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*Research Article*

# Digital Financial Inclusions for Sustainable Growth: Employing Natural Resources through Digital Governance

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## Abstract

Digital financial inclusion (DFI) initiatives have transformed the economy and environment by providing previously underbanked regions with enhanced access to banking, payment processing, and other financial services. This study analyses the correlations among DFI, GDP growth, and ecological sustainability, using the rapid expansion of digital finance in China as a case study. The research used econometric models to examine the impact of DFI on GDP growth and $CO_2$ emissions, including factors such as renewable energy adoption, industrial efficiency, and trade patterns. This purpose employs panel data from many national and international sources. The results demonstrate that reduced carbon intensity and improved economic inclusion correlate with heightened DFI penetration. Improved resource allocation, less travel for transactions, and increased green investment flows contribute to lower carbon intensity. The results suggest that DFI may fulfil climate action goals while promoting equitable growth, benefiting policymakers aiming to include financial innovation in sustainable development plans.

**Keywords:** Natural Resources, Digital Financial Inclusion, Sustainable Development, Digital Governance, China

## Introduction

The digital revolution of financial inclusion is often viewed as a means of reducing inequality, but its environmental implications have received less attention. The potential ecological advantages of DFI, including its ability to boost the use of renewable energy sources, mitigate climate change, and ultimately contribute to achieving the Sustainable Development Goals (SDGs), are still largely overlooked. Nonetheless, several studies have concentrated on the financial aspects of DFI. Current research also overlooks the connection between DFI and its environmental and economic impacts. This pattern is particularly noticeable in countries that are rapidly digitizing their economies, like China. This divide prevents governments from fully harnessing the promise of digital finance for sustainable development. According to Gulzar et al. [1], the environmental footprint increases significantly whenever human cultures experience fast economic growth.

Deterioration of the natural environment, making it more vulnerable and reactive, might result from insufficient technical resources. According to Xiong et al. [2], this might worsen the "butterfly effect" of growing environmental impacts. Abou Houran [3] found that ecological degradation significantly hinders socioeconomic progress, and this adverse effect only worsens with time. As a result, it threatens the sustainability of human progress in the long run [4]. The International Energy Agency [5] all agree that China is the biggest polluter and user of natural resources on Earth. Economic growth and environmental preservation are likely in China. China's ecological impact is approximately two to three times that of the US and India combined.

The increasing environmental impact in China is hindering economic growth. In 2018, China allocated 2.63 trillion Yuan for cleaning efforts, including 0.63 trillion Yuan for environmental damage and 1.99 trillion Yuan for pollutant loss and remediation. Ecological damage and pollutant degradation increased by 27.99% from 2012 to 2013, resulting in a cost equivalent to 2.1% of the economic-ecological gross

output. To achieve a sustainable future, it is essential to mitigate the environmental effects of human activities and curtail the expansion of the human ecological footprint. The growth and development of contemporary human groups depend heavily on financial assistance [6]. Environmental restrictions are becoming more severe, and the banking industry must adapt to these problems [7].

On the other hand, enough funding has always been an issue for sustainable growth. Capital-intensive, energy-intensive, and very polluting companies have received a large quantity of loan money from the banking industry to achieve profitability and liquidity. The consequence is a more significant environmental impact [8]. There is a considerable chance to solve ecological and environmental problems with the fast development of digital technology in the digital era. A novel financial inclusion model has emerged due to the deep merging of digital technology and capital. When internet banking and financial technology come together, it's called financial inclusion. "fintech" refers to the modern trend of banks and other online businesses offering loans, payments, and investment services via digital technology [9]. As financial inclusion has shifted from being dependent on credit to being data-driven, the financial system has undergone substantial changes. Significant improvements in the precision and effectiveness of capital allocation, as well as advancements in the breadth and depth of economic redistribution, have been achieved by the increasing separation of financial dispersion from human and environmental factors. As a result, conventional finance hasn't been able to make as much progress toward sustainable development as it might have. We are considering the potential of digital currency advancements to promote environmentally sustainable growth, mitigate the negative impacts of human activities, and reduce the ecological footprint. This post provides excellent answers to your question as well as a lot more.

Ecological research has long faced difficulties in measuring the natural world. Researchers have historically used emissions from industrial waste as a surrogate measure for evaluating ecosystem health. Emissions of carbon and sulfur dioxide ($SO_2$) are a widely used indicator. This framework facilitates the empirical analysis of human behavior, notwithstanding the ensuing limitations. This research suggests that some commodities produced are highly damaging to the Earth. Researchers must contemplate the essentials for the advancement of human civilization, even though this research often advocates for pollution reduction. Unilateral emission estimations of anthropogenic pollution are intrinsically inadequate. Research suggests that these measures are subjective and biased, inadequately reflecting the population. To understand the enduring effects of human activities on ecosystems, it is crucial to use more than only static indicators at the local level. Research conducted by the Intergovernmental Panel on Climate Change (IPCC) from 2007 to 2023 suggests that achieving zero emissions does not guarantee an instantaneous improvement in environmental conditions. The irreversible retreat of glaciers, as illustrated by Canh et al. [10], is evidence of this. Environmental sustainability, however, is an everlasting resource that can repair and renew itself. The ability of the natural environment to recycle and spread human-made trash is not taken into consideration by static flow indicators, nor is the ever-changing interaction between humans and the environment taken into consideration.

According to Pham et al. [11], human activities damage the biosphere, deplete natural resources, and emit toxic and hazardous waste, which are part of ecological degradation. Any detrimental effects on the natural environment have long-lasting consequences due to nature's limited ability to decompose and regenerate [12]. Consequently, assessing the natural environment from a stock-based viewpoint is more beneficial. Using the idea of the environment as a financial resource, the environmental footprint provides a quantitative assessment of humans' damage to the natural world. According to the paper, its influence on measuring sustainable development over the last 20 years has been substantial. Each individual's environmental footprint reflects the interplay between their consumption habits and the resources they use. The environmental footprint quantifies the alterations people impose on the natural environment by assessing both immediate and enduring effects. It has the capacity to provide an unbiased and comprehensive assessment of environmental alterations, including resource use and contamination. This metric comes from a complex calculation that considers many factors; research by Zheng et al. [13] concurs. Scholars argue that this method offers a practical approach to determining how much natural resources may be consumed without going overboard with the planet's regenerative potential.

