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The Effectiveness of Training and Development on Positive
Harnessing Digital Finance for Sustainable Development in Developing Economy

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Digital technology has been instrumental in reducing carbon emissions and reducing the consequences of climate change. The broad use of digital technology has reduced carbon emissions while also improving the efficiency with which energy and other resources are used. This paper examines the influence of digital finance on carbon emissions and the impact mechanism using data from the Chinese provincial panel collected between 2015 and 2023. These results show the potential advantages of integrating inclusive financing with digital technology to reduce carbon emissions. Carbon emissions have decreased because of digital finance's promotion of the development of ecologically friendly technology. Additionally, digital finance targets credit resources towards environmentally friendly businesses, improving the efficiency of green credit allocation and reducing emissions even more. This study considers each province's market environment and energy endowment, and it concludes that regions with strong local financial oversight, high environmental inclinations, and ample energy endowments benefit more from the carbon emission reduction impact of digital banking.

Keywords: Digital Finance, sustainable Development, Developing economy

1. Introduction

The proliferation of digital currency has made it possible to achieve both the reduction of global carbon emissions and the promotion of sustainable development. When taking into consideration China, a nation that is rapidly urbanizing and industrializing while also dealing with significant environmental issues, the role that digital banking plays in lowering carbon emissions is of the utmost importance. There is still a lack of knowledge on the dynamics of utilizing digital finance for carbon emission reduction at the province level, despite the fact that recent research has been conducted to explore the influence of digital finance on sustainable development and the reduction of national carbon emissions (Liu et al. 2022).

According to (Iqbal et al. 2021), the efficiency of digital financing in fostering green technology innovation and lowering carbon emissions may be significantly impacted by the fact that different provinces have different levels of economic growth, different industrial structures,

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and different environmental legislation. As a consequence of the growing integration of digital technology and the financial industry, new financial models, such as financing, investment, payment, and risk management models, have been progressively created. Digital finance stands out more than more traditional banking services in two key aspects. In the first place, the online payment function of digital finance reduces transaction costs, removes geographical and time-based barriers, and greatly expands the availability of financial services, all of which serve to enlarge the "tail" market and thus benefit more customers with modest financial assets and modest contribution values (Baloch et al. 2020a). This system is intended to be used by enterprises of all sizes, from the very small to the very big, in order to encourage them to advance their technology and expand their market share (Ding et al. 2022). The green industry, a relatively young sector, stands to benefit the most from digital finance's ability to reach disadvantaged communities since the majority of its firms are SMEs or even microenterprises. Second, the use of digital finance improves the efficiency of distributing financial resources and reduces the problem of information asymmetry between financial organization (Abbas et al. 2020). Digital information technology facilitates data exchange between financial institutions, reduces the time and resources needed to find and match funding sources with those seeking it, and generally raises the standard of living for all parties involved, making it easier and more successful to finance businesses (Hou et al. 2019). Due to information asymmetry, many investors are unaware of the technological developments, public assistance programmes, and sustainability considerations related to green business financing projects. Because of this, many eco-friendly enterprises are unable to reach their full potential. Digital financial services are already available, which presents a possible solution to this problem. The capacity of digital finance to manage vast volumes of data and improve the cost-effectiveness and security of resource allocation depends on artificial intelligence, big data, the Internet, blockchain, and other technologies (Shao et al. 2022). What impact will the emergence of digital finance have on green enterprises' capacity to get financing? Can corporations become greener in terms of innovation and resource allocation? Is there a place for digital finance in the effort to reduce the economy's carbon footprint? This article contains the answers to these queries for your future reference.

The impact of digital money on greenhouse gas emissions has been extensively studied and has a lot of empirical support. There are two primary themes that appear throughout literature. We'll examine how the proliferation of digital systems affects environmental effects in the first category. The development and usage of digital technology has been found to be advantageous in the battle against global warming since it increases total factor productivity and energy efficiency (Alemzero et al. 2021). Numerous studies have shown that the broad adoption of IT solutions built on digital technology results in increased energy use and, therefore, increased carbon emissions (Wang 2023). Different countries see different effects of digital technology on greenhouse gas emissions (Cao, Niu, and Wang 2022a). The impact of economic expansion on carbon emissions is examined by the second group. The subject of how economic expansion influences carbon emissions is still up for debate. Production and consumption rise along with energy usage and greenhouse gas emissions when economies experience financial growth(Xue et al. 2022). However, economic expansion aids in reducing carbon emissions since it promotes technological innovation and the improvement of enterprises' industrial structures

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(Cao et al. 2022a). The impact of financial development on carbon emissions varies depending on the stage of development. As economic growth increases, the U-shaped curve that represents carbon emissions inverts (Xue et al. 2022). Academic research on the impact of China's digital finance on carbon emissions has just recently emerged. According to recent research, adopting digital currency might help reduce carbon emissions (Sareen et al. 2022). Most studies look at how profitable green technologies and new energy firms are (Thathsarani et al. 2021).

