Value |
|---|---|---|---|---|---|
| *igg* | 2970 | 3.066 | 0.794 | 1.055 | 7.199 |
| *dfii* | 2970 | 5.007 | 0.508 | 3.057 | 5.773 |
| *breadth* | 2970 | 4.936 | 0.549 | 1.502 | 5.738 |
| *depth* | 2970 | 4.993 | 0.508 | 2.525 | 5.805 |
| *digitization* | 2970 | 5.165 | 0.623 | 0.993 | 5.998 |
| *gpatent* | 2970 | 5.219 | 1.659 | 0.000 | 10.454 |
| *business* | 2970 | 10.466 | 0.827 | 8.351 | 13.715 |
| *ts* | 2970 | 0.980 | 0.535 | 0.176 | 5.154 |
| *post* | 2970 | 4.767 | 0.924 | 2.238 | 9.080 |
| *loan* | 2970 | 0.995 | 0.650 | 0.118 | 9.622 |
| *urban* | 2970 | 0.422 | 0.176 | 0.129 | 1.059 |
| *gdp* | 2970 | 1.496 | 0.552 | 0.009 | 3.369 |
| *tech* | 2970 | 10.420 | 1.342 | 6.624 | 15.282 |

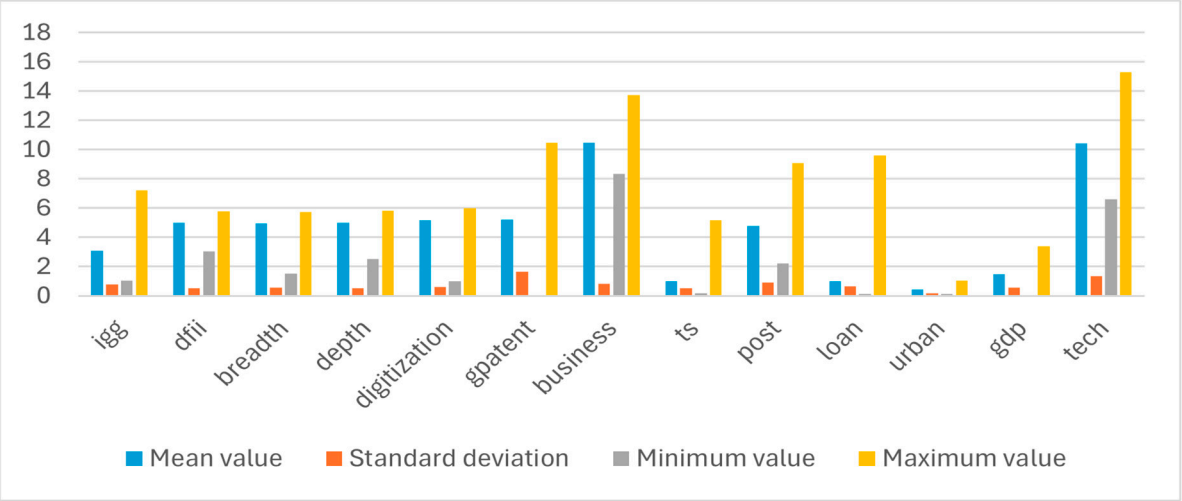



**Figure 2.** The Descriptive statistics of the study's variables.

### *3.4. Correlation Analysis*

Table 3 reports Pearson correlation values the study's variables. The findings suggest that digital inclusive finance has a positive and significant correlation with inclusive green growth that provides preliminary evidence that digital finance promotes green initiatives in China.

**Table 3.** Correlation analysis.

| Variables | igg | dfii | Loan | Urban | gdp | Tech |
|---|---|---|---|---|---|---|
| igg | 1 | | | | | |
| dfii | 0.425 *** | 1 | | | | |
| loan | 0.280 *** | 0.313 *** | 1 | | | |
| urban | 0.600 *** | 0.287 *** | 0.397 *** | 1 | | |
| gdp | 0.798 *** | 0.459 *** | 0.277 *** | 0.661 *** | 1 | |
| tech | 0.724 *** | 0.350 *** | 0.295 *** | 0.441 *** | 0.639 *** | 1 |

Note: *** symbolize the 1% significance levels.

## 4. Results and Discussion

### *4.1. Benchmark Model Test*

This study employed a fixed effects model as a baseline regression to examine the role of digital financial inclusion and inclusive green growth, and the projected outcomes are

listed in Table 3. Column (1) of Table 4 presents that digital financial inclusion (dfii) has a positive and significant effect ($\beta = 0.397$, $\rho < 0.01$) on inclusive green growth (igg). In column (2), the control variables are included and get consistent results ($\beta = 0.156$, $\rho < 0.01$) that suggest that maintaining the other factors constant, inclusive green growth increased by 0.156 units rise in digital financial inclusion for every unit increase, which is significant at the 1%. This indicates that digital financial inclusion imposed a positive promoting effect on inclusive green growth, which verifies hypothesis 1 (H1: digital financial inclusion promotes inclusive green growth). Furthermore, the control variable coefficients, namely, financial development level, economic development, and level of scientific and technological investment, were positive and significant, consistent with expectations.

