

Research on the impact of digital inclusive finance on China's carbon emissions under the background of "dual carbon"

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Abstract: Digital inclusive finance, which is based on the integration of financial technology underlying technology and financial inclusive value, can provide new ideas for China to achieve the "dual carbon" strategic goal and promote China's green low-carbon transformation. This paper uses panel data of 31 provinces, autonomous regions and cities from 2011 to 2019 to explore the impact of digital inclusive finance on China's carbon emission intensity. The study found that digital inclusive finance can significantly inhibit carbon emissions, of which the coverage depth of sub dimensions has the largest inhibition effect on carbon emission intensity, and the carbon emission reduction effect of digital inclusive finance is particularly significant in the eastern region. At the same time, the carbon emission reduction effect of digital inclusive finance is gradually enhanced with the improvement of economic development level. Based on this, this study puts forward corresponding suggestions to promote the integration of digital inclusive finance and green finance and promote China's green low-carbon transformation.

Keywords: Digital Inclusive Finance, Low Carbon Transformation, Green Development, Carbon Emissions, Carbon Emission Intensity

1. Introduction

With the global warming, energy crisis, environmental pollution and other issues becoming increasingly serious, carbon dioxide emissions can not be ignored. In order to assume the responsibility of major countries to solve the climate change problem, China proposed the "double carbon" goal vision of carbon peak and carbon neutral in 2020. The proposal of the "double carbon" strategic goal is of great historical significance, which reflects China's responsibility and responsibility for building a community with a shared future for mankind. The realization of the "double carbon" goal will be a systematic reform at the economic and social level led by the state and widely participated by social members, which can not only promote the construction of ecological civilization and promote the high-quality development of the economy in China, but also bring opportunities for the innovation of China's business model and the improvement of international competitiveness.

With the vigorous development of a new generation of information technology, digital inclusive finance, as a new financial service model, can link financial services with carbon emissions, green trading, etc., guide the transfer of green financial resources to high-tech, green low-carbon industries, thus promoting China's economic green transformation. In the context of the "dual carbon" strategic goal proposed by China, the internal relationship between digital inclusive finance and China's carbon emissions is of great significance. The focus question is, can digital inclusive finance help to reduce carbon emissions? How does it help reduce carbon emissions and its mechanism? From the perspective of carbon emission intensity, this paper constructs a panel regression model and a panel threshold model to study the impact of digital inclusive finance on carbon emissions at the provincial level, test the relationship between carbon emissions and digital inclusive finance, analyze the regional heterogeneity of the impact of digital inclusive finance on carbon emission intensity, and clarify the internal relationship between the development of digital inclusive finance and carbon emission reduction, in order to provide useful policy inspiration for achieving the dual carbon goals.

2. Literature review and hypothesis presentation

With the intensification of global warming, around the issue of how to reduce carbon emissions,

scholars have gradually paid attention to the research on digital inclusive finance and green development. Some scholars have found that digital inclusive finance can promote the growth of regional green economy and improve the green innovation performance of enterprises. At the same time, some scholars have begun to attach importance to the impact of digital inclusive finance on carbon emissions. Theoretically, Digital inclusive finance directly curbs carbon emissions. At the level of individual consumers, it can not only integrate environmental protection activities that participate in carbon emission reduction into public life by using platform advantages [1], but also use mobile payment and other technologies to facilitate consumer payment activities, greatly reducing the carbon emissions generated by these behaviors offline [2]. At the level of enterprises, it can improve the convenience of enterprise financing channels, In this way, the transaction costs of enterprises and the carbon emissions generated by enterprises' borrowing from and to financial institutions can be reduced [3]. At the same time, sufficient financial resources can be provided to support enterprises' green innovation [4]. Some scholars have also studied the path mechanism of digital inclusive finance to curb carbon emissions. For example, digital inclusive finance can play a positive role in carbon emission efficiency by promoting technological innovation [5], improving entrepreneurship [6], improving energy structure [7], etc., and the level of urbanization [8] and industrial structure [9] can regulate the carbon emission reduction effect of digital inclusive finance. From a spatial perspective, some scholars proposed that the positive impact of digital inclusive finance on carbon emission efficiency has a spatial spillover effect, and there is regional heterogeneity.