The environmental impact of online banking has not been evaluated; so, consensus among specialists is necessary. Addressing this knowledge deficit may facilitate more investigation. This article examines the environmental impact of advancements in online banking technology. This research examines the environmental impacts of digital banking and the effect of digitizing conventional financial services on ecological restoration. This study examines environmentally biased technological breakthroughs and the effectiveness of green loans to determine the impact of improved financial inclusion on the environmental footprint. The study examines the transmission process to ascertain the influence of qualitative and quantitative elements on outcomes. This study addresses a gap in the process analysis literature by examining the relationship between financial inclusion and its environmental impact. This study examines the impact of digital financial expansion on environmental inclusivity, including regional resource accessibility and ecological degradation. This study examines how financial inclusion can promote ecological and environmental justice, considering regional disparities in environmental quality.

Environmental deterioration is a significant, although often neglected, impediment to sustainable development. Digital money is becoming prevalent in the second industrial revolution, influencing everyday life and commerce. Experts frequently encounter challenges related to complex environmental concerns, and the current study on the evolution of digital banking and its ecological impact necessitates greater coherence and consistency. This research illustrates the effect of online banking on ecosystems. Policymakers possess extensive information, and the practice sector can utilize digital financial resources to formulate effective policies that enhance environmental quality and promote sustainable development. This study examines ecological emissions and the potential of financial technology to mitigate anthropogenic environmental harm, thereby addressing a gap in the existing literature. This research made a modest contribution. A multitude of research has investigated the ecological effects of the proliferation of digital currency [14]

This study contributes to the body of research by examining China's progress in achieving its goals and reducing its dependence on conventional energy, a crucial aspect for its economic development. The smaller contributions include constructing a comprehensive index that aids in a statistical analysis of financial inclusion and digitization, beginning with an examination of China's data collection methods regarding financial inclusion, digitalization, and environmental responsibility. We use innovative robustness assessments known as endogenous variable tests. The research investigates the impact of digitization and financial inclusion on ecological sustainability. It analyzes deficiencies in current research and offers remedies, assisting government initiatives in advancing environmental sustainability via digital innovations. This research presents an innovative examination of cooperation between digitization and financial inclusion aimed at reforming China's political system and advancing sustainability. It offers critical insights that help China reconcile economic development with environmental conservation by integrating digital advancements and financial inclusion into its cohesive governance policies.

The following section adheres to this structure. A thorough literature review is presented here. Part three theoretically analyzes the consequences of digital currency on transmission channel analysis and its environmental impact. The fourth component formulates an empirical technique. The fifth part examines several potential ecological effects of digital currency, utilizing statistical data to support its analysis. The sixth element of the research empirically examines the impact of financial inclusion on the environment. The seventh and concluding portion of the study summarizes the findings and proposes further investigation.

## Literature review

Economic growth and ecological advancement depend on the financial and ecological systems being intertwined. This field of study often uses the environmental Kuznets curve. During the first phases of economic growth, industrialisation proliferated, and energy sources were uncontrolled, leading to ongoing environmental deterioration. Economic development is being slowed by environmental degradation, which is also affecting public health. The usage of renewable energy sources has increased, and pollution rules have become more stringent as a result of a growing awareness of the significance of conserving the

environment. Economic development and ongoing ecological improvement are consistently linked after a certain level of per capita income is attained.

Zhou et al. [15] found that financial development might benefit and negatively impact the environment. Economic growth can reduce the strain on energy sector finance, free up capital for investments in environmental protection, and pave the way for renewable and other technology improvement and acceptance. Potentially reducing energy usage and pollution emissions would positively affect the environment. Nevertheless, this has the dual effect of increasing ecological strain and footprint. Xu et al. [16] are the researchers responsible for the investigations above. Consequently, wisely allocating funds is the most critical part of using technology to our advantage while reducing our environmental impact.

Digital finance relies heavily on new digital technology, the ever-changing nature of which has the potential to impact the whole ecosystem. To reduce Carbon emissions and tackle environmental pollution, the Government of China has devised a digital transformation plan for the digital economy [17]. According to many studies [18]. Digital technologies are also essential in supporting a circular economy and establishing sustainable economic growth. The ability to precisely regulate and supervise industrial operations is enhanced by using digital technologies. According to numerous studies [19], data-driven information storage allows for comprehensive product lifespan monitoring, advanced management of potential product harm. A new financial inclusion model has emerged due to the merging of conventional banking with rapidly developing digital technologies; this model incorporates the accuracy and efficiency offered by digital technology into traditional banking. The development of digital finance has various advantages.

To begin with, it removes barriers associated with physical location, making financial services accessible from anywhere. Furthermore, it makes financial resources more accessible. In addition, it dramatically reduces the difficulties businesses face while trying to get capital.

Last but not least, it fixes the problems with traditional banks' services. However, financial inclusion can analyze a company's production and transaction data to determine its creditworthiness and provide loans accordingly. This improves the efficacy of financing while reducing the inefficiencies of traditional finance caused by information asymmetry [20]. Compared to conventional funding methods, financial inclusion may more effectively address the issue of mismatched resources, speeding up the growth of environmentally conscious projects and businesses. Not only that, it helps get rid of old manufacturing capacity, improves the industrial structure, and encourages long-term development. Without well-established industry standards, however, the fast growth of digital finance might lead to undesirable outcomes, including unlawful fundraising, financial fraud, and exorbitant interest rates [21].

