

Article

Impact of Digital Inclusive Finance on Urban Carbon Emission Intensity: From the Perspective of Green and Low-Carbon Travel and Clean Energy

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Abstract: This paper uses the non-balanced panel data of 285 prefecture-level cities in China from 2011 to 2017 and the Peking University Digital Inclusive Finance Index to examine the impact of the development of digital inclusive finance on urban carbon emission intensity. The results show that the development of digital inclusive finance has a significantly negative impact on urban carbon emission intensity. By using the spherical distance between various cities and Hangzhou as an instrumental variable to deal with the potential endogeneity problem, the results still hold. Mechanism analysis shows that digital inclusive finance can reduce urban carbon emission intensity by promoting green and low-carbon travel modes of public transport and the use of clean energy. Compared with other regions, the effect of digital inclusive finance in reducing urban carbon emission intensity is more significant in the western region and in cities with low economic development. Against the background of the carbon peaking and carbon neutrality goals, we find that accelerating the development of digital inclusive finance can effectively promote the green and low-carbon transition of cities.

Keywords: digital inclusive finance; carbon emission intensity; green and low-carbon travel; clean energy; green and low-carbon transition



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1. Introduction

Since the United Nations Climate Change Conference in 2005, the proposal for inclusive finance has received high attention from various countries. Inclusive finance refers to following the requirements of equal opportunity and the principle of commercial sustainability and providing appropriate and effective financial services to all sectors and groups in a society that have a need for financial services by increasing policy guidance and support, strengthening the construction of the financial system, and improving the financial infrastructure. Digital inclusive finance refers to all actions that promote inclusive finance through the use of digital financial services. Digital inclusive finance is an important component of inclusive finance, which is dedicated to serving small and medium-sized enterprises, as well as the general public. According to an analysis report of China's inclusive finance indicators published by the People's Bank of China, in recent years, with the rapid development of information science and technology, such as Internet, big data, and cloud computing, China's digital inclusive finance has also experienced significant growth, which includes the widespread application of technologies such as digital currency and internet credit reporting systems. For example, commercial banks in China have increased the application of digital technology in the field of inclusive finance, built digital banks, and provided more convenient and accessible financial products and services. The development of digital inclusive finance has not only transformed people's lifestyles in terms of consumption, investment, and payment but also, more significantly, has helped to reduce the financing costs of small and medium-sized enterprises, broaden financing

channels, and effectively alleviate financing constraints. Furthermore, the development of China's digital inclusive finance has also directed more idle social funds toward remote and poor areas, facilitating more rational resource allocation.

The relationship between inclusive digital finance and economic development has been examined by many scholars. Jiang et al. (2021) [1] discovered that digital finance can promote economic growth by improving regional entrepreneurship. Shen et al. (2021) [2] found that inclusive digital finance can stimulate national economic growth and have spatial spillover effects on neighboring countries. Wang et al. (2022) [3] discovered that inclusive digital finance can promote economic growth by increasing residents' income, augmenting government expenditure, and enhancing education levels. Lee et al. (2023) [4] found that inclusive digital finance can promote high-quality business development to drive economic growth.

In recent years, carbon emissions have become a major concern of governments around the world. At the 75th United Nations General Assembly in September 2020, China formally proposed the goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060. According to the State Council of China, as the world's second-largest economy, China faces significant challenges in achieving its dual-carbon goals while balancing economic development. As carbon emission intensity (the ratio of carbon dioxide emissions to GDP) effectively portrays the degree of dependence of economic development on high-carbon forms of energy, conducting a comprehensive and objective analysis of the influencing factors and mechanisms behind China's carbon emission intensity is fundamental for realizing China's green and low-carbon economic transformation.

This study is an empirical analysis of the impact of digital inclusive finance on urban carbon emission intensity using a two-way fixed effects panel data model. It is found that the development of digital inclusive finance can affect urban carbon emission intensity by promoting green and low-carbon travel and clean energy use in cities.

The two main contributions of this study are: (a) it enriches the research on the impact of digital inclusive finance on carbon emission intensity and extensively examines the endogeneity issues and robustness tests to ensure the reliability of empirical results; and (b) it innovatively explores the impact mechanisms of digital inclusive finance on carbon emission intensity from the perspectives of green low-carbon travel and clean energy use, providing a scientific reference basis for formulating development policies for China's urban green and low-carbon transition.

The rest of this paper runs as follows. Section 2 consists of a literature review. Section 3 presents the research hypotheses. Section 4 discusses the materials and methods. Section 5 contains the results and discussion. Section 6 provides the conclusion.

2. Literature Review

The literature relevant to this study can be classified into three categories. The first category is the literature on financial development. It is widely acknowledged by scholars that financial development can promote economic growth (Saint Marc, 1970; King and Levine, 1993; Levine et al., 2000) [5–7]. The critical rationale behind the positive relationship between financial development and economic growth is its ability to optimize resource allocation and reduce a firm's financing constraints. Greenwood and Jovanovic (1990) [8] verify that financial intermediaries can channel capital to places with higher capital return rates, thus optimizing the efficiency of capital allocation and promoting economic growth. Rajan and Zingales (1998) [9] confirm that financial development can promote economic growth by reducing external financing costs for firms and find that industrial sectors with greater external financing needs tend to grow faster in countries with more developed financial markets. Estrada et al. (2010) [10] conduct an empirical study on 125 developing Asia countries from 1987 to 2008 and found that financial development has a significant positive effect on economic growth. They further find that financial development propels economic growth by improving the efficiency of investment.