Digital inclusive finance can affect carbon emissions at two levels. One is the enterprise level. Digital inclusive finance alleviates the financing constraints of enterprises, reduces the operating costs of enterprises, and promotes green innovation of enterprises to reduce carbon dioxide emissions; Second, at the consumer level, digital inclusive finance can provide convenience through financial technology and digital technology, reduce transaction costs at the individual level, and at the same time, penetrate the environmental protection activities of carbon emission reduction into the lives of the public, thereby inhibiting carbon emissions to a certain extent. At the same time, the three dimensions of digital inclusive finance, namely, coverage, depth of use and digital level, are depicted from different perspectives of digital inclusive finance as a whole. Therefore, the impact of the three on carbon emission intensity may be different. Based on this, hypothesis 1 is proposed:

H1: Digital inclusive finance can reduce carbon emissions to a certain extent, and different dimensions have different impacts on carbon emission intensity.

Due to the imbalance in economic development, scientific and technological innovation, opening up and other aspects in different regions of China, whether digital inclusive finance can significantly affect carbon dioxide emissions may be significantly different due to different regional development. Based on this, hypothesis 2 is proposed:

H2: The impact of digital inclusive finance on carbon emissions has regional heterogeneity.

At the same time of economic development, consumers will pay more attention to the environment, which will change the investment of financial resources in the environmental protection industry to a certain extent, thus affecting the level of green innovation of enterprises, and can effectively reduce carbon emissions. That is, the relationship between digital inclusive finance and carbon emissions may have a threshold effect under different levels of economic development. Assumption 3 is proposed based on this:

H3: Under different economic development levels, there is a non-linear relationship between the development level of digital inclusive finance and carbon emissions.

3. Research Design

3.1 Sample data

Considering the availability of data, the data used in this study are panel data (excluding Taiwan, Hong Kong and Macao) of 31 provinces (cities) in China from 2011 to 2019. The data sources include Guotai'an Database, National Bureau of Statistics, Peking University Digital Inclusive Financial Index, China Urban Statistical Yearbook and the State Intellectual Property Office.

3.2 Variable definition

1) Dependent variable: carbon emission intensity (CI): refer to the China Energy Yearbook, measured by the ratio of total regional carbon dioxide emissions to GDP, where the total regional carbon dioxide emissions add up the carbon dioxide emissions of coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil, liquefied petroleum gas and natural gas in the region.

2) Independent variables: Digital Inclusive Financial Index (DIF). This part selects the digital inclusive finance index prepared by Peking University from 2011 to 2019 to measure the development degree of digital inclusive finance in each province. This set of indexes includes digital inclusive finance index (DIF), digital financial coverage coverage index (CB), digital financial use depth index (UD) and digital inclusive finance index (DI) (Guo Feng et al., 2020) [10].

3) Control variables: Select technology innovation level (TE), urbanization level (URB), opening up level (OPEN), economic development level (EC), and industrial structure level (IND) as control variables, and the specific definitions are shown in Table 1.

Table 1: Variable description

Type	Name	Symbol	Calculation method
Dependent variable	Carbon emission intensity	CI	CO2 emissions/Regional GDP
Independent variables	Digital inclusive financial index	DIF	Logarithm of digital inclusive financial index
	Breadth of its coverage	CB	Coverage of digital inclusive finance
	Use Depth	UD	Use depth of digital inclusive finance
	Digitization degree	DI	Digitalization degree of digital inclusive finance
Control variable	Technological innovation level	TE	Number of patents granted per capita
	Urbanization level	URB	Urban population/total population
	Opening level	OPEN	Total regional imports and exports/regional GDP
	Economic development level	EC	Logarithm of per capita real GDP
	Industrial structure level	IND	GDP of tertiary industry/regional GDP

3.3 Model Setting

According to the above theoretical analysis and assumptions, in order to study whether digital inclusive finance can curb carbon emissions, this paper first constructs the following benchmark panel model:

$$CI_{it} = \alpha_0 + \alpha_1 DIF_{it} + \alpha_2 TE_{it} + \alpha_3 URB_{it} + \alpha_4 OPEN_{it} + \alpha_5 EC_{it} + \alpha_6 IND_{it} + \lambda_i + \nu_t + \varepsilon_{it} \quad (1)$$

i and t represent the region and year of data respectively, λ Represents individual fixed effect, ν represents time solid effect, ε Represents a random perturbation term.