The majority of the study examines the impact of traditional financial development on environmental footprints and explores how digital banking can mitigate pollution and promote sustainable development. The connection between environmental damage and economic development might have both positive and negative effects. Through a more efficient use of funds, digital financial development might enhance the ecological environment and encourage sustainable growth if it is put into practice. There are, however, very few studies examining the relationship between digital finance and sustainable development in terms of its environmental impact. Will blockchain technology mitigate the environmental impact of human economic activities? Will the expansion of financial inclusion, especially in developing nations, change the belief that environmental preservation should come second to economic growth?

***Theoretical hypotheses***

Engaging in social and economic efforts that support a green circular economy—which is defined by lower energy consumption and environmental harm—is one approach to decreasing one's influence on the environment. In addition, it aims to reduce human intervention in the natural environment, ultimately bringing about balance and harmony between the two. Financial inclusion is the term used to describe a financial framework that places a high priority on ecological sustainability. The efficiency and productivity of financial institutions have significantly increased due to the advancement of financial inclusion and the pervasive use of Internet transactions. Moreover, digital technology has mitigated financial barriers in capital markets resulting from information asymmetry and incomplete contracts. This

has effectively resolved variable inconsistencies within and between industries, resulting in decreased resource consumption in certain areas and enhanced efficiency in others.

From a supply-side perspective, nascent sustainable enterprises need substantial amounts of low-interest capital over a prolonged duration. Established firms must adopt more ecologically sustainable practices. The proliferation of methods to obtain cash is enhancing financial inclusion. The identification and testing technique may enhance sustainable manufacturing, enabling more judicious use of funds to promote green growth and transformation. Careful consumer behavior is a significant contributor to environmental deterioration [22]. Using a decentralized and networked transaction technique, financial inclusion incorporates the idea of environmentally responsive growth into financial services. This has a lasting effect on eco-conscious consumer actions. Consequently, this encourages people to live more sustainably and makes them more conscious of their environmental responsibilities [23].

For example, look at the "Ant Forest" app on Alipay's platform for digital financing. The software links mobile usage and the natural world by adapting users' consumption-based ecological conservation education in real time. This is achieved to restore and preserve the environment. Nearly 600 million Ant Forest users have planted 3.97 million acres of vegetation and contributed 326 million trees by 2021, restoring the natural environment and reducing the ecological impact. There is little question that the expansion of digital finance has not been without its share of accidental consequences. Mining Bitcoins uses much power, negatively impacting the environment [24]. The ecological impact of digital finance is primarily beneficial because of technical developments and heavier regulations that seek to reduce the negative consequences of digital technology on the environment. As a result, we hypothesize that'

How is digital finance being developed in a way that minimizes its impact on the environment? *Technological advancement* is the primary force propelling human social progress, determining the course and scale of environmentally conscious human growth. Innovation is a significant factor propelling technological advancement. "Green technological innovation" describes new ways of considering environmental factors. In it, we find innovations that lessen our environmental impact by conserving energy and materials and preventing, eliminating, or drastically cutting down on pollution. Regarding reducing negative environmental impacts, green technology innovation outperforms conventional technological innovation. Concentrating on creating technical advancements, emphasizing eco-friendly actions to lessen the human impact on the environment is critical.

In response to rising public awareness of environmental issues, businesses are being pushed to invest in green technology R&D by government restrictions and market forces. As a result, there has been a noticeable increase in technology developments, particularly regarding environmentally responsive options. Efforts to innovate environmentally approachable technologies are costly, uptight with failure, and conspicuous from the outside. A transition towards technical innovation focused on environmentally responsive solutions is hindered by the risk-averse behaviors of conventional financial institutions, which limit their ability to provide substantial assistance for green technological innovation. Two advantages of digital finance are bypassing physical barriers and substantially enhancing the movement of funds across different locations. More novel environmentally responsive technology may become possible as a result of this. In addition, by changing the logic of risk analysis, financial inclusion makes it more precise to identify project investment hazards. The system then uses these risks to find the best risk management solutions, which makes risk funding more efficient. According to Ibrahim et al. [25], skilled labor and capital are complementary. Funds are being redirected to businesses that do their part for the environment, attracting more qualified individuals to the green technology innovation sector. This development emphasizes the value of expertise in encouraging the development of environmentally responsive technologies [26]. In keeping with the tendency of ecologically responsive technical advances and reductions in impact, the development of Financial inclusion is a motivating factor for encouraging innovation in green technology [27].

Financial inclusion's forward energy encourages the development of environmentally responsive technology advances, reducing the negative impact of human activities on the planet.

As technology in financial inclusion improves, green credit becomes more effective, and the environmental impact of human activities is reduced.

## Data and methodology

### *Explanation of parameters*

The environmental footprint is the only evidence required to support this article (EF). The natural environment provides the material needs of humans by serving as an absorber, filter, and eliminator. The conversion of human waste into new and valuable resources contributes to the advancement of humanity. The extent of human influence on the environment is contingent upon the volume of carbon emissions generated by their activities, reflecting the efficacy with which our planet can meet human demands for natural resources and environmental services. This study facilitates the extraction of resources to enhance the comprehension and assessment of the sustainability of regional expansion throughout time. Sustainable development challenges are often investigated using the environmental footprint. The environmental footprint identifies six kinds of natural land need for various activities: arable land, grassland, forestland, fishing land, building land, and fossil fuel land states that there are six different types of land use, with the first five describing the areas used for natural resources and the sixth describing the areas theoretically used for energy.