In recent years, as environmental issues have gained attention, scholars have also focused on the impact of financial development on carbon emissions and other related aspects. One perspective suggests that financial development can contribute to reducing carbon emissions. Liberalization and financial openness can increase FDI in domestic green energy enterprises, bringing environmentally friendly, innovative, and green technologies from developed countries into developing countries, thereby reducing their carbon emissions (Zaidi et al., 2019; Zafar et al., 2021) [11,12]. However, another perspective argues that financial development can increase carbon emissions or have no significant impact. Ozturk and Acaravci (2013) [13] explore the causal relationship among financial development, foreign trade, economic growth, energy consumption, and carbon emissions in Turkey from 1960 to 2007. They find that in the long-term, the impact of financial development on per capita carbon emissions in Turkey was not significant. Acheampong et al. (2020) [14] conducted an empirical analysis of the comprehensive panel data of 83 countries from 1980 to 2015. They found that financial development reduces the intensity of carbon dioxide emissions in developed and emerging financial economies but increases the level of carbon dioxide emissions in frontier financial economies. In summary, the impact of financial development on carbon emissions needs to be considered and analyzed for different countries, different time dimensions, and different impact mechanisms.

The second category is literature on digital inclusive finance. Most of the research on digital inclusive finance focuses on its impact on economic growth. A prevailing perspective is that the development of digital inclusive finance can stimulate economic growth (Ahmad et al., 2021) [15]. According to Liu et al. (2021) [16], digital inclusive finance can promote China's economic growth by improving the startup of small and medium-sized enterprises as well as enhancing household consumption, and this promotion effect has an Internet threshold effect. Sun and Tang (2022) [17] show that with the assistance of emerging technologies, such as Internet, mobile payment, and digital currency, digital inclusive finance can promote economic growth through three channels: increasing the lending capacity of financial institutions, boosting household savings, and raising the consumption level of residents. Ding et al. (2022) [18] show that digital inclusive finance can promote economic growth in China by enhancing environmental regulations, with the largest growth impact in the central region. In addition, digital inclusive finance not only has a macro-level impact on economic growth but also affects individuals at the micro-level. Yu et al. (2021) [19] discover that digital inclusive finance can promote consumption upgrading among rural residents in China by increasing income, alleviating liquidity constraints, and improving payment convenience. Li and Li (2022) [20] demonstrate that the development of digital inclusive finance can drive urban innovation.

In the context of global advocacy for the transition toward low-carbon energy in various countries, scholars have also explored the impact of digital inclusive finance on carbon emissions. Qin et al. (2021) [21] conduct a panel quantile regression analysis of E7 countries and found that the development of inclusive finance can reduce carbon dioxide emissions at the 20th and 50th percentile levels. Li et al. (2020) [22] contend that digital inclusive finance can improve the efficiency of energy allocation by enhancing the efficiency of financial services, reducing information costs, and alleviating the problem of information asymmetry. Lee and Wang (2022) [23] conducted empirical analyses on panel data from 277 Chinese cities and found that digital inclusive finance can lower carbon emission intensity through two mechanisms: optimizing industrial structure and promoting green technology.

The third category is the literature on carbon emission intensity. Due to differences in economic scale, the total amount of carbon emission reduction may not necessarily measure the effectiveness of carbon reduction. Therefore, carbon emission intensity, which reflects the degree of carbon dependency in economic development as the amount of carbon dioxide emitted per unit of economic growth, has been widely used in academic research (Fan et al., 2007; Zhang et al., 2019) [24,25]. Most of the literature on carbon emission intensity focuses on studying the influencing factors and mechanisms that affect

its changes. Zhang (2009) [26] conducts a structural decomposition analysis on the historical changes in China's carbon emission intensity and finds that the main reason for the decline in carbon emission intensity from 1992 to 2002 was due to changes in production patterns in various sectors, which reduced energy intensity. Cheng et al. (2018) [27] confirms that technological progress can indirectly lower carbon emission intensity in China by promoting the upgrading and optimization of industrial structure.

In summary, most of the existing literature explores the impact of digital inclusive finance on carbon emissions from the perspectives of improving energy allocation efficiency, reducing carbon emission intensity, digital technology industrialization, and optimizing industrial structure. However, there is still a limited amount of literature that analyzes the impact of digital inclusive finance on urban carbon emission intensity from the perspective of green and low-carbon travel and clean energy use. Therefore, this study aims to analyze the impact of digital inclusive finance on urban carbon emission intensity from the perspectives of green and low-carbon travel and clean energy use.