**Table 4.** Test results of the benchmark model.

| Variable | igg | |
|---|---|---|
| | (1) Fixed Effect Regression | (2) Fixed Effect Regression |
| dfii | 0.397 *** | 0.156 *** |
| | (0.018) | (0.025) |
| loan | | 0.050 *** |
| | | (0.018) |
| urban | | 1.229 *** |
| | | (0.348) |
| gdp | | 0.400 *** |
| | | (0.062) |
| tech | | 0.085 *** |
| | | (0.019) |
| Constant | 1.080 *** | 0.229 |
| | (0.089) | (0.177) |
| City-fixed effect | YES | YES |
| Time-fixed effect | YES | YES |
| R-squared | 0.454 | 0.556 |
| Observations | 2970 | 2970 |

Note: The standard error values are reported in parenthesis. *** symbolize the 1% significance levels.

### 4.2. Robustness Test

To validate our baseline results, we conduct different robustness analyses which are as follows; (1) there is inadequate regional development in China, which can lead to varying effects of digital financial inclusion on inclusive green growth. The developed state of construction in municipalities is different than that of other types of cities and may lead to biased outcomes. Therefore, the cities' research samples, such as Beijing, Tianjin, Shanghai, and Chongqing, were excluded. (2) The core explanatory variable was replaced. Notably, according to the three sub-indexes of digital financial inclusion published by the China Digital Finance Research Center of Peking University, the total index of digital financial inclusion was replaced by the coverage breadth sub-index, use depth sub-index, and digitalization degree sub-index. (3) The data were winsorized at the 1% level. (4) Quantile regression was performed at different quantiles (10%, 25%, 50%, 75%, and 90%) to determine whether digital financial inclusion might greatly encourage inclusive green growth. The analysis outcomes are listed in Tables 5 and 6, where we consistently find that digital financial inclusion positively and significantly influences inclusive green growth. Thus these findings verify that the empirical results are robust.

**Table 5.** Robustness test results.

| Variable | (1) Exclude Municipalities | (2) Winsorization | igg (3) Coverage Breadth Subindex | (4) Use of the Depth Subindex | (5) Digital Degree Subindex |
|---|---|---|---|---|---|
| dfii | 0.151 *** | 0.147 *** | 0.130 *** | 0.134 *** | 0.108 *** |
| | (0.025) | (0.023) | (0.023) | (0.025) | (0.018) |
| loan | 0.051 *** | 0.050 *** | 0.058 *** | 0.054 *** | 0.062 *** |
| | (0.018) | (0.018) | (0.021) | (0.019) | (0.021) |
| urban | 1.243 *** | 1.245 *** | 1.313 *** | 1.282 *** | 1.322 *** |
| | (0.352) | (0.338) | (0.365) | (0.352) | (0.350) |
| gdp | 0.407 *** | 0.417 *** | 0.425 *** | 0.438 *** | 0.446 *** |
| | (0.063) | (0.056) | (0.063) | (0.061) | (0.059) |
| tech | 0.084 *** | 0.082 *** | 0.086 *** | 0.089 *** | 0.083 *** |
| | (0.019) | (0.018) | (0.019) | (0.020) | (0.020) |
| Constant | 0.248 | 0.278 | 0.278 | 0.217 | 0.361 ** |
| | (0.176) | (0.172) | (0.180) | (0.179) | (0.178) |
| City-fixed effect | YES | YES | YES | YES | YES |
| Time-fixed effect | YES | YES | YES | YES | YES |
| R-squared | 0.556 | 0.570 | 0.551 | 0.551 | 0.556 |
| ID number | 266 | 270 | 270 | 270 | 270 |
| Observations | 2926 | 2970 | 2970 | 2970 | 2970 |

Note: The standard error values are reported in parenthesis. ** and *** symbolize the 5%, and 1% significance levels, respectively.