In order to determine the impact on the environment, this research uses general accounts data and follows the combined technique laid out by Saidani et al. [28]. All six of the land uses above must be considered in order to arrive at the environmental footprint. In order to determine the environmental footprint per person, we divide the total area required to meet the demand for all land types by the population size. The amount of artificial fertilization, soil fertility, and weather conditions are some of the variables that cause a significant annual variation in agricultural productivity per unit of land. According to Duan et al. [29], this study takes into account the land's sustainable ecological carrying capacity by adjusting the weights of different lands using the land's equivalency factor. With this change, we can rewrite equation (1) to calculate the EF for each person.

$$CF = \frac{\sum_i^n (r_j * A_i)}{N} = \frac{\sum_i^n \left(\frac{P_i}{Y_i}\right)}{N} \left(i = 1,2,\ldots,n; j = 1,2,\ldots,6\right) \quad (1)$$

$$\mathrm{EF} = f(\mathrm{FI}, \mathrm{TI}, \mathrm{EER}, \mathrm{GDP}, \mathrm{DA}) \quad (2)$$

$$\mathrm{EF_{it}} = \alpha_1 + \alpha_2 \mathrm{FI_{it,}} + \alpha_3 \mathrm{TI_{it}} + \alpha_4 \mathrm{EER_{it}} + \alpha_5 \mathrm{GDP_{it}} + \alpha_6 \mathrm{DA_{it}} + \mu_{it} \quad (3)$$

$$Y_{jt} = \alpha_{jt} + \vartheta_{jt} X_{jt} + \mu_{jt} \quad (4)$$

In this context, "where" denotes the equivalency factor for the j-th land type and "N" represents the absolute population.

One unit of measurement for a vast expanse of land that may sustain biological production is the "area of biologically productive land" in hectares. In this case, it refers to the area occupied by the i-th consumable item after commutation. Kilograms (kg) represent the entire amount of the i-th consumable.

There is a global mean yield in kilos per hectare for the i-th consumption item. Consumer product data imports and exports inside the arable footprint are straightforward. Instead of concentrating on consumption as is customary, this research looks at how arable land is farmed to produce consumer goods to keep accounting practices consistent. According to Shahriar et al. [30], the environmental footprint is derived from the arable footprint created during the production of eight primary agricultural commodities: sugar, cotton, tobacco, yams, oilseeds, grains, and pulses.

The development of the average environmental footprint per person and the associated category footprint in various Chinese regions is investigated in this study. The study is based on the findings of the computations. The area of land allocated for agriculture, pasture, forestry, construction, and aquaculture expanded from 2011 to 2018, while per capita fossil energy use also rose. A notable escalation in the environmental impact was seen throughout this era. The per capita footprint for fossil fuels increased

from 1.7267 to 1.92204 global hectares; for arable land, wooded land, buildings, fisheries, and the environment overall, it increased from 0.168982 to 0.210212 worldwide hectares; and for the aggregate of these, it grew from 2.59597 to 2.91317 worldwide acres. The mining of fossil fuels from dry regions is the leading cause of China's environmental issues. Despite the decrease in total energy consumption from 66.51% to 65.98%, the per capita fossil fuel use increased by 11.31%. From 2011 to 2023, there was an astonishing 29.15% increase in the per capita environmental footprint. The reduction in the per capita environmental footprint growth rate post-2011 cannot be deemed a coincidence. A notable increase in financial inclusion occurred in 2021, signifying a pivotal moment in the sector's rapid growth.

Due to China's slowing economy and its focus on home development, financial inclusion has emerged as a critical player in its economic transformation. Because of this, innovation and R&D have flourished, and the industrial structure has been transformed and improved. All of China's provinces are seeing an increase in their environmental footprint per inhabitant. During the period from 2011 to 2023, there was a decline from 10 to 7 regions that demonstrated a reduced environmental footprint, as shown by the dark green areas in the picture. Some have speculated that the heavy reliance on resource-intensive and polluting industrial systems the Human Development Index in central provinces like Shanxi, Shandong, and Inner Mongolia is to blame for the deterioration of their per capita environmental footprint. These regions are already experiencing heightened ecological and environmental challenges, and the trend toward greener technology is only likely to become worse [31]. Here, financial inclusion (FI) serves as the primary independent variable. According to Pata et al. [32], financial organizations and Internet enterprises provide various financial services via digital technology, including lending, payment, and investment services.

Furthermore, Financial inclusion may revolutionize financial markets, institutions, and service delivery by developing novel business models, application scenarios, and product processes [33]. When evaluating digital currency, academics mainly utilize one of three methods. Studies assessing online finance through technology make up the first group. One way to do this is to look at search data for terms linked to Financial inclusion and how often they appear in searches for specific locations [34]. Research evaluating the consequences of advancements in financial inclusion that use dummy variables makes up the second group. Explanatory variables in the research include policies at the national level that aim to promote Financial inclusion [35]. Thirdly, some studies quantify the state of Financial inclusion by constructing indices utilizing various calculation techniques and one or more sets of sub-indices [36]. As for the third metric, the Peking University Digital Financial Inclusion Index of China (PKU-DFIIC) is now the go-to choice among academics.

Given the exponential growth of online banking, the index above is computed using Alipay3's extensive use of information. The last index is obtained by processing the data using a logarithmic effectiveness function in conjunction with ranked analysis. This index has been monitoring the growth of digital currency in China since its launch in 2011. With information gathered from 33 different subcategories and four primary sectors, the index sheds a detailed picture of China's Internet financial development. One advantage it provides is that it keeps signals and time consistent. Judging the index is appropriate when done using individual-level consumption data analysis. With more demand comes more digital finance, which means more digital financial advancement.

Therefore, a higher score on this indicator indicates expanded access to financial services. Collecting corporate data is a challenge, which makes it hard to use it to quantify the supply-side financial inclusion index. Furthermore, implementing the supply-side financial inclusion index is only in the beginning stages. One way to measure the progress of digital finance and its effects on technological advancement and environmental control is via the index mentioned in a previous study [37]. Therefore, to measure the advancement in financial inclusion from 2011 to 2023, this study used the digital financial inclusion index at the provincial level.

The China Digital Inclusive Finance Index and its sub-indices have a timeline that runs from 2011 to 2023. The government's and the financial inclusion index's digitalisation surpassed all other sub-indices in terms of growth rate between 2011 and 2023. Approaching a record-breaking growth rate, indicative of the breadth of digital financial inclusion. Nonetheless, the index quantifying digital financial use grew at a

diminished pace. Each indicator has a distinct annual growth rate. The utilisation depth indicator surged significantly from 2014 to 2017, which is essential for bolstering the upward trajectory of the digital inclusion index. The use of financial inclusion serves as a pivotal catalyst for exponential global expansion once a specific barrier related to digital banking coverage and acceptance is surmounted.