3. Research Hypotheses

Digital inclusive finance has the dual characteristics of digitization and inclusive finance, both of which contribute to the reduction of carbon emissions in urban areas. Firstly, digitization increases the convenience of financial services and reduces various service costs and resource consumption. The development of digital inclusive finance greatly enhances the convenience of financial services for people. Furthermore, increasing the accessibility of financial services will improve the convenience of corporate financing channels and thereby reduce the operational costs of enterprises and the amounts of carbon emissions generated by enterprise personnel traveling to and from financial institutions for borrowing and lending purposes (Yin et al., 2019) [28]. Li et al. (2020) [22] also point out that the emergence of mobile payments not only makes payments more convenient but also greatly reduces transaction costs and resource consumption. Irimiás and Mitev (2020) [29] explored the relationship between digital technology and the green development of enterprises and found that the application of digital technology can guide entrepreneurs to promote green development. Secondly, the development of inclusive finance has a negative effect on urban carbon emissions. Zaidi (2021) [30] found, through empirical research in 21 OECD countries, that there is a negative correlation between the development of inclusive finance and carbon emissions. Therefore, our first hypothesis is:

H1. *The impact of digital inclusive finance on urban carbon emission intensity is negative.*

According to China UnionPay data, as of September 2018, UnionPay mobile payment products support public transportation in more than 400 cities and counties in China. The development of digital inclusive finance has greatly increased the coverage of mobile payments. Technologies such as mobile payments are now widely integrated with public transportation, improving convenience and reducing travel costs for urban residents. As a result, people are more inclined to choose convenient and low-cost public transportation (Brakewood et al., 2020) [31]. Therefore, the development of digital inclusive finance promotes the use of public transportation as a green travel mode by increasing the coverage of mobile payments. Public transportation, as the main tool for green and low-carbon travel, has a protective and restorative effect on the environment. The per capita carbon emissions and harmful gas emissions of public transportation are much lower than those of private cars, and the large passenger capacity of public transportation can significantly reduce the use of private cars (Dong et al., 2018; Jing et al., 2022) [32,33]. At the practical level, China's inclusive financial practices have gradually expanded from initial philanthropic microcredit to encompassing comprehensive financial services such as payment and credit, including the development of platforms such as Alipay. In 2014, Alipay announced that it could recharge bus passes and offer discounts for taking public transportation. Therefore, our second hypothesis is:

H2. *Digital inclusive finance will reduce urban carbon emissions by promoting green and low-carbon travel.*

In China, the green economy is a new model of economic development that is strongly advocated, and increasing the use of clean energy is the main goal of the green economy, which cannot be separated from the help of digital inclusive finance. Therefore, with the development of digital inclusive finance, traditional energy will be green upgraded, and the use of clean energy will increase. Digital inclusive finance has the potential to promote corporate green innovation by alleviating financing constraints and rationally allocating financial resources (Xue and Zhang, 2022) [34]. Chen (2022) [35] found that the digital economy can promote the use of urban clean energy through two mechanisms: green technological innovation and urban bank loans. Therefore, digital inclusive finance can promote the use of clean energy by driving corporate green innovation. The use of clean energy is one of the most effective ways to reduce urban carbon emissions. Clean energy has significant positive effects on reducing urban carbon emissions due to its environmental friendliness, renewability, and low pollution levels (Dovì et al., 2009; Lin and Li, 2022) [36,37]. Based on the above theoretical analysis, our third hypothesis is:

H3. *Digital inclusive finance can reduce urban carbon emissions by promoting the use of clean energy sources.*

4. Materials and Methods

4.1. Data and Variables

The dependent variable was the carbon emission intensity (*CEI*) of prefecture-level cities. Carbon emission intensity is defined as the ratio of carbon dioxide emissions to GDP, also known as unit GDP carbon emissions. As this indicator takes into account the dual objectives of economic growth and ecological protection, it is commonly used to measure the degree of a country's economic dependence on carbon-emitting economic activities.

The independent variable was the Peking University Digital Inclusive Finance Index (*DIFI*), which is compiled jointly by the Peking University Digital Finance Research Center and Ant Financial. This index consists of three dimensions: breadth of digital financial coverage, depth of digital financial use, and degree of digitalization of financial inclusion, with 33 specific indicators. This index has the following advantages: firstly, it takes into account the breadth and depth of digital financial services; secondly, it takes into account both vertical and horizontal comparability; thirdly, it reflects the multi-layered and diversified nature of digital financial services. This index comprehensively reflects the development of digital inclusive finance in different regions of China. It is widely used by scholars to measure the development level of digital inclusive finance in China.

To control for the impact of other factors, such as regional macroeconomic conditions on carbon emission intensity, the following control variables were selected in this study: (1) level of economic development (*ECON*): GDP per capita (10^3 CNY/person); (2) industry structure (*IS*): the ratio of gross tertiary product to GDP; (3) government intervention (*GI*): the ratio of government fiscal expenditure to GDP; (4) level of openness (*OPEN*): the ratio of real foreign investment to GDP; (5) urban population (*POP*): total population at the end of the year by prefecture-level city, natural logarithm; (6) degree of urbanization (*URBAN*): the ratio of urban labor force to total labor force; (7) per capita green space area (*GREEN*): the ratio of urban green space to total population (10^{-3} square meter/person).

This study analyzes the impact of digital inclusive finance on carbon emission intensity from the perspective of green low-carbon travel and clean energy use in China. Therefore, the total number of passengers transported on public buses (*BUS*) per year was selected as a proxy variable for green low-carbon travel, and the total supply of liquefied petroleum gas (*LPG*) was selected as a proxy variable for clean energy use.