At the same time, this paper draws on the panel threshold model proposed by Hansen (1999) [11] to build a measurement model of digital inclusive finance and carbon emissions:

$$CI_{it} = u_i + \beta_1 DIF_{it} I(EC_{it} \leq \gamma_1) + \beta_2 DIF_{it} I(\gamma_1 < EC_{it} \leq \gamma_2) + \dots + \beta_n DIF_{it} I(\gamma_{n-1} < EC_{it} \leq \gamma_n) + \alpha_1 TE_{it} + \alpha_2 URB_{it} + \alpha_3 OPEN_{it} + \alpha_4 IND_{it} + \varepsilon_{it} \quad (2)$$

$I(\cdot)$ is an indicative function, and the level of economic development (EC) is a threshold variable, γ represents threshold value, u represents individual fixed effect, ε represents a random perturbation term.

4. Empirical analysis

4.1 Basic regression

Through Hausman test, it can be found that the P value is 0.0000, that is, the original hypothesis is rejected, and the fixed effect model is better than the random effect model. In this paper, the fixed effect model is selected for subsequent econometric research. At the same time, in order to prove the robustness of the sample estimation results, this paper also includes the OLS mixed regression and random effect regression as the comparison of fixed effect estimation results.

Table 2: Full sample regression results

Variables	(1)	(2)	(3)
	OLS	RE	FE
DIF	-0.305 (-1.63)	-0.171*** (-3.74)	-0.173*** (-3.75)
TE	-0.922*** (-6.24)	-0.031 (-0.52)	-0.011 (-0.18)
URB	9.665*** (5.94)	1.408 (1.19)	0.824 (0.68)
OPEN	-2.150*** (-4.98)	-0.524*** (-2.74)	-0.465** (-2.39)
EC	-0.844* (-1.77)	-1.852*** (-9.12)	-1.809*** (-8.86)
IND	0.273 (0.21)	2.054*** (3.93)	2.199*** (4.18)
Constant	9.567** (2.23)	21.623*** (12.02)	21.384*** (11.92)
Observations	279	279	279
R-squared	0.360		0.706

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

It can be seen from Table 2 model (3) that the regression coefficient of the core explanatory variable figure inclusive finance is negative and significant at the level of 1%, that is, for every 1 percentage point increase in the overall index, the carbon emission intensity will be reduced by 0.173 percentage points, which shows that the figure inclusive finance can significantly curb the carbon emission intensity.

4.2 Heterogeneity analysis

4.2.1 Distinguish the dimension of digital inclusive finance

The development of digital inclusive finance includes the continuous improvement of coverage, depth of use and digital support services. Based on this, this paper further analyzes the impact of coverage, depth of use and digital level on carbon emission intensity. The regression results are shown in Table 3.

Table 3: Regression analysis results of dimensional heterogeneity

Variables	Dependent variable: carbon emission intensity(CI)		
	(1)	(2)	(3)
CB	-0.151*** (-4.52)		
UD		-0.114** (-2.42)	
DI			-0.072** (-2.12)
Constant	20.858*** (11.78)	22.901*** (13.16)	22.811*** (12.77)
Controls	Yes	Yes	Yes
Year/Region	Yes	Yes	Yes
R-squared	0.714	0.697	0.695
Observations	279	279	279

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

The improvement of coverage can extend digital inclusive finance to regions and groups hard to reach by traditional finance; The increase in the depth of use will provide diversified channels for raising funds for vulnerable groups and provide them with financial security; The improvement of digitalization can increase the convenience of financing, reduce the cost of financial services, activate the effective flow of capital elements, and promote carbon emission reduction at the enterprise and individual levels. It can be seen from Table 3 that the three dimensions of digital inclusive finance will have a significant negative impact on the carbon emission intensity, but the coverage depth has the strongest carbon emission reduction effect, followed by the depth of use, while the degree of digitalization is relatively weak, indicating that China's current digital infrastructure construction is relatively weak, and long-term investment and continuous improvement are needed.