The control variables in the study's model were chosen based on the criteria established by Banna et al. [38]. Examining GDP per capita is one method to assess the level of the Human Development Index, which is a significant factor. The GDP per capita of a nation serves as one metric of its Human Development Index. To do this, we divide the GDP by the population of the country at the end of the year. An individual's ability to safeguard the environment and their level of environmental consciousness enhance the Human Development Index, significantly influencing their ecological footprint. Digitalisation and Automation (DA) pertains to the financial resources designated for projects in the scientific and technical domains. Increased funding for research may facilitate technological advancements that are environmentally beneficial and energy-efficient, hence reducing our ecological footprint. Regional education expenditure is the foundation of the third tier, ETI. Enhanced education augments an individual's human capital and understanding of environmental protection, hence considerably influencing their ecological footprint. Openness (ERR) is the attribute discussed at the fourth level. A method to assess a region's openness is to examine its GDP as a proportion of the total value of foreign commerce. The biological environment of an area is significantly influenced by the transmission and competitive impacts resulting from economic openness. People density (PD), the fifth level, is determined by the proportion of people residing in urban areas compared to the total population. Rapid urbanisation exacerbates industrial production, energy consumption, and land use, significantly impacting the environment.

***Proposed models***

The fixed effects model used in this research is two-way. Between 2011 and 2023, the data research primarily focused on panel data from several provinces in China. Although conventional banking has limitations, including inadequate accessibility and inefficient cash distribution, financial inclusion aims to rectify these problems and provide a reliable and adequate monetary supply. Consequently, there is less financial opposition to the eco-conscious transformation of the economy, increased backing for the initiation of green initiatives and enterprises, and a deceleration in the expansion of the environmental imprint left by humanity. A novel paradigm for economic analysis has been developed.

$$CF_{it} = \alpha_0 + \alpha_1 FI_{it} + \alpha_x Controls_{it} + \theta_i + \mu_t + \varepsilon_{it} \qquad (5)$$

***Data sources and descriptive statistics***

This study's empirical examination makes use of the following data sets. The China Digital Inclusive Finance Index, published by Peking University's Financial Inclusion Research Center, is the source for the statistics on digital inclusive finance. Every year, the regional statistics yearbooks, the China Energy Statistics Yearbook, and the China Statistical Yearbook are consulted for the primary data used in calculating the Environmental footprint, not to mention the control factors. The quantitative summaries of the variables are shown in Table 2.

## Empirical analysis

***Analyzing regression benchmarks***

The primary explanatory variable, the coefficient of FI, is consistent with our hypotheses and shows a significant negative correlation at the 5% level. The explanatory variable FI has a coefficient of -2.303, whilst the control variables are shown in column (2). At the 5% significance level, the coefficient remains statistically significantly negative. With an increase of one standard deviation in digital financial development, the average per capita environmental footprint decreases by 1.14% (calculated as 2.303 multiplied by 0.01 and divided by 2.023). Initial evidence from the empirical data corroborates hypothesis

H1. This suggests that systems can significantly reduce the ecological footprint of individuals, thereby mitigating the considerable harm people inflict on the ecosystem.

Table 1. Summary of variables.

| Variable | Initials | Description | Measurement |
|---|---|---|---|
| Environmental footprint | CF | Conservation of natural resources and the long-term viability of economic growth in the area | synthetic approach in three dimensions |
| Financial inclusion | FI | An innovative approach to banking that emphasizes the use of digital tools with more conventional banking services | PKU's Electronic Equitable Funding Rating |
| Human Development Index | HDI | Increase in real wellbeing throughout the nation and the rate at which it is occurring | Economic output as a percentage of the total inhabitants in a particular area |
| Digitalization and Automation | DA | The power that people have to alter natural systems in order to facilitate societal development | Spending on research and development |
| Population Density | PD | The movement of people from rural areas to metropolitan centers | Ratio of city dwellers to the general population |
| Exchange Rate Regime | ERR | Actively broadening international business relationships | Gross domestic product (GDP) is a measure of all the international commerce |
| Education Technology Investment | ETI | Interventions, both psychological and valuable, that influence how people grow psychologically and physically | Distribution of funds for educational purposes within regions |

The ecological equilibrium is swiftly declining as a result of China's economic framework, marked by excessive energy use and environmentally detrimental enterprises. The need for sustainable growth is driving the reorganisation and enhancement of the regional economic structure. The advancement of financial inclusion, alongside the reorganisation of financial transactions and enhancement of industry efficiency, has incorporated environmentally responsive elements that effectively address the economic requirements of sustainability initiatives, such as investments in renewable energy, technological innovations in established sectors, and environmental technology. The objective of financial inclusion is to streamline resource allocation by substituting the existing investment framework with a more logical alternative. By reallocating those dollars to ecologically sustainable initiatives, we can diminish our ecological footprint and alleviate the adverse effects of human activities on the earth.

Table 2. Statistical descriptions.

| Variables | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| CF | 280 | 2.066 | 2.624 | .606 | 0.828 |
| FI | 280 | 2.024 | .026 | .262 | 4.204 |
| DA | 280 | 8.642 | 20.882 | .028 | 60.842 |
| HDI | 280 | 6.248 | 2.66 | 2.602 | 24.846 |
| ETI | 280 | 0.246 | 2.080 | 4.666 | 22.802 |
| ERR | 280 | .284 | .204 | .024 | 2.464 |
| PD | 280 | .668 | .242 | .228 | .806 |