The data were sourced mostly from the China Energy Statistical Yearbook and the China City Statistical Yearbook. The Peking University Digital Inclusive Finance data was sourced from the Peking University Digital Finance Research Center. To make the sample

data more representative, we processed the sample data as follows: First, we excluded samples with missing data in major variables, then excluded data from prefecture-level cities that have undergone regional mergers. Lastly, we excluded data from Hong Kong, Macau, and Taiwan. After this processing, the final sample was comprised of 1991 annual city-level observations spanning 2011 to 2017.

Table 1 presents the fundamental statistical characteristics of the main variables. To facilitate empirical research calculations and mitigate the heteroscedasticity of the model, logarithmic transformations were applied to non-proportional variables.

Table 1. Descriptive statistics.

Variable	Definition	Obs.	Mean	Std. Dev.	Min	Max
CEI	Carbon emission intensity	1991	0.0572	0.0651	0.0016	0.7398
DIFI	Digital inclusive finance development	1991	4.8646	0.5044	2.8344	5.6450
BUS	Total number of passengers transported on public buses per year	1991	9.0935	1.3170	3.7136	13.1527
GAS	Total supply of LPG	1991	9.1601	1.5696	1.3863	13.8438
ECON	Level of economic development	1991	71.6959	55.2623	7.9983	568.8359
IS	Industry structure	1991	0.4454	0.1133	0.1015	0.8056
GI	Government intervention	1991	0.1769	0.1002	0.0339	1.4278
OPEN	Level of openness	1991	0.0572	0.1379	0.0000	1.8304
POP	Urban population	1991	4.6482	0.7774	2.7147	7.6634
URBAN	Degree of urbanization	1991	41.7703	82.3535	0.0002	2452.3
GREEN	Per capita green space area	1991	0.0463	0.0470	0.0004	0.4344

Figure 1 displays the mean of the digital inclusive finance index in China from 2011 to 2017. As can be seen from Figure 1, the overall level of development of digital inclusive finance in China is on an upward trend.

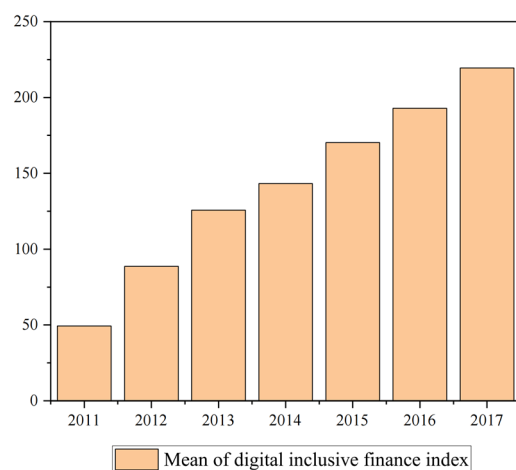


Figure 1. The mean of the digital inclusive finance index in China, 2011–2017.

Figure 2 shows the breadth of coverage and the depth of use of digital finance in China from 2011 to 2017. The data were from the Peking University Digital Finance Research Center and were all in index form. Breadth of use reflects the reach of digital inclusive finance, and depth of use reflects the actual use of digital inclusive finance. As can be seen from Figure 2, from 2011 to 2017, China's digital inclusive finance has continued to grow in terms of both breadth and depth dimensions.

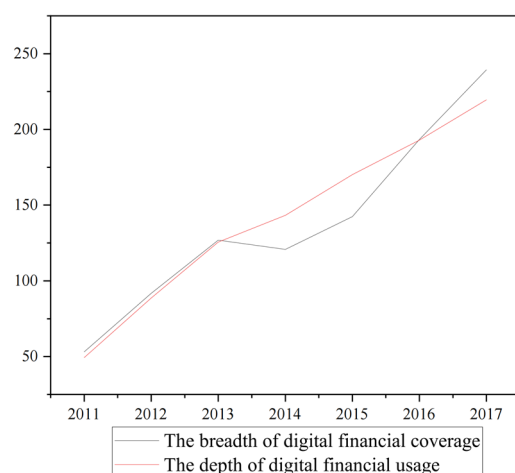


Figure 2. The breadth of coverage and depth of use of digital finance in China, 2011–2017.

4.2. Econometric Models

We used a two-way fixed-effects panel data model to analyze the impact of digital inclusive finance on urban carbon emission intensity. The factors that influence urban carbon emission intensity include not only observable factors such as industrial structure, government intervention, degree of openness, urban population, degree of urbanization, and per capita green space area but also unobservable factors such as regional development concepts. The use of a two-way fixed-effects model can control for unobservable regional factors and improve the accuracy of model estimation. The following regression model was constructed to analyze the impact of digital inclusive finance on urban carbon emission intensity:

$$CEI_{it} = \beta_0 + \beta_1 DIFI_{it} + \sum \beta_j X_{it} + city_i + year_t + \mu_{it} \quad (1)$$

where the dependent variable CEI_{it} represents the carbon emission intensity of city i in year t , while the independent variable $DIFI_{it}$ represents the level of digital inclusive finance of city i in year t , measured by the Peking University Digital Inclusive Finance Index. The control variables, X_{it} , include level of economic development, industrial structure, government intervention, degree of openness, urban population, degree of urbanization, and per capita green space area. The term $city_i$ represents individual fixed effects for each city, $year_t$ represents time fixed effects, and μ_{it} represents the error term.