**Table 6.** Quantile regression results.

| Variable | (1) Q10 | (2) Q25 | igg (3) Q50 | (4) Q75 | (6) Q90 |
|---|---|---|---|---|---|
| dfii | 0.240 *** | 0.206 *** | 0.154 *** | 0.106 *** | 0.073 ** |
| | (0.032) | (0.024) | (0.018) | (0.023) | (0.031) |
| loan | 0.019 | 0.031 | 0.050 *** | 0.069 *** | 0.081 ** |
| | (0.035) | (0.026) | (0.019) | (0.025) | (0.034) |
| urban | 1.089 *** | 1.146 *** | 1.232 *** | 1.314 *** | 1.369 *** |
| | (0.353) | (0.261) | (0.192) | (0.257) | (0.344) |
| gdp | 0.278 *** | 0.328 *** | 0.403 *** | 0.474 *** | 0.522 *** |
| | (0.083) | (0.061) | (0.045) | (0.060) | (0.081) |
| tech | 0.089 *** | 0.088 *** | 0.085 *** | 0.083 *** | 0.081 *** |
| | (0.022) | (0.016) | (0.012) | (0.016) | (0.021) |
| City-fixed effect | YES | YES | YES | YES | YES |
| Time-fixed effect | YES | YES | YES | YES | YES |
| Observations | 2970 | 2970 | 2970 | 2970 | 2970 |

Note: The standard error values are reported in parenthesis. ** and *** denote the 5% and 1% significance levels, respectively.

### *4.3. Endogeneity Test*

#### 4.3.1. Instrumental Variable Method

Endogeneity occurs when the explanatory variables are related to interference terms (Usman et al., 2022). For instance, the evolution of digital inclusive finance is rooted in traditional finance, which may reverse causality with inclusive green growth that can bias the main results. To address this issue, instrumental variables can be applied to identify the parts of endogenous variables unrelated to interference terms while satisfying the conditions of correlation and exclusivity. This helps to alleviate potential endogeneity problems. Geographic location is an exogenous variable for stripping economic systems (Bai & Zhang, 2021). According to the research of X. Zhang et al. (2020), each region's spherical distance from Hangzhou was selected as the instrumental variable of digital financial inclusion, and regression estimation was performed through two-stage least squares (2SLS). Hangzhou, where digital finance first emerged with the launch of Alipay, has emerged as a leading region in the advancement of digital finance in China. Subsequently, this variable was chosen to be an instrumental variable to satisfy the correlation conditions related to endogenous explanatory variables. On the other hand, geographic and natural factors are

exogenous to the economic variables, so the instrumental variable fulfills the requirement for exogeneity. In addition, time-varying variables were included to create instrumental variables for the panel data (Nunn & Qian, 2014). We specifically did this by constructing an interaction term between the number of Internet users in the region in the current year ($iu_{it}$) and the spherical distance between each region and Hangzhou ($dis_i$) and treating the two variables in logarithmic terms separately to eliminate the effect of the scale.

The following two-stage equation was constructed:

$$dfii_{it} = \alpha_0 + \alpha_1(ln(iu_{it}) \times ln(dis_i)) + \alpha_2 loan_{it} + \alpha_3 urban_{it} + \alpha_4 gdp_{it} + \alpha_5 tech_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (2)$$

$$igg_{it} = \beta_0 + \beta_1 dfii_{it} + \beta_2 loan_{it} + \beta_3 urban_{it} + \beta_4 gdp_{it} + \beta_5 tech_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (3)$$

We used the above instrumental variables to perform a regression analysis by 2SLS. Table 7 presents the results of the estimations analysis. The outcomes of the initial stage of regression revealed that the coefficient between the instrumental variable and digital financial inclusion is positive and significant at the 1% level, suggesting that this instrumental variable satisfies the correlation conditions. The probability value of the Kleibergen–Paap rk Lagrange multiplier (LM) statistic falls under 0.05. Therefore, it is possible to reject the null hypothesis, which posits that there is inadequate identification of instrumental variables, and the unidentifiable test is passed. The Kleibergen–Paap Wald rk F statistic exceeds the 10% threshold, indicating that the selected instrumental variable fulfills the test for weak tool variables. The findings of the second stage of regression indicated that digital financial inclusion exerts a noteworthy effect on inclusive green growth at the 1% significance level. Furthermore, the positive and significant coefficient is verifying that digital financial inclusion continues to generate a significant promoting effect on inclusive green growth, even after eliminating the endogeneity issues' influence with the regression estimation outcomes of the benchmark model.

**Table 7.** Instrumental variable 2SLS regression results.

| Variable | Dfii<br>(1)<br>First-Stage Regression | igg<br>(2)<br>Second-Stage Regression |
|---|---|---|
| dfii | | 0.193 ***<br>(0.049) |
| ln(iu) × ln(dis) | 0.001 ***<br>(0.000) | |
| Control variable | YES | YES |
| Constant | 1.571<br>(0.227) | 0.973<br>(0.293) |
| Kleibergen–Paap rk LM statistic | | 51.081<br>[0.000] |
| Kleibergen–Paap Wald rk F statistic | | 106.456<br>{16.380} |
| City-fixed effect | YES | YES |
| Time-fixed effect | YES | YES |
| R-squared | 0.719 | 0.555 |
| Observations | 2970 | 2970 |

Note: () is the standard error values, [] is the p value, and {} is the critical value corresponding to the Stock–Yogo test at the 10% significance level. *** symbolize the 1% significance levels, respectively.