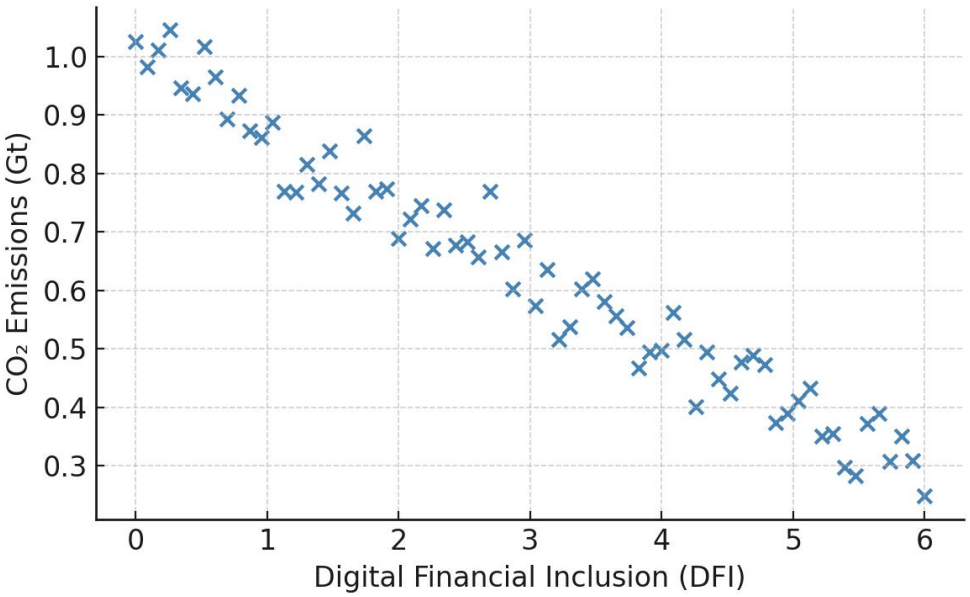


Figure 1. Digital Financial Inclusion VS $CO_2$ Emission

This Figure examines the relationship between carbon dioxide emissions, a key environmental indicator, and the growth of digital financial inclusion (DFI). The Digital Financial Inclusion (FI) index, shown on the X-axis, serves as a metric for assessing the accessibility of digital financial services across various areas. Carbon dioxide ($CO_2$) emissions, shown on the y-axis, serve as a metric for the environmental impact of many economic activities. The graph illustrates a substantial negative association between the two variables: increased digital financial inclusion is often associated with reduced per capita environmental consequences. This discovery suggests that digital financial services promote eco-friendly financial options, reduce energy consumption in conventional banking systems, and provide more efficient means for executing financial transactions, while minimizing the need for physical travel. While digital banking facilitates sustainable development by reducing environmental impacts, this graph prompts an inquiry into how the expanding digital economy counteracts these advantages through heightened energy consumption in data centers and electronic waste.

Table 3. A look at the findings of the benchmark regression analysis.

| VARIABLES | (2) | (2) |
|---|---|---|
| FI | −2.040** | −2.404** |
| | (-2.604) | (-2.280) |
| Constant | 4.688*** | 2.460 |
| | (24.20) | (2.446) |
| Controls | NO | YES |
| Region | YES | YES |
| Year | YES | YES |
| Observations | 280 | 280 |
| R-squared | 0.404 | 0.426 |
| N | 42 | 42 |

***Environmental inclusion effect***

In order to achieve a fairer Human Development Index and go beyond the limitations of traditional banking, it is essential to encourage financial inclusion and use the advantages of digital technology. Specifically, problems have been found with attribute mismatch, domain mismatch, and stage mismatch (Charfeddine & Ben Khediri, 2016). In addition to hindering sustainable development, these issues worsen ecological gaps and regional growth inequities. According to studies, both underdeveloped areas and SMEs gain from financial inclusion, increasing economic inclusion (Qayyum et al., 2021). Considering the environmental consequences of electronic financial growth is of utmost importance, especially in economically poor regions and locations with high pollution levels. Financial inclusion is vital in these areas because it provides the finances needed to convert to more ecologically responsive practices. This phenomenon causes the catch-up effect [39]. The development of digital financing likely positively impacts the natural world. Divided into three equal groups according to GDP per capita, this study examines how digital financial progress affects regional environmental fairness and whether or not less developed regions can handle pollution before remediation. For regression analysis, these segments stand in for poor, undeveloped, and developed regions. Next, we check whether, under certain ecological conditions, the growth of digital financial services is associated with varying effects on the natural world.

Table 4. The impact on environmental integration.

| VARIABLES | Poverty regions | Underdeveloped regions | Developed regions | Quantile of 0.2 | Quantile of 0.6 | Quantile of 0.0 |
|---|---|---|---|---|---|---|
| FI | −3.464** | −4.684** | −0.880** | −0.640*** | −0.646** | −0.066*** |
| | (-0.688) | (-0.484) | (-0.240) | (-0.282) | (-0.424) | (-0.886) |
| Controls | YES | YES | YES | YES | YES | YES |
| Region | YES | YES | YES | YES | YES | YES |
| Year | YES | YES | YES | YES | YES | YES |

| VARIABLES | Poverty regions | Underdeveloped regions | Developed regions | Quantile of 0.2 | Quantile of 0.6 | Quantile of 0.0 |
|---|---|---|---|---|---|---|
| Observations | 84 | 84 | 222 | 280 | 280 | 280 |
| $R^2$/Pseudo $R^2$ | 0.626 | 0.648 | 0.440 | 0.886 | 0.860 | 0.020 |
| N | 15 | 20 | 17 | | | |

Deteriorating levels of the Human Development Index highlight the impact of digital financing. Not only that, but at the 5% significance level, all of the regression coefficients. A negative regression coefficient of -3.464 is the biggest for financial inclusion in economically deprived locations. Next, the regression coefficient for developed areas is -0.688, whereas the result for less developed regions is -0.484. As a function of changes in Environmental footprint levels, adopting digital financial systems considerably reduces the Environmental footprint at the 0.1, 0.5, and 0.9 quartiles.