In order to test the mechanism of the impact of digital inclusive finance on the intensity of carbon emissions in urban areas, we introduced the total number of passengers transported on public buses per year in cities as a mediating variable, thereby examining the hypothesis that digital inclusive finance can reduce the urban carbon emission intensity through the mechanism of green and low-carbon travel. The model for testing the mediating effect mechanism is presented as follows:

$$BUS_{it} = \beta_0 + \beta_1 DIFI_{it} + \sum \beta_j X_{it} + city_i + year_t + \mu_{it} \quad (2)$$

$$CEI_{it} = \beta_0 + \beta_1 DIFI_{it} + \beta_2 BUS_{it} + \sum \beta_j X_{it} + city_i + year_t + \epsilon_{it} \quad (3)$$

where BUS_{it} represents the total number of passengers transported on public buses in city i in year t .

Then, we also introduced the total supply of LPG to cities as a mediating variable for testing the hypothesis that digital inclusive finance can reduce urban carbon emission intensity by promoting the use of clean energy.

$$LPG_{it} = \beta_0 + \beta_1 DIFI_{it} + \sum \beta_j X_{it} + city_i + year_t + \mu_{it} \quad (4)$$

$$CEI_{it} = \beta_0 + \beta_1 DIFI_{it} + \beta_2 LPG_{it} + \sum \beta_j X_{it} + city_i + year_t + \varepsilon_{it} \quad (5)$$

where LPG_{it} represents the total annual supply of LPG for city i at year t .

5. Results and Discussion

5.1. Benchmark Regression Results

Table 2 presents the regression results of the fixed-effect model (1) examining the impact of digital inclusive finance on urban carbon emission intensity. Column (1) displays the regression outcome without the inclusion of control variables. Column (2) exhibits the regression outcome with the incorporation of control variables. Column (3) demonstrates the regression outcome of the clustered standard errors at the city level. All three regressions have accounted for the fixed effects of both city and year.

Table 2. Benchmark regression results.

Variables	(1) CEI	(2) CEI	(3) CEI
DIFI	−0.0308 *** (0.0041)	−0.0436 *** (0.0034)	−0.0436 *** (0.0083)
ECON		−0.0000 *** (0.0000)	−0.0000 *** (0.0000)
IS		0.0719 *** (0.0085)	0.0719 ** (0.0334)
GI		0.0880 *** (0.0069)	0.0880 (0.0403)
OPEN		0.0452 *** (0.0046)	0.0452 ** (0.0190)
POP		−0.0275 *** (0.0022)	−0.0275 *** (0.0057)
URBAN		−0.0000 *** (0.0000)	−0.0000 * (0.0000)
GREEN		−0.0163 (0.0146)	−0.0163 (0.0160)
Constant	0.1897 *** (0.0158)	0.3310 *** (0.0195)	0.3310 *** (0.0527)
Observations	1991	1991	1991
R ²	0.2563	0.5080	0.5080
Year FE	Yes	Yes	Yes
City FE	Yes	Yes	Yes

Note: *, **, and *** indicate significance at the levels of 10%, 5%, and 1%, respectively. FE denotes fixed effects. Standard errors are in parentheses.

The empirical results indicate that the coefficient of Peking University's digital inclusive finance index is negative at the significance level of 1% in all three regression results, indicating a significant negative effect of digital inclusive finance development on urban carbon emission intensity. Thus, Hypothesis 1 holds. From an economic standpoint, taking the regression outcome of column (2) as an example, given the natural logarithm transformation of the digital inclusive finance index, a 1% increase in digital inclusive finance development in a city is associated with a decrease of 0.000436 million tons/CNY in urban carbon emission intensity.

5.2. Endogeneity Issue

To ensure their accuracy, the regression analysis results summarized above require the fundamental assumption that digital inclusive finance is an exogenous variable. Although this study employs methods such as a two-way fixed-effects panel model and control variables to reduce model errors, the estimation process may still be subject to endogeneity bias due to omitted variables and reverse causality. To mitigate this endogeneity issue, we used instrumental variable methods.

In this study, we utilized the cross-interaction of the spherical distance from Hangzhou to various prefecture-level cities and the national average of the digital inclusive finance index (IV) as an instrumental variable. This instrumental variable satisfies the two constraints of relevance and exogeneity. Firstly, Hangzhou is at the forefront of digital inclusive finance development in China, with digital finance represented by Alipay, originating from Hangzhou and spreading to other parts of the country. Therefore, it is expected that the closer the spherical distance between a prefecture-level city and Hangzhou, the higher the level of digital inclusive finance development. Secondly, the spherical distance between prefecture-level cities and Hangzhou is unlikely to affect urban carbon emission intensity significantly, mainly due to the fact that carbon dioxide emissions are not influenced by spherical distance. The first column of Table 3 shows a significant negative correlation between the spherical distance instrumental variable and the digital inclusive finance index, indicating that the farther the prefecture-level city is from Hangzhou, the lower the level of digital inclusive finance development, which is consistent with our expectation.