#### 4.3.2. Difference-in-Differences Method

The launch of Yu'e Bao in 2013 marked the entrance of inclusive finance into the digital realm (Z. Huang, 2018). The launch of Yu'e Bao in 2013 signified a transformative shift in China's financial landscape, integrating inclusive finance with digital platforms. This transformation provided access to financial services by permitting individuals to invest small amounts of money with ease and convenience. It catalyzed the growth of

digital financial inclusion, fostering greater participation in formal financial systems and reshaping savings and investment behaviors across demographics. By lowering entry barriers and leveraging technology, Yu'e Bao highlighted the potential of digital platforms to bridge financial gaps, a key context for understanding the broader implications of digital financial inclusion and its relevance to inclusive green growth in China. Traditional financial institutions cannot manage the enormous amount of funds generated by Alipay. However, the emergence of Yu'e Bao resolved this deadlock, and it continued to develop into one of the largest money fund businesses in China, which indicates the profound policy impact of Yu'e Bao's 2013 launch.

The advantage of the difference-in-differences method in resolving the endogenous model of causal inference is that it avoids the interference of endogenous problems, such as reverse causation, by introducing the impact of exogenous policies. The beginning of Yu'e Bao in 2013 is considered to have generated an external policy impact. This method aims to classify cities into treatment and control groups according to their per capita economic development level to evaluate the impact of this policy. The model is expressed in Equation (4):

$$igg_{it} = \alpha_0 + \alpha_1 treated_i \times period_t + \alpha_2 loan_{it} + \alpha_3 urban_{it} + \alpha_4 gdp_{it} + \alpha_5 tech_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (4)$$

where $i$ denotes the city, $t$ indicates the year, and the explained variable $igg$ denotes inclusive green growth. Moreover, $treated$ is a group dummy variable (the value of the regional per capita economic development level above the mean $gdp$ is 0, and that below the mean $gdp$ is 1), and period denotes the virtual variable of time. Before Yu'e Bao was launched in 2013, its value was 0, whereas after its launch, the value was 1. The remaining variables are identical to those in Equation (1). The city fixed effect $\mu_i$ and year fixed effect $\delta_t$ were further controlled, and $\varepsilon_{it}$ is the error disturbance term.

However, the policy effect estimated by the difference-in-differences model can mitigate the estimation bias brought on by the model's endogeneity issue. The regression results are detailed in Table 8, where the coefficient of the cross-multiplication term (did) is significantly positive at the 1% significance level in both columns. Implementing a digital inclusive finance development strategy can greatly advance the inclusive green growth level of regions with comparatively less developed regions. The benchmark regression model's parameter estimation outcomes demonstrate no discernible changes relative to the baseline results.

**Table 8.** Difference-in-differences model regression results.

| Variable | igg | |
|---|---|---|
| | (1) | (2) |
| | Difference-In-Differences | |
| did | 0.190 *** | 0.051 *** |
| | (0.022) | (0.016) |
| loan | | 0.088 *** |
| | | (0.030) |
| urban | | 1.656 *** |
| | | (0.405) |
| gdp | | 0.583 *** |
| | | (0.060) |
| tech | | 0.095 *** |
| | | (0.021) |
| Constant | 2.980 *** | 0.398 ** |
| | (0.010) | (0.192) |
| City-fixed effect | YES | YES |
| Time-fixed effect | YES | YES |
| R-squared | 0.874 | 0.938 |
| Observations | 2970 | 2970 |

Note: The standard error values are reported in parenthesis. ** and *** symbolize the 5% and 1% significance levels, respectively.

## 5. Mechanism Analysis

To accomplish environmental sustainability and inclusive green growth, green technology innovation, entrepreneurship, and industrial structure upgrading are crucial within the context of unbalanced regional development in China. These three variables were used as intermediary factors to investigate the process of transmission of digital inclusive finance–intermediary factors and inclusive green growth under the parallel multi-intermediary model.