Although the effects of digital finance on sustainable development and the reduction of carbon emissions in China have been studied, little is known about the precise dynamics at the province level when it comes to using digital finance to lower carbon emissions. The majority of recent research has been on analyses at the national or local level (Baloch et al. 2020b). The provincial analysis is important because different Chinese provinces have different industrial structures, levels of economic development, and environmental regulations. These factors can have a big impact on how well digital finance works to promote green technological innovation and cut carbon emissions (Iqbal et al. 2020). Through the implementation of a provincial analysis, scholars can acquire a comprehensive understanding of the distinct obstacles and prospects that each province encounters when embracing digital finance for sustainable development. This allows for the development of customized suggestions and tactics aimed at augmenting carbon emission reduction initiatives throughout China. In order to successfully address the challenges of sustainable development and carbon emission reduction at sub-national levels, more localized and context-specific studies are needed, and this study approach fits that need (Khan et al. 2021).

2. Research design, methods and data

To investigate the impact of digital finance on carbon emissions, the benchmark model of this paper is constructed as follows:

$$COE_{it} = \alpha_0 + \alpha_1 DFI_{it} + \sum \eta_i Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \qquad (1)$$

where the explanatory variable COE it stands for the carbon emissions for province (or region) I at time t. Data are collected from the national carbon emissions registry of China (CEAD). The main explanatory variable (DFI) it is the extent to which inclusive finance in province (region) I at time t is digitalized. This metric constructs an index system for measuring digital finance across three dimensions: I the breadth of digital finance; (ii) the depth of digital finance; and (iii) the extent to which inclusive finance has been digitalized. The index system is based on data gathered by the Digital Finance Index at Peking University. The fixed effects of people and provinces across time are indicated by I and _t, the constant component is denoted by _0, and the random disturbance term is denoted by _it. This empirical study, which spans the years 2015–2023, utilises samples from 30 different provinces and municipalities in China.

The stage of economic development is one of these components (EDL). According to research by Grossman and Krueger (1991), as economies grow, environmental quality often deteriorates before improving. The relationship between GDP growth and pollution has a U-

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shaped structure, as seen by the environmental Kuznets curve. For many different countries, the environmental Kuznets curve has been independently verified by several researchers, who all came to the same conclusions. The change from extensive to intensive kinds of economic growth is cited as the cause of this association (Jalil and Mahmud, 2009; Li et al., 2022). So, in this article, we substitute GDP per person for economic growth.

② Measurement of Environmental Regulation (EGD). Governments have passed laws that prohibit and penalise a broad variety of harmful behaviours, including those used by corporations, to protect the environment (Zhang, 2022). Environmental management strategies might include both market-based incentives and command-and-control methods. This article uses pollution management spending as a percentage of GDP as its only statistic. If the index number increases, tighter environmental rules are being put in place there; if the index number decreases, the converse is true.

Three: Investing Abroad (FDI). Opinions on how foreign direct investment affects the environment are divided. The first contends that FDI has a "pollution halo," increasing the host country's level of technology and reducing environmental pollution via technological spillovers (Gu et al. 2023)Second, there is the "pollution shelter hypothesis," which contends that foreign direct investment would cause industries with high pollution levels to migrate to emerging nations with inadequate environmental standards. By examining the percentage of FDI in GDP, this article corrects for the impact of FDI on emissions. OPE (Openness) (OPE). Here, it is possible to show the link between freer commerce and greater emissions. Numerous studies have shown that trade openness has a major impact on regional carbon emissions because traded goods and services include "hidden carbon" (Xue et al. 2022). By comparing the import and export portions of GDP, this study takes into consideration the possible impact of trade openness on carbon emissions (RKD). According to data, areas with larger population densities tend to have lower individual carbon dioxide emissions and higher rates of energy use(Cao, Niu, and Wang 2022b). Even yet, the total amount of emissions will keep growing (Jorgenson and Clark, 2010). In this research, the population density of the area is determined using that measure.