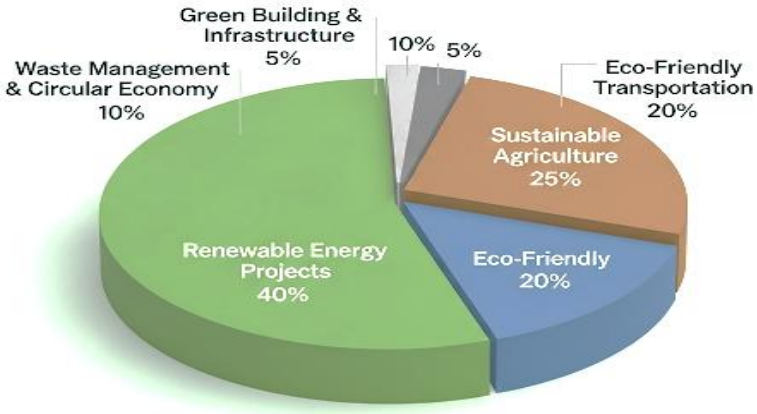


Figure 2. Green Investment Flows Breakdown.

The green investment flow is broken out in this Figure in relation to digital financial inclusion. The green investment sectors shown on the X-axis include renewable energy initiatives, sustainable agriculture, and environmentally friendly technology, among others. The percentage of green investments or the overall investment amount relative to all investments is shown on the Y-axis. The data unequivocally demonstrates that digital financial platforms have enabled the allocation of resources towards environmentally sustainable industries, including sustainability initiatives and renewable energy. As digital banking systems evolve, it is evident that investments in environmentally sustainable activities are increasing. This graph illustrates how digital banking may direct funds towards green initiatives to foster sustainable development and mitigate environmental impacts.

Additionally, the regression coefficient continually changes from -0.648 to -0.886, indicating that this impact is becoming increasingly apparent. According to these findings, the impact of digital financing is more inhibitive in areas with higher Environmental footprint values. The regression analysis above indicates that digital finance development has substantial ecological and economic inclusiveness implications. Specifically, in economically and environmentally low regions, it has a more substantial positive impact on the environment. The foundation for this is that financial inclusion offers a distinct

edge in funding and can efficiently assign funds to achieve sustainable development objectives. Notably, the environmental inclusion effect neglects areas that avoid the brutal cycle of pollution and cleanup. In addition, it encourages development in these communities' economies while protecting their natural resources, which is a win-win situation. Furthermore, environmental inclusion seeks to lessen environmental inequalities across different areas. It encourages a sense of fairness and inclusivity in the relationship between the environment and the economy, ultimately leading to sustainable development.

***Robustness tests***

According to earlier research, the spread of online investment can significantly lessen its impact on the environment. However, concerns about the model's missing variables, measurement errors, and reverse causality raise the possibility of endogeneity issues and skewed regression findings. When environmental degradation causes changes in regional income distribution, which impacts economic growth, we get an example of reverse causality [40]. Therefore, the variables may be symmetrically correlated with each other. Missing variables are the subject of the second problem. This research aims to create a two-way fixed effects model that will account for missing factors that are both district-level and time-varying. In order to minimize the possibility of bias in the regression findings, the model takes into account a large number of characteristics that might affect the Environmental footprint. Incomplete parameters are an insurmountable problem, an unsuccessful reality to challenge. Due to the possibility of correlations between the explanatory variables and the error terms caused by faulty measurement, the parameter estimations may be of low quality. This study uses instrumental variables and difference-in-differences (DID) methodologies to assess the actual impact of online banking on environmental impact, notwithstanding the endogeneity issue.

$$\Delta Y_{it} = \theta_i + \sum_{j=0}^{z-1} \alpha_{ij} \Delta X_{i,t-j} + \pi_i \tau_t + \sum_{j=1}^{q-1} p_{ij} \Delta Y_{i,t-j} + \mu_{it} \quad (6)$$

The quantity of internet broadband port accesses is the primary emphasis of this investigation. Access to high-speed internet is closely related to developing and expanding the digital financial sector, as it supports the whole industry. The direct relationship between broadband internet access and the random disturbance component in the model becomes less apparent when factors such as technology improvements and regional economic growth have been controlled. This led the researchers to conclude that the number of access points to broadband internet in each area was vital for financial integration. We ensured consistency and correlation by factoring in the number of broadband internet port accesses in each region. A country's per capita environmental footprint is inversely proportional to its level of digital financial growth. We also demonstrate the reliability of the earlier regression results. In the first phase, the F-value exceeds 16.38, with a value of 27.029. Consequently, it may be necessary to resolve the issue of inadequate instrumental parameters.

The abbreviation for the Decentralized Identifier method is DID. China presented a strategy in September 2016—the G20 High-Level Principles for Digital Financial Inclusion—to encourage the growth of Financial inclusion in low-income developing countries (LIDCs) and in China itself. An outside force proposed the policy change, and its effects were felt more strongly by the less developed western and central regions than by the more developed eastern regions. Thus, this study investigates the research by Cetin et al. [41], where the experimental group consists of the central and western areas, while the control group consists of the eastern regions. To guarantee that the sample durations are comparable before and after the policy's implementation, the research focuses on 2013–2023. One way to measure how much the policy-affected group shrank relative to the control group before and after an experiment is by using the Difference-in-Differences (DID) method. This aims to deal with the issue of reverse causality, which might lead to skewed results, and to assess the impact of digital money's progress.

Table 5. Outcomes of the heterogeneity testing

| VARIABLES | Phase Ⅰ | Phase Ⅱ | DID |
|---|---|---|---|
| Inter | 0.882*** | | |
| | (4.002) | | |
| FI | | −4.260** | |
| | | (-2.204) | |
| Treat*Post | | | −0.280* |
| | | | (-2.884) |
| Constant | −0.0882 | | 4.024*** |
| | (-0.284) | | (4.020) |
| Controls | YES | YES | YES |
| Region | YES | YES | YES |
| Year | YES | YES | YES |
| KP-LM | 24.220*** | | |
| Wald test | 28.020 | | |
| Observations | | 280 | 280 |
| R-squared | | 0.088 | 0.248 |

The X-axis in this graph represents industrial efficiency, which measures how effectively businesses utilize resources such as energy, labor, and materials to produce products and services. Time series data on renewable energy adoption rates are shown on the Y-axis. This graph shows how renewable energy sources have increased industrial efficiency (or how little) over time. According to the numbers, industrial efficiency has not improved to the same extent as renewable energy usage. Companies are transitioning to renewable energy sources without fully optimizing their operations, which results in inefficiencies. When systemic inefficiencies continue even after improvements in energy supply, these results may indicate that there are obstacles to completely integrating renewable energy into industrial processes. The findings require further research into ways businesses can improve efficiency and sustainability simultaneously.