Table 3. Results of the instrumental variable regression analysis.

Variables	(1) DIFI	(2) CEI
IV	−0.0553 *** (0.0042)	
DIFI_IV		−0.0489 ** (0.0210)
Constant	3.5122 *** (0.0271)	0.3268 *** (0.0758)
Control variables	Yes	Yes
Observations	1991	1991
R ²	0.9460	0.4619
Year FE	Yes	Yes
City FE	Yes	Yes
The first stage F-statistic		175.193
<i>p</i> -value for the Durbin-Watson-Hausman test		0.3168

Note: ** and *** indicate significance at the levels of 5% and 1%, respectively.

The regression results of the instrumental variable two-stage least squares (TSLS) are reported in column (2) of Table 3. The effectiveness of the instrumental variable was analyzed first. Firstly, the F-statistic value of the weak instrument test was greater than 10, rejecting the null hypothesis of weak instruments, indicating no weak instrument problem. Secondly, in the endogeneity test of the instrumental variable, the *p*-value of the endogeneity test statistic was greater than 0.10, indicating acceptance of the null hypothesis that the instrumental variable is exogenous. In summary, the selected instrumental variable in this study was effective. The regression results of the instrumental variable were then analyzed. It can be observed from the results in column (2) that the coefficient of digital inclusive finance remained negative and significant, indicating that the development of digital inclusive finance can significantly reduce urban carbon emission intensity, which is consistent with the previous results.

5.3. Robustness Tests

5.3.1. Substitution of Explanatory Variables

In this study, the usage depth of digital finance (*DIFI_DEPTH*) was employed as a substitute for the explanatory variable. The usage depth of digital finance includes payment services, monetary fund services, credit services, insurance services, investment services, and credit services, which more specifically reflect the level of development of urban digital inclusive finance. The data source was the Digital Finance Research Center of Peking University. As shown in columns (1) and (2) of Table 4, although the coefficient of the usage depth of digital finance without control variables in the regression was not significant, its regression coefficient was significantly negative at the 1% level after adding control variables, indicating that the development of digital inclusive finance still has a significant negative impact on urban carbon emission intensity and the results remain robust.

Table 4. Regression results with Replacement and Control variables.

Variables	(1) CEI	(2) CEI	(3) CEI	(4) CEI
DIFI_DEPTH	−0.0044 (0.0028)	−0.0132 *** (0.0023)		
DIFI			−0.0308 *** (0.0041)	−0.0431 *** (0.0034)
ROAD				−0.1747 ** (0.0689)
Constant	0.0868 *** (0.0109)	0.1989 *** (0.0167)	0.1897 *** (0.0158)	0.3339 *** (0.0195)
Control variables	No	Yes	No	Yes
Observations	1991	1991	1991	1991
R ²	0.2321	0.4707	0.2563	0.5098
Year FE	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes

Note: ** and *** indicate significance at the levels of 5% and 1%, respectively.

5.3.2. Addition of Control Variables

Omitted variable bias is a common issue in empirical analysis. To mitigate this, this study adds per capita urban road area (*ROAD*) as a control variable. The increase in per capita urban road area leads to an increase in transportation routes, which in turn leads to an increase in the use of public transportation by urban residents, further reducing urban carbon emissions. Table 4, columns (3) and (4) show the regression results after adding per capita urban road area as a control variable. The coefficient of digital inclusive finance is still significantly negative at the 1% level, indicating that the development of digital inclusive finance still has a significant negative impact on urban carbon emission intensity, and the results remain robust.

5.3.3. Incorporating High-Dimensional Fixed Effects

To control for the year-to-year variations in regional carbon emissions, this study includes province–year interactions as high-dimensional fixed effects. Table 5 displays the regression results of the province–year fixed effects, where the coefficient of digital inclusive finance is significantly negative at the 1% level in both regressions, consistent with the previous findings, and the results remain robust.

Table 5. Regression results for the high-dimensional fixed effects.

Variables	(1) CEI	(2) CEI
DIFI	−0.1695 *** (0.0096)	−0.0733 *** (0.0119)
Constant	0.8819 *** (0.0470)	0.4882 *** (0.0547)
Control variables	No	Yes
Observations	1991	1991
R ²	0.4223	0.6233
Year FE	Yes	Yes
City FE	Yes	Yes
Province × Year FE	Yes	Yes

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

5.4. Heterogeneity Analysis

5.4.1. Regional Heterogeneity Analysis

China's vast territory and uneven distribution of resources have resulted in varying levels of economic development across regions, thus leading to an imbalance in the development of digital inclusive finance in different areas. In order to further analyze the regional differences in the impact of digital inclusive finance on urban carbon emission intensity, we divided the entire sample into the eastern, western, and central regions based on the provinces where the prefecture-level cities are located, using dummy variables, and conducted a regional heterogeneity analysis by multiplying them with the digital inclusive finance index.