This study establishes a path model, as expressed in Equations (5)–(7), which is evaluated by the bootstrap method.

$$igg_{it} = \alpha_0 + \alpha_1 dfii_{it} + \tau \cdot Z_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (5)$$

$$A_{it}^n = \beta_0 + \beta_n dfii_{it} + \tau \cdot Z_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (6)$$

$$igg_{it} = \delta_0 + \delta_1 dfii_{it} + \sum_{n=1}^{3} \varphi_n A_{it}^n + \tau \cdot Z_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (7)$$

where $Z_{it}$ represents a set of control variables, $A$ is the intermediary variable, and $n$ exhibits values of 1, 2, and 3, denoting the three intermediary variables, namely, the number of green patent applications, the quantity of recently established businesses in every city, and the proportion of the secondary industry's added value to that of the tertiary industry, respectively, which are employed to evaluate innovative green technology, entrepreneurship, and industrial structure upgrading, respectively. Moreover, $\alpha_1$ denotes the total effect of digital financial inclusion on inclusive green growth, $\delta_1$ denotes the direct effect, $\beta_n$ and $\varphi_n$ denotes the individual intermediary effects, and $(\alpha_1 - \delta_1)$ denotes the overall intermediary effect. The variables satisfy Equation (8), which can be expressed as:

$$\alpha_1 = \delta_1 + \sum_{n=1}^{3} \beta_n \varphi_n \quad (8)$$

As indicated in Table 9, the findings of the regression for the intermediary effect showed that, first, the overall intermediary effect is 0.090, which is significant at the one percent level. Therefore, including green technology innovation, entrepreneurship level, and industrial structure upgrading in the model as intermediary variables achieves statistical significance. Second, the mediating impact of green technology innovation is 0.039, which is significant at the 1% level. This verifies hypothesis H2 that digital inclusive finance can promote inclusive green growth by enhancing the level of green technology innovation, indicating that digital inclusive finance can help businesses overcome their financial limitations and encourage enterprises to implement green technology innovation. Moreover, green technology can increase the effectiveness of energy use to achieve inclusive green growth. The mediating effect of entrepreneurship is 0.025 and significant at the 1% level, which verifies the hypothesis (H3) that digital inclusive finance can promote inclusive green growth by increasing the entrepreneurship level, which implies that digital inclusive finance can essentially reduce the liquidity constraint of the entrepreneurship threshold and release many entrepreneurial opportunities while generating new businesses, thus bridging the disparity in income between residents and effectively stimulating inclusive green growth. The mediating effect through industrial structure upgrading is 0.026 and is significant at the 1% significance level, which verifies hypothesis H4 that digital inclusive finance promotes industrial structure upgrading and facilitates inclusive green growth, demonstrating that digital inclusive finance encourages the flow of production elements toward businesses with high levels of value added, minimal pollution, and low energy usage while guiding a diversified consumer demand and putting sustainable growth of industrial structure upgrading into practice. Ultimately, this will increase the level of

inclusive green growth. Finally, the mediating effects of green technology innovation, entrepreneurship level, and industrial structure upgrading accounted for 43.344%, 28.148%, and 28.796%, respectively, of the total effect. The mediating effect of green technology innovation was the greatest, and it played a significant role in the strategy by which inclusive green growth is backed by digitally inclusive finance. The existing measures for improving green technology innovation can help digital financial inclusion effectively promote inclusive green growth.

**Table 9.** Mediation effect test results.

| | igg | Gpatent | Business | ts | igg |
|---|---|---|---|---|---|
| dfii | 0.156 *** (0.025) | 0.830 *** (0.025) | 0.329 *** (0.015) | 0.341 *** (0.015) | 0.066 *** (0.017) |
| gpatent | | | | | 0.047 *** (0.011) |
| business | | | | | 0.077 *** (0.019) |
| ts | | | | | 0.076 *** (0.019) |
| Controls | YES | YES | YES | YES | YES |
| Observations | 2970 | 2970 | 2970 | 2970 | 2970 |

Note: The standard error values are reported in parenthesis. *** symbolize the 1% significance levels, respectively.

## 6. Heterogeneity Analysis

China has various subnational institutional contingencies that are different from each other in terms of regulatory environment and complexities (F. U. Khan et al., 2024c). Considering institutional variations in the Chinese context, digital inclusive finance may exert differing effects on inclusive green growth. In this paper, the effect of the heterogeneity in digital inclusive finance on inclusive green growth in China was examined by considering various factors, such as regional differences, differences in the administrative hierarchy, financial marketization, policy intensity, and environmental regulation as assumed in H5. This research addresses the findings regarding H5 in Tables 10–14.

### *6.1. Analysis of Regional Heterogeneity*

The regional development and their available resources can affect the relation between digital inclusive finance and inclusive green growth in various domains. Therefore, the sample was categorized into western, central, eastern, and northeastern regions for group regressions to examine regional diversity. Table 10 presents the specific findings of the regression analysis.