4.2.2 Distinguishing regional development level

Due to the differences in resource conditions, economic development and industrial structure in different regions, there is a large gap in the development of digital inclusive finance in different regions. Therefore, in order to further explore the regional heterogeneity of the impact of digital inclusive finance on carbon emission intensity, this paper divides the selected provinces into eastern The central and western regions [that is, the eastern region includes 10 provinces (cities) in Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan; the central region includes 6 provinces (provinces) in Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan; the western region includes 12 provinces (districts and cities) in Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang], The regression results are presented in Table 4.

Table 4: Regression analysis results of regional heterogeneity

Variables	Eastern region	Western region	Central region
	(1)	(2)	(3)
DIF	-0.147*** (-3.46)	-0.090 (-0.99)	-0.110 (-1.57)
TE	-0.065* (-1.93)	0.077 (0.53)	0.102 (0.80)
URB	0.033 (0.04)	4.453 (1.48)	0.018 (0.01)
OPEN	-0.159 (-1.27)	0.887 (1.33)	-1.231 (-0.69)
EC	-0.604*** (-3.97)	-3.061*** (-6.43)	-2.368*** (-5.60)
IND	-1.044* (-1.93)	2.289** (2.20)	4.083*** (3.58)
Constant	9.781*** (6.89)	32.387*** (8.19)	26.232*** (7.73)
Observations	90	108	54
R-squared	0.879	0.748	0.861

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

It can be seen from the regression results that digital inclusive finance in the eastern region can significantly curb the intensity of carbon dioxide emissions, while the development of digital inclusive finance in the central and western regions cannot significantly curb carbon dioxide emissions. This may be because the level of digital inclusive finance can drive economic growth and technological innovation. The level of digital inclusive finance development, economic development and technological innovation in the eastern region is higher than that in the central and western regions.

4.3 Further analysis: threshold effect

According to the previous analysis, the impact of the development level of digital inclusive finance on the carbon emission intensity in different regions will be affected by the level of economic development, so a panel threshold model is set. The single threshold, double threshold and triple threshold tests are conducted respectively. As shown in Table 5, the economic development level passed the single threshold and double threshold tests at the significance level of 5%. This paper uses Bootstrap repeated sampling method to estimate the threshold value of the economic development level. The test results show that there is a double threshold effect in the economic development level. The threshold values are 10.1394 and 10.6169, respectively. The results are shown in Table 6.

Table 5: Threshold effect test results

Threshold	F value	P value	1% critical value	5% critical value	10% critical value
Single	47.00	0.0200	22.4955	30.0887	52.7375
Double	40.22	0.0133	25.1541	30.4680	43.0859
Triple	10.11	0.8067	32.9208	41.4151	56.4600

Table 6: Double threshold estimation results

Threshold	Threshold estimate	95% confidence interval
1	10.1394	[10.0742,10.1396]
2	10.6169	[10.6100,10.6273]

According to Hansen threshold theory, there is a double threshold of economic development level in the relationship between the development level of digital inclusive finance and carbon emission intensity. It can be seen from the regression results in Table 7 that when the intensity of economic development level is lower than 10.1394, the carbon emission reduction effect of economic development level on the development level of digital inclusive finance is positively correlated at a significant level of 5%, indicating that the low intensity of economic development level is conducive to the digital inclusive finance level to curb carbon emissions; When the economic development level is between 10.1394-10.6169, the role of economic development level in carbon emission reduction of digital inclusive finance is enhanced and significant at the level of 1%; When the threshold value is higher than 10.6169, the impact of economic development level on the development level of digital inclusive finance is further enhanced. From the empirical results, it is easy to see that the development level of digital inclusive finance under different economic development levels has significant threshold effect characteristics on carbon emission intensity. The reason may be that, with the economic growth, the per capita income level continues to improve, and consumers' awareness of environmental protection and preference for environmental protection products also increase accordingly. From a macro perspective, the government will guide and promote the flow of inclusive financial resources to the environmental protection industry, while promoting the green transformation of traditional industries to further meet consumer demand, alleviate the current situation of overproduction, and thus achieve the matching of supply and demand and balanced development. From a micro perspective, demand determines the direction of enterprise production. The increase in preference and demand for environmental protection products will guide more and more enterprises to use financial resources for research, development and production of environmental protection technologies and green production technologies, thereby improving the level of green innovation of enterprises and achieving financial development to promote carbon emissions reduction.