The first column of Table 6 displays the regression results by region. Taking the eastern region as the base category, the results show that the estimated coefficient of digital inclusive finance is negatively significant at the 1% level, indicating a significant negative effect of the development of digital inclusive finance on urban carbon emission intensity in the eastern region. Moreover, the estimated coefficients of the interaction terms between digital inclusive finance and the western and central regions are also negatively significant at the 1% level, suggesting that the development of digital inclusive finance in these regions has a more significant effect on reducing urban carbon emission intensity compared to the eastern region. This is mainly because, relative to the central and western regions, the eastern region is more economically developed and has a higher level of digital inclusive finance, with limited upward potential, thus resulting in a smaller marginal negative effect on urban carbon emission intensity.

Table 6. Results of heterogeneity analysis.

Variables	(1) CEI	(2) CEI
DIFI	−0.0342 *** (0.0042)	−0.0215 *** (0.0011)
DIFI × WEST	−0.0047 *** (0.0015)	
DIFI × CENTRAL	−0.0057 *** (0.0015)	

Table 6. Cont.

DIFI × Medium GDP		0.0079 *** (0.0013)
DIFI × High GDP		0.0174 *** (0.0015)
Constant	0.3147 *** (0.0200)	0.2541 *** (0.0096)
Control variables	Yes	Yes
Observations	1991	1991
R ²	0.5125	0.5037
Year FE	Yes	Yes
City FE	Yes	Yes

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

5.4.2. Heterogeneity Analysis of Economic Development

As a result of variations in economic development among regions, the reliance on high-carbon forms of energy in economic development also differs significantly. Moreover, the impact of the development of inclusive digital finance on the intensity of carbon emissions in regions with varying degrees of economic development also differs. We divided the entire sample into three distinct regions with different levels of economic development, namely low, medium, and high, based on the gross domestic product of each prefecture-level city. The heterogeneity of economic development is analyzed by multiplying these regions with the index of inclusive digital finance.

The second column in Table 6 presents the regression results by level of economic development. Using the low level of economic development as the base category, the results show that the estimated coefficient of the inclusive digital finance variable is significantly negative at the 1% level. This indicates a significant negative effect of the development of inclusive digital finance on the carbon emission intensity in regions with low economic development. The results also show that the estimated coefficients of the interaction terms between inclusive digital finance and medium and high levels of economic development are both significantly positive at the 1% level. This suggests that as the level of economic development rises, the negative effect of inclusive digital finance on the carbon emission intensity in cities gradually decreases. The main reason for this could be that regions with high levels of economic development rely more on high-end manufacturing and financial services, and their dependence on high-carbon forms of energy for economic growth is relatively low. Therefore, the development of inclusive digital finance has a less significant effect on reducing carbon emissions in these regions. In contrast, regions with lower levels of economic development have mainly traditional industries, and their dependence on high-carbon forms of energy for economic growth is higher. Therefore, the development of inclusive digital finance has a more significant effect on reducing carbon emissions in these regions.

5.5. Mechanism Test

5.5.1. Green and Low-Carbon Travel

In China, buses are the main mode of public transportation travel. According to data from the National Bureau of Statistics of China, in 2017, the actual total number of passengers transported on public buses for 78.24% of total public transportation passenger traffic. Thus, the total number of passengers transported on public buses was selected as a proxy variable for green, low-carbon travel. Table 7 reports the results of the mechanism testing model (2) and (3). Firstly, the results in columns (1) and (2) indicate the impact of green and low-carbon travel on the urban carbon emission intensity. From the results, it can be seen that the coefficient of the actual total number of passengers transported

on public buses is significantly negative at the 1% level, indicating that the use of public buses as a green travel mode can significantly reduce urban carbon emission intensity. Secondly, the results in columns (3) and (4) demonstrate the impact of the development of digital inclusive finance on green and low-carbon travel, with the coefficients of the DIFI being positive and significant at the 1% level. This indicates that the development of digital inclusive finance can promote green and low-carbon travel. Finally, the results in columns (5) and (6) show that both the DIFI and the actual total number of passengers transported on public buses were significantly negative at the 1% level. This shows that the development of digital inclusive finance can reduce urban carbon emission intensity by promoting green and low-carbon travel, which confirms Hypothesis 2.

Table 7. Results of verification of the green and low-carbon travel mechanism.

Variables	(1) CEI	(2) CEI	(3) BUS	(4) BUS	(5) CEI	(6) CEI
DIFI			0.3015 *** (0.1070)	0.2759 ** (0.1104)	−0.0299 *** (0.0040)	−0.0428 *** (0.0034)
BUS	−0.0034 *** (0.0009)	−0.0034 *** (0.0008)			−0.0029 *** (0.0009)	−0.0028 *** (0.0008)
Constant	0.0997 *** (0.0084)	0.1690 *** (0.0146)	7.8047 *** (0.4184)	7.6849 *** (0.6287)	0.2125 *** (0.0173)	0.3527 *** (0.0203)
Control variables	No	Yes	No	Yes	No	Yes
Observations	1991	1991	1991	1991	1991	1991
R ²	0.2368	0.4667	0.0349	0.0485	0.2607	0.5120
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: ** and *** indicate significance at the levels of 5% and 1%, respectively.