The findings revealed that fostering inclusive green growth is greatly aided by digital inclusive finance in central and western regions. The values of the coefficients varied significantly by region. The coefficients of the eastern, central, and western data were significantly positive with a 1% significance level, indicating that in these regions, digital inclusive finance maturation is comparatively more advanced. This more notably impacted the promotion of inclusive green growth than in the other regions. In contrast, in the northeastern sample, the role was not significant, signifying that a function of digital inclusive finance varies per area in influencing inclusive green growth. This mainly occurred because the existing economic structure in the northeastern region is relatively insufficient, with traditional industries occupying a large share. Consequently, it is difficult to create a new business environment to transform and upgrade the industry and economic models. This makes it difficult for inclusive growth to promote sustainable and green practices.

**Table 10.** Tests for regional heterogeneity.

| Variable | igg | | | |
|---|---|---|---|---|
| | (1) East | (2) Central | (3) West | (4) Northeast |
| dfii | 0.279 *** | 0.063 ** | 0.149 *** | 0.045 |
| | (0.071) | (0.030) | (0.042) | (0.064) |
| loan | 0.012 | 0.034 | 0.037 | 0.118 |
| | (0.059) | (0.026) | (0.024) | (0.086) |
| urban | 1.308 ** | 0.600 | 1.884 *** | −0.921 |
| | (0.638) | (0.408) | (0.571) | (0.746) |
| gdp | 0.296 ** | 0.613 *** | 0.312 *** | 0.145 |
| | (0.124) | (0.099) | (0.088) | (0.242) |
| tech | 0.134 *** | 0.112 *** | 0.014 | −0.005 |
| | (0.044) | (0.034) | (0.024) | (0.036) |
| Constant | −0.497 | 0.322 | 0.714 *** | 2.756 *** |
| | (0.413) | (0.299) | (0.266) | (0.522) |
| City-fixed effect | YES | YES | YES | YES |
| Time-fixed effect | YES | YES | YES | YES |
| R-squared | 0.960 | 0.903 | 0.884 | 0.838 |
| Observations | 935 | 858 | 803 | 374 |

Note: The standard error values are reported in parenthesis. ** and *** symbolize the 5% and 1% significance levels, respectively.

### 6.2. Analysis of the Administrative Hierarchical Heterogeneity

Cities with a high administrative rank can attract greater factor inflows, increase their resource allocation capacity, and enhance the efficiency of government policy implementation, thus significantly impacting the efficiency of policies pertaining to digital financial inclusion. The sample data were split up into two sets, namely, central cities (municipalities or subprovincial cities) and noncentral cities (prefectural cities), based on the administrative level of cities to explore the different impacts of digital inclusive finance on inclusive green growth caused by differences in administrative levels. The regression analysis results are detailed in Table 11.

**Table 11.** Tests for the administrative hierarchical heterogeneity.

| Variable | igg | |
|---|---|---|
| | (1) Central Cities | (2) Noncentral Cities |
| dfii | 0.516 *** | 0.146 *** |
| | (0.124) | (0.025) |
| Constant | −0.863 | 0.306 * |
| | (1.196) | (0.173) |
| Controls | YES | YES |
| City-fixed effect | YES | YES |
| Time-fixed effect | YES | YES |
| R-squared | 0.944 | 0.928 |
| Observations | 198 | 2772 |

Note: The standard error values are reported in parenthesis. * and *** symbolize the 10% and 1% significance levels, respectively.

Regression analysis results concluded that in both central and noncentral cities, digital inclusive finance significantly boosted inclusive green growth. However, the impact of digital inclusive finance on inclusive green growth was greater in central cities, indicating that the effect varies among cities at different administrative levels. In contrast to those in peripheral cities, the development advantages of digital inclusive finance in central cities are greater and notably impact inclusive green growth. There are two main reasons why central cities are better equipped for development. First, they possess better infrastructure and technology to promote digital inclusive finance and a skilled workforce to facilitate inclusive green growth. Second, central cities can more effectively implement policies and strategies due to their vital strategic planning and execution abilities (F. U. Khan

et al., 2024b). This allows them to better connect various industrial chains and achieve mutual benefits.

### 6.3. Heterogeneity Analysis of the Degree of Financial Marketization

Regions with high levels of financial marketization encompass more developed financial infrastructure and comprehensive support systems. This results in a more transparent and open market where market factors can accurately match the traditional financial supply and demand. Such an environment promotes the expansion of digital inclusive finance. According to previous evidence, two groups were created from the sample depending on financial marketization—high and low levels—using the median of the financial marketization index, after which each group was separately regressed (Zhe et al., 2021). The regression analysis results are detailed in Table 12. The outcomes demonstrated that the coefficients between digital inclusive finance and inclusive green growth are higher and significant in the sample group with greater degrees of financial marketization with a 1% significance level, establishing that increasing the degree of financial marketization ensures the importance of inclusive digital finance in fostering inclusive green growth.