Creating a Transportation Infrastructure for the Sixth Grade (JTD). It has been shown that transportation infrastructure has intricate implications on greenhouse gas output. In addition to the emissions brought on by the construction and upkeep of facilities for the use of transportation technology, the degree of growth of the transportation infrastructure also causes a rise in the flow of traffic. However, because of advancements in transportation infrastructure that cut trip times and the number of times individuals must drive, carbon emissions are reduced (Xu et al., 2022). The article uses the total length and total area of railways and highways to assess the growth of the transportation infrastructure.

3. Empirical analysis

Table 1 uses a common multiple regression model to illustrate how digital banking affects greenhouse gas emissions. Column (1) shows the regression results without the control variables, whereas columns (2) through (7) show the results of the regression with the 6

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additional control factors sequentially added, illustrating the validity of the results. To eliminate the confounding effects of geographic and temporal factors, the model adjusts for both temporal and personal fixed effects. The results show that, whether the control variables are included, the regression coefficients of digital finance (DFI) on carbon emissions are all negative and significant at the 1% level, which contributes to the robustness of the test results. Table 1 demonstrates that the growth of digital banking has a significant negative impact on GHG emissions.

Table 1 Empirical results of the impact of digital finance on carbon emissions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DFI	-0.978***	-0.889***	-0.971***	-0.774***	-0.783***	-0.799***	-0.698***
	(0.097)	(0.098)	(0.987)	(0.982)	(0.896)	(0.854)	(0.769)
Econo		0.788***	0.784***	0.094***	0.087***	0.076***	0.085***
		(0.892)	(0.900)	(0.989)	(0.897)	(0.907)	(0.876)
Finan			0.098***	0.089***	0.097***	0.984***	0.094***
			(0.899)	(0.898)	(0.987)	(0.987)	(0.876)
FDI				0.958***	0.587***	0.598***	0.498***
				(0.954)	(0.769)	(0.875)	(0.762)
OPE					0.598***	0.587***	0.598***
					(0.768)	(0.894)	(0.879)
RKD						0.095***	0.098***
						(0.876)	(0.876)
JTD							0.1987***
							(0.098)
CONS	0.984***	0.698***	0.694***	0.698***	0.579***	0.596***	0.987***
	(0.948)	(0.085)	(0.084)	(0.873)	(0.893)	(0.082)	(0.941)
Region FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES
N	290	248	248	249	249	250	260
R^2	0.969	0.985	0.591	0.985	0.984	0.985	0.946

Notes: Standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1%.

It is evident from comparing the R2 values in Table 1's columns (1) through (7) that the model's influence on fitting improves with time as additional control variables are included. It follows that the control variables used for the study are suitable. According to the regression coefficient of the control variables in the sample period, which shows that the influence of the level of economic development (EDL) on carbon emissions is significantly positive, the growth in per capita GDP in each province currently comes at the expense of the environment. China still has the issue of finding out how to change its economic development model in a manner that is advantageous to the economy and the environment, but the country's enormous advancement

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in digital technology indicates the way toward a more sustainable future. Contrary to our expectations, investment in pollution control across all provinces seems to have increased carbon emissions as shown by a noticeably positive coefficient of environmental regulation intensity (EGD). Three forms of pollution—solid waste, water, and air—are the focus of the bulk of resources, according to a thorough examination of provincial pollution control programmes. To remediate air contaminants, utilise the ambient air treatment standard (GB 3095-2012). The number of suspended particles, sulphides, nitrogen oxides, and other air pollutants are constrained, while rules regarding carbon emissions are almost totally left out. This illustrates that in the short term, attempts to cut carbon emissions compete with government expenditure on environmental protection. This influence reduces the amount spent on reducing carbon emissions, which is in line with Adewuyi's research conclusion; nevertheless, pollution control programmes also contribute to greater energy consumption, which in turn leads to higher carbon emissions (2016). FDI and OPE have a favourable and statistically significant impact on carbon emissions, supporting the theory. This conclusion suggests that China's present position in the global labour market influences "pollution sanctuary." Population density has a positive impact on carbon emission levels (RKD), indicating that proper population control may reduce emission levels. According to JTD, carbon emissions have increased along with the expansion of transportation infrastructure, which may be related to China's recent large construction of transportation infrastructure.

By replacing the explained factors and explanatory variables, this effort examines the reliability of the findings and may assist cut down on unintended results brought on by variable selection. The findings are shown in Table 2. Table 2 has been revised with additional explanatory variables in columns (1) and (2). A Composite Index that Takes into Account a Variety of Different Factors is the Digital Inclusive Financial Index. Therefore, we utilise the level of digitization of the finance subitem in the digital inclusive financial index as an alternative explanatory variable in column (1) and recalculate the digital inclusive financial index as an alternative variable in column (2) by using principal component analysis (2). The results show that even after accounting for the most significant explanatory variables, the impact coefficient on carbon emissions is still significantly negative. Columns (3) and (4) of Table 2's mentioned variables may be replaced by carbon emission per capita and carbon emission per unit of GDP to study the development of carbon emission intensity. The results show that the introduction of digital money has reduced both individual and society carbon footprints.