5.5.2. Clean Energy

LPG is a hydrocarbon composed of Carbon3 and Carbon4, which can be completely burned without pollution. Thus, LPG is recognized as a clean form of energy. Raslavičius et al. (2014) [38] indicate that LPG is also a low-polluting and cost-effective form of energy for motor vehicles. Talib Hashem et al. (2023) [39] conducted a comparative analysis of LPG and gasoline fuels and found that LPG, as an engine fuel for automobiles, can significantly reduce the emissions of carbon dioxide and carbon monoxide. In addition to its use as automobile fuel, LPG is also widely used as a clean energy source in various industries. El-Morsi (2015) [40] finds that LPG, as a refrigerant, has advantages such as its low cost and potential for zero ozone consumption. Sharma et al. (2019) [41] showed that LPG is widely used in the housing sector, notably for household cooking. Hence, this study uses LPG as the proxy variable for clean energy.

Table 8 reports the results of the mechanism testing model (4) and (5). The results in columns (1) and (2) indicate the impact of LPG use on urban carbon emission intensity, showing a significant reduction in urban carbon emission intensity as a result of LPG use. Columns (3) and (4) show the effect of the development of digital inclusive finance on the total supply of LPG, with the coefficient of the DIFI being significantly positive at the 5% level, indicating that the development of the DIFI can increase the use of LPG as a clean form of energy and promote the transition towards low-carbon clean energy consumption. Column (6) shows that the coefficients of DIFI and LPG are significantly negative at the 1% and 10% levels, respectively. This indicates that the development of digital inclusive finance can reduce urban carbon emission intensity by promoting the use of clean energy, such as LPG, which supports Hypothesis 3.

Table 8. Results of the mechanism test for clean energy.

Variables	(1) CEI	(2) CEI	(3) LPG	(4) LPG	(5) CEI	(6) CEI
DIFI			0.3714 ** (0.1739)	0.4219 ** (0.1799)	−0.0302 *** (0.0040)	−0.0432 *** (0.0034)
LPG	−0.0019 *** (0.0006)	−0.0012 ** (0.0005)			−0.0016 *** (0.0006)	−0.0008 * (0.0005)
Constant	0.0865 *** (0.0053)	0.1480 *** (0.0135)	7.7651 *** (0.6800)	6.0929 *** (1.0248)	0.2025 *** (0.0164)	0.3360 *** (0.0197)
Control variables	No	Yes	No	Yes	No	Yes
Observations	1991	1991	1991	1991	1991	1991
R ²	0.2357	0.4626	0.0088	0.0172	0.2600	0.5089
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: *, **, and *** indicate significance at the levels of 10%, 5%, and 1%, respectively.

5.6. Limitations

However, there are also limitations in this study. Firstly, the total number of people on buses might not always be an accurate representation of green, low-carbon travel because green and low-carbon travel also includes modes such as subways, but at present, only a few cities in China have subways, and there is not enough data to support this study. Secondly, this study assumes that LPG is a clean energy source, but whether LPG is strictly clean energy is still controversial, and other strictly clean energy sources, such as nuclear energy and wind energy, have data availability issues. Thirdly, Hypothesis 1 has been proven by previous studies, but the selection of control variables and robustness tests in this paper still differ from previous studies.

6. Conclusions

6.1. Research Conclusions

The development of digital inclusive finance in China has not only contributed to the rapid growth of the country's economy but also holds significant importance for China's pursuit of its green and sustainable economic transition in the context of the “dual carbon” goals. Thus, investigating the impact of digital inclusive finance development on urban carbon emission intensity is of great practical significance. This study employs the 2011–2017 Peking University Digital Inclusive Finance Index to empirically explore the impact of digital inclusive finance on urban carbon emission intensity and innovatively analyzes the mechanism of the impact of digital inclusive finance development on urban carbon emission intensity from the perspective of green and low-carbon travel and clean energy use in China. The results show that the development of digital inclusive finance significantly reduces urban carbon emission intensity. After considering endogeneity issues and a series of robustness tests, this conclusion still holds. In the mechanism testing results, it is confirmed that digital inclusive finance can reduce urban carbon emission intensity by promoting green and low-carbon travel and the use of clean energy. Furthermore, we found that the negative impact of digital inclusive finance on urban carbon emission intensity is greater in the central and western regions and in areas with low economic development.

6.2. Policy Recommendations

Based on the above research findings, the following recommendations are proposed: Firstly, accelerate the development of digital inclusive finance. Emphasis should be placed on the innovation of digital inclusive finance development and on increasing the investment in relevant digital financial technologies. Secondly, it is recommended that the application of digital inclusive finance in the area of green and low-carbon travel be strengthened. Policies

and commercial partnerships should be implemented to enhance the impact of digital inclusive finance on reducing urban carbon emissions through the mechanism of green and low-carbon travel. Thirdly, the government should explore the deep integration of digital inclusive finance and clean energy, for example, by promoting “green loans” on digital inclusive finance platforms to encourage and support enterprises and individuals in the use of clean energy and low-carbon emission projects, thus promoting the popularization and application of clean energy. Fourthly, it is essential to ensure the balanced development of digital inclusive finance in all regions. The government should formulate relevant policies to unleash the growth potential of digital inclusive finance in underdeveloped regions and improve its coverage and depth of use.

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