**Table 12.** Tests for heterogeneity in the degree of financial marketization.

| Variable | igg | |
|---|---|---|
| | (1) High Degree of Financial Marketization | (2) Low Level of Financial Marketization |
| dfii | 0.187 *** | 0.173 ** |
| | (0.047) | (0.034) |
| Constant | 0.116 | 0.346 |
| | (0.279) | (0.256) |
| Controls | YES | YES |
| City-fixed effect | YES | YES |
| Time-fixed effect | YES | YES |
| R-squared | 0.957 | 0.950 |
| Observations | 1411 | 1559 |

Note: The standard error values are reported in parenthesis. ** and *** symbolize the 5% and 1% significance levels, respectively.

### 6.4. Analysis of Policy Intensity Heterogeneity

Digital inclusive finance is a new business model created by a new industry and therefore exhibits greater policy dependence. In 2015, China issued the Outline of Action for the Promotion of Big Data Development and established big data comprehensive pilot zones in Guizhou, Beijing, Tianjin, Hebei, Henan, Inner Mongolia, Liaoning, Chongqing, Shanghai, and Guangdong to realize the interoperability of data and to help industrial agglomeration accelerate industrial transformation to vigorously develop the digital economy chain. The growth of digital inclusive finance, which employs digital technology to innovate traditional financial services, may receive varying levels of support from government policies. Therefore, the condition of the pilot city determined the division of the sample into two groups to explore the effects of the policy intensity on the contribution of digital inclusive finance to the promotion of inclusive green growth. The regression analysis results are detailed in Table 13.

The regression analysis results demonstrated that one substantial role that digital financial inclusion plays in achieving inclusive green growth is in both pilot and nonpilot cities. However, the regression coefficient in nonpilot cities was lower than that in pilot cities. This suggests that inclusive green growth is more effectively driven by digitally inclusive finance in the pilot cities of national policy-supported big data comprehensive pilot zones due to the focused expansion of the information technology sector.

**Table 13.** Heterogeneity test for the policy intensity.

| Variable | igg | |
|---|---|---|
| | (1) Pilot City | (2) Nonpilot City |
| dfii | 0.531 *** | 0.121 *** |
| | (0.179) | (0.028) |
| Constant | −0.467 | 0.082 |
| | (0.706) | (0.209) |
| Controls | YES | YES |
| City-fixed effect | YES | YES |
| Time-fixed effect | YES | YES |
| R-squared | 0.979 | 0.941 |
| Observations | 416 | 2554 |

Note: The standard error values are reported in parenthesis. *** symbolize the 1% significance levels, respectively.

### 6.5. Heterogeneity Analysis of Environmental Regulation

In line with Porter's theory, environmental regulations can firmly guide and incentivize enterprises to implement technological innovations and upgrade the greening of their industrial chains. As was previously mentioned, digital inclusive finance can be crucial in reducing the liquidity threshold for green technological innovation (Y. Wang et al., 2023b). Companies motivated by environmental regulations are encouraged to access credit funds and invest in high-value production activities, leading to increased levels of inclusive green growth. We obtained data on industrial wastewater, industrial sulfur dioxide, and industrial soot emissions from the statistical yearbook of each city. We adopted the entropy weighting method to determine the environmental regulatory intensity composite index. The sample was split into two categories due to each year's median. The group with a high ecological regulation intensity comprises samples with an environmental pollution index lower than the annual median. Conversely, the group with a low environmental regulation intensity comprises samples with an ecological pollution index greater than or equal to the annual median. We then performed grouping regression, and the results are listed in Table 14.

**Table 14.** Tests of heterogeneity in environmental regulation.

| Variables | igg | |
|---|---|---|
| | (1) High Intensity of Environmental Regulation | (2) Low Intensity of Environmental Regulation |
| dfii | 0.171 *** | 0.131 ** |
| | (0.039) | (0.030) |
| Constant | −0.106 | 0.573 |
| | (0.271) | (0.229) |
| Controls | YES | YES |
| City-fixed effect | YES | YES |
| Time-fixed effect | YES | YES |
| R-squared | 0.952 | 0.901 |
| Observations | 1569 | 1401 |

Note: The standard error values are reported in parenthesis. ** and *** symbolize the 5% and 1% significance levels, respectively.

Research has shown that digital financial inclusion can significantly enhance urban inclusive green growth (Shen et al., 2024; Sun et al., 2024), particularly in locations with high standards of environmental control. While positive effects were observed in cities where environmental regulations are negligent, they were less notable than those in areas with high ecological regulation. This was reflected by the regression coefficient, which is higher and significant at the 1% significance level in regions with a high environmental regulations intensity than in regions with a low intensity. There were variations in the ways that inclusive green growth was urged on by digital inclusive finance in environments with

varying levels of environmental regulation. This suggests that under a high environmental regulatory intensity, the government can signal to the market to encourage stakeholders to more quickly promote green technological innovations. Under this scenario, corporate credit limits can be loosened, and inclusive green growth can be encouraged with the aid of digital inclusive finance.