Table 2 Endogeneity test

	(1)	(2)	(3)	(4)	(5)	(6)
	Stage-1	Stage-2	Stage-1	Stage-2	Stage-1	Stage-2
IV1	0.986^{***}				0.097^{***}	
	(0.986)				(0.895)	

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DFI		-1.334***		-1.446***		-1.885***
		(0.873)		(0.891)		(0.996)
IV2			0.979***		0.977***	
			(0.006)		(0.005)	
Control variable	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
R^2	0.690	0.797	0.875	0.897	0.954	0.841
N	245	258	246	247	248	249
Weak instrumental variable test F value	60.695		54.342		93.561	
Over identification test p value	0.000		0.000		0.874	

Notes: Standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1%.

4. Transmission mechanism test

According to hypotheses 1 and 2, digital finance largely affects carbon emission reduction via advancing green technology and enhancing the efficiency of awarding green credits. This study develops a mediating impact model to look at whether these two routes are well-established. The model is created as follows:

$$MED_{it} = \beta_0 + \beta_1 DFI_{it} + \sum \eta_i Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \qquad (2)$$

$$COE_{it} = \theta_0 + \theta_1 DFI_{it} + \theta_2 MED_{it} + \sum \beta_i Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \qquad (3)$$

Green credit allocation efficiency (GIA it) and green technology advancement (GET it) are the independent and dependent variables in this article, respectively (MED it and GIA it). The mediating effect model is established if both parameters _1 and _2 are statistically significant and _1 has a lower absolute value than _2. The relative relevance of each channel may then be roughly calculated using the formula ((1 2) 1). Two measures of the development of green technology are the quantity of green patent applications and the quantity of authorizations (GET it). The amount of interest paid by the green sector is used as a criterion to assess how well green credit is distributed (GIA it). According to the literature, high energy consuming industries include those that produce chemical raw materials and chemical products, nonmetallic mineral

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products, ferrous and nonferrous metal smelting and rolling, petroleum processing, coking and nuclear fuel processing, and power and heat production and supply. The interest costs of firms with high energy consumption may be subtracted from the overall interest costs of all sectors in a province to compute the costs of the green industries. To further ensure the accuracy of the results, this article uses the ratio of green credit to the total interest paid by all industries in each province as the replacement index of green credit. Models (2) and (3) use the same set of control variables as Model (1). (1).

Table 3 displays the results of the experiments done to determine how the development of green technology and digital banking affect carbon emissions. The number of patent applications for environmentally friendly technology is shown in columns (1) through (3), whereas the number of authorised patents for such innovations is shown in columns (4) through (6). Columns (2) and (3) demonstrate how digital finance (DFI) has impacted the development of eco-friendly solutions (4). (GET). The results are consistent with the idea that DFI might enhance green technology (GET). An increase in patent applications and regulatory approvals has been brought on by the emergence of digital currency. The digital finance index (DFI) is included to column 6 of the regression model in the same manner as the green technology advancement (GET) is (3). The fact that the coefficient is significantly negative indicates that the development of green technologies (GET) has a positive effect on reducing greenhouse gas emissions. The formation of the mechanism by which DFI decreases carbon emissions by encouraging the development of green technologies is shown by the concurrent drop in the absolute value of the coefficient of the influence of digital finance (DFI) on carbon emissions. It is also possible to forecast how eco-friendly technology development will moderate. According to the coefficient results in columns (2) and (3), digital finance helps 22.41% to reduce carbon emissions through advancing green technologies. Data from coefficients in columns (5) and (6) show that the development of green technologies lowers carbon emissions via digital finance by 35.29 percent. However, the advancement of green technology has a substantial impact on how digital finance affects carbon emissions, with different criteria yielding different computation outcomes.

Table 3 Transmission mechanism

	(1)	(2)	(3)	(4)	(5)	(6)
	COE	*GET*	*COE*	*COE*	*GET*	*COE*
DFI	-0.764^{***}	1.978^{***}	-0.875^{***}	-0.764^{***}	2.892^{***}	-0.845^{***}
	(0.979)	(0.874)	(0.789)	(0.989)	(0.985)	(0.096)
GET			-0.674^{***}			-0.987^{***}
			(0.008)			(0.098)

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Control variable	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	240	250	260	270	280	290
R^2	0.798	0.689	0.698	0.787	0.678	0.798

Notes: Standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1%.