Table 7: Regression results of double threshold model

VARIABLES	CI
IND	2.833*** (0.529)
URB	-2.782*** (0.997)
OPEN	0.531*** (0.158)
TE	0.0349 (0.0604)
EC≤10.1394	-0.104** (0.0524)
10.1394<EC≤10.6169	-0.302*** (0.0423)
EC>10.6169	-0.365*** (0.0436)
Constant	4.079*** (0.409)
R-squared	0.706
Observations	279

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

4.4 Endogenous discussion

In order to avoid the endogenous problem that may be caused by the reverse causality of "the higher the development level of digital inclusive finance, the lower the carbon emission intensity of the region", this paper selects the Internet penetration rate of all provinces and cities in the country provided by China Internet Network Information Center (CNNIC) as the tool variable of digital inclusive finance development with reference to the method of Xie Xianli et al. (2018) [12], Two stage least square estimation is used to correct the endogenous problem of the model.

The unrecognized test was carried out for the tool variables, and the Kleibergen Paaprk LM statistic was 49.109. The results showed that $p=0.000<0.01$, significantly rejecting the original hypothesis at the 1% level. By comparing the critical value of Cragg Donald Wald F statistic with that of Stock Yogo weak ID test, the study found that Cragg Donald Wald statistic is 107.534, which is greater than the critical

value (16.38) of 10% of Stock Yogo weak ID, so the original assumption that "tool variable is a weak tool variable" was rejected. In addition, since the number of endogenous variables is the same as that of tool variables, tool variables were just identified, There is no over recognition.

Table 8: Endogenetic analysis: IV-2SLS

	Phase I	Phase II
	Digital inclusive finance	Carbon emission intensity
Internet penetration	3.0499*** (0.294)	
Digital inclusive finance		-0.7310** (0.293)
Controls	Yes	Yes
Year/Region	Yes	Yes
Observations	279	279

According to the estimation results of instrument variables in Table 8, after considering the endogeneity of digital inclusive finance variables, the development of digital inclusive finance still has a significant negative impact on the intensity of carbon dioxide emissions. This shows that the above regression analysis results are robust and consistent.

5. Conclusions

This paper analyzes the direct impact of digital inclusive finance on carbon emission intensity and its heterogeneity, and uses 31 provincial panel data in China from 2011 to 2019 to build a fixed effect model for regression calculation. Based on the above analysis conclusions, combined with relevant policies and actual development, the following policy recommendations are proposed:

First, vigorously promote the integration of digital inclusive finance and green finance, and give play to the leading role of digital inclusive finance in China's green and low-carbon transformation process. At the same time, we will strengthen the construction of big data, cloud computing, 5G communication technology and other infrastructure, ease the digital divide in weak areas, and ensure the coordinated development of digital inclusive finance in all regions. Second, we should constantly adjust and optimize the industrial structure and improve the allocation and utilization of financial resources in the real economy. The government should reasonably encourage financial institutions to increase their support for green entrepreneurship and guide more funds to high-tech enterprises and environment-friendly enterprises. We should also continue to work to promote technological innovation and reduce carbon emissions. At the same time, by raising the environmental threshold for capital introduction, improving the environmental regulation and intellectual property protection system, we will force import and export enterprises to achieve green, low-carbon and clean production, optimize China's import and export structure, and thus enhance the contribution of foreign trade to carbon emission reduction. Third, formulate reasonable and effective policies according to local conditions. Considering the internal and external conditions of each region, we should formulate the policy of travel alienation to give full play to the inclusive nature of digital inclusive finance, and ensure that digital inclusive finance can benefit weak regions. In addition, the government should guide and support the high-tech in the east to gradually radiate to the central and western regions, and drive the development of green industries with innovation.

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