## 7. Policy Implications

The study proposes the following policy recommendations, developed based on its findings: implementing targeted measures to enhance digital financial inclusion, fostering sustainable economic practices to support inclusive green growth, and addressing structural inequalities through policies that promote equitable access to financial resources and environmentally responsible innovation. First, with the continuous cross-fertilization of finance and technology and the amplification of financial regulatory risks, policymakers should actively balance the risks and innovations of digital inclusive finance and establish relevant market rules and regulations to prevent systemic risks for creating a strong base considering the root cause of the development of digital inclusive finance business. They should strengthen the coverage of digital infrastructure in remote and underdeveloped areas according to local conditions, popularize digital inclusive financial services and knowledge to enhance the depth of the use of digital inclusive finance and the recognition and trust among residents in digital inclusive financial tools, and expand digital technology and its capital investment to increase the degree of digitization and efficiently empower micro and small-sized groups in green business activities.

Second, to achieve green growth, it is essential to promote industry–university–research cooperation. This can help in developing innovative green technologies, which should be self-sustainable and continuously improved through research and development. Enhancing green entrepreneurship is crucial for shifting industrial structures toward sustainability. In such a case, digital inclusive finance can play a key role in this transformation by providing wider financial access, fostering innovation in the green sector, and supporting environmentally responsible business practices. By promoting digital financial tools, cities can accelerate inclusive green growth and drive sustainable economic development.

Third, to advance inclusive and green quality development of cities, we can start by improving the administrative efficiency of government directives, promoting the degree of financial marketization, assisting the implementation of policies connected to digital financial inclusion, and enhancing the binding force of environmental rules and regulations to alleviate the problem of unbalanced regional development due to the environment's and resources' combined restrictions. Finally, to address the lack of effectiveness of digital financial inclusion in different regions, policymakers should accelerate the modernization of education and focus on enhancing the digital financial literacy of underprivileged consumers to avoid the emergence of the Matthew effect, where wealth and opportunities disproportionately accumulate among those already advantaged. By improving digital financial literacy, underprivileged consumers can better participate in and benefit from the digital economy, ensuring more equitable growth. This approach not only promotes financial inclusion but also helps mitigate the risk of widening inequality, fostering a more balanced and sustainable economic development.

## 8. Conclusions

Considering the case of China that shifts from an investment-driven to an innovation-led economy, technological advancements and digital transformation play a pivotal role in driving inclusive green growth and sustainable development. Digital inclusive finance, as an important factor of this transformation, enables equitable access to financial services for

underserved populations and businesses, fostering economic participation and innovation. By bridging gaps in resource allocation and supporting green initiatives, these advancements contribute to both industrial efficiency and environmental sustainability, aligning with the goals of an innovation-led and globally competitive economy. As a key growth driver of industrial digitization in the digital economy, can digital inclusive finance promote sustainable, inclusive, and green growth in China's cities? Our research provides in-depth empirical analyses to explore the role of digital inclusive finance in driving inclusive green growth and its underlying mechanisms, using data from 270 Chinese cities between 2011 and 2021. Additionally, a multi-dimensional heterogeneity analysis of the research subjects is conducted. The estimation analysis established that digital inclusive finance significantly promotes regional inclusive green growth, primarily through enhancing green technology innovation, boosting entrepreneurship, and facilitating industrial structure upgrades, with green technology innovation being the key driver. There are noticeable regional disparities in the impact of digital financial inclusion on equitable green development. The regional analysis shows that there is a noticeable effect of digital financial inclusion on equitable green development in cities. The eastern, midwestern, and western regions indicate a considerable favorable impact on inclusive green growth through digital financial inclusion, with the eastern region exhibiting the greatest impact. However, the northeastern region does not demonstrate a statistically significant effect. Finally, the analysis suggests that inclusive green growth is more effectively driven by digitally inclusive finance in central and pilot cities and areas with higher environmental regulations and with a high degree of financial marketization.

*Limitations*

Our research investigates the impact of digital financial inclusion on inclusive green growth in China but has some limitations. For instance, this research has considered the Chinese context for the case study, where institutional policies and regulations differ from those in other countries, potentially limiting the generalizability of the findings. Secondly, future research could expand upon these findings by employing more comprehensive models, such as investigating the moderating effects of the digital divide and other regional factors to offer a broader perspective on the relationship between digital finance and inclusive green growth.

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## Note

[1] https://idf.pku.edu.cn/index.htm (accessed on 26 March 2017).

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