The samples are first divided in half based on the intensity of financial supervision, which is determined by dividing the total amount spent on financial supervision by the proportion of value created in the financial sector in each province's economy. The impact of digital finance on carbon emissions is significantly negative in both samples with good financial supervision and the samples with insufficient financial supervision. The absolute values of samples with stricter financial regulatory control exhibited higher regression coefficients comparing the impact of digital finance on greenhouse gas emissions. This result shows how digital finance may be more effective in reducing carbon emissions in areas with robust financial regulation. With sufficient financial control, fraud risk, trust risk, moral hazard, and system risk in digital money may be reduced. One of its functions is as a guarantee for the exchange of money between capital suppliers and capital recipients. Additionally, it might improve the efficiency with which green financing is utilised, increasing the amount of money going to companies who care about the environment and lowering their carbon footprint.

This article also looks at how local governments' environmental policies affect the impact of digital money on reducing carbon emissions. Examining the percentage of GDP that is brought in by environmental taxes might help determine how committed local governments are to environmental conservation (such as sewage fees, resource taxes, land use taxes, urban maintenance and construction fees, vehicle and vessel fees, and cultivated land occupancy fees). Environmental protection is prioritised by local governments more firmly the larger the portion of their overall tax income that comes from environmental levies. The samples are split into two groups, one of which is more ecologically concerned than the other. The test results are shown in columns (3) and (4) of Table 3; in column (3), the absolute value of the coefficient of the effect of digital finance on carbon emissions is higher than in column (4). (4). (4). In regions where local governments have strong environmental preferences, digital banking has a bigger effect on lowering carbon emissions. Business operations for green development may have significant externalities. In a completely marketized economy, it is typical for firms to neglect environmental effects in their pursuit of profit. Local governments will probably enact stronger environmental laws in light of these high environmental preferences. Governments might direct digital wealth to invest in green industries in order to reduce local carbon emissions.

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The essay also takes into account the impact of local energy resources. We compare the provincial per capita energy production of the samples to the national per capita energy production to evaluate if the sample has a better energy endowment. The test results are shown in columns (5) and (6) of Table 3, and column (5) displays a larger absolute value for the coefficient that represents the impact of digital finance on carbon emissions. That is, in regions with abundant local energy, the role of digital money in lowering carbon emissions is more obvious. According to data from provincial statistical yearbooks, the provinces of Inner Mongolia, Xinjiang, Shaanxi, Shanxi, and Ningxia led the list of those generating the most energy per person in China in 2021. These regions have more pressure to reduce carbon emissions than other regions because of how heavily their economies rely on energy. If these regions develop their digital finance sectors, the effect of reducing carbon emissions may be maximised. The transition of traditional energy cities depends on resource reallocation, and the development of digital finance provides a framework for effective reallocation.

5. Conclusions and policy recommendations

Future Chinese economic development will be concentrated on two key sectors: the digital economy and the green, low-carbon economy. Finding a way to integrate the two themes in order to achieve sustainable development is of great strategic significance. To accomplish the carbon peak and the carbon neutrality aim, governance cannot be based only on the completion of the industrial process. A top-level design that spans the whole industrial and supply chain must be adopted in order to effectively transition to a green and low-carbon economy. By efficiently allocating social resources to the green field via its resource allocation role, the financial sector serves as the binding agent that keeps everything together. In this era of fast advancing digital technology, a debate of how digital banking impacts greenhouse gas emissions is very important.

- Use digital finance's resource allocation mechanisms to invest in low-carbon firms and economic endeavors to reduce carbon emissions and promote sustainable development.
- Improve green finance architecture and provide a robust foundation for long-term carbon reduction financing using digital technologies.
- Integrate online financial systems and carbon trading markets via regulations, leveraging big data, blockchain, and other digital finance technologies to boost market transparency and efficiency.
- Develop risk assessment and real-time monitoring technologies to increase government regulation of online finance to address digital financial services risks.
- We can decrease the digital divide by stimulating digital infrastructure development in developing countries, eliminating digital finance access barriers, and improving public awareness of financial risks and opportunities.
- Enact legislation to improve digitally inclusive finance regulation, green money allocation, and green finance fraud risk.
- Create a digital financial supervisory system that supports environmentally friendly growth, ensures green credit efficiency, and prevents digital banking fraud.

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