The DID technique must be used to meet the parallel trend assumption's requirements. The parallel trend approach is used to evaluate hypotheses to attain this purpose. The image demonstrates that in the three periods before the policy's introduction, the influence of digital financial development on mitigating the environmental footprint is negligible. The results indicate that the environmental footprints of the treatment and control groups were comparable before the policy's implementation, indicating little to no effect. The environmental footprint has significantly deteriorated over the past three years due to the implementation of digital financial development. The influence of internet banking has intensified over time. The outcome indicates that the DID model used in this study effectively meets the criteria for the parallel trend test. The data used to construct the index is derived from Alipay application records maintained by Ant Group. This technique is connected with two issues. The index evaluates consumer components but overlooks the growth of digital finance within the industrial sector. Alipay's rapid growth enabled it to dominate the Chinese digital banking sector at one time. Since then, emerging online startups have started to erode Alipay's dominance.

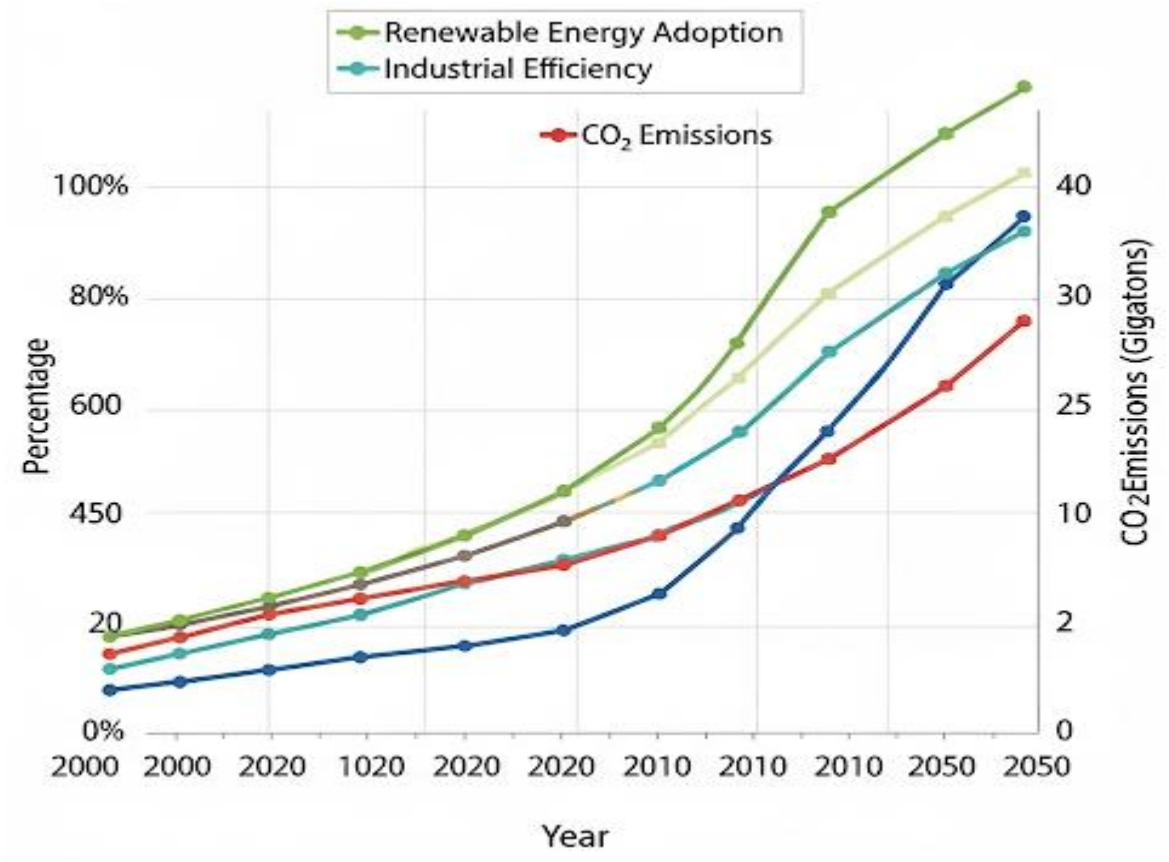


Fig.3. Renewable energy adoption vs Industrial efficiency

Furthermore, it is essential to acknowledge that the development indicators of the financial sector are not included in the evaluation. This necessitates delivering a precise representation of the digital financial report's magnitude. This research used a web crawler approach to scan Baidu News's advanced search tool for "digital finance"-related phrases, categorised by year. By aggregating all the search results, we can assess the extent of digital financial growth across various areas. The subsequent step is to do a regression analysis.

The concept of exclusion is illustrated. Cities in China that report directly to the national government appreciate more administrative independence and better opportunities for economic growth. In addition to their positive effects on the national economy and the environment, these cities are in the spotlight because of the political clout they've used to attract national resources and industry leaders. Because of this, their advantage in the expansion of the regional economy is more apparent. Contaminating the sample with this variable may compromise the reliability and consistency of the regression results. By not including the sample of municipalities, this study conducts an empirical examination. You can find the regression results in Table 6, column (2). Regression analysis reveals that the introduction of digital money significantly worsens the Environmental footprint (r=-3.058).

Temporal dependence on the independent variables. A model that considers changes in the factors influencing the explanatory variables over time was suggested by (Y. Li et al., 2023). This model incorporates terms for the cross-product of control and temporal trend variables. This study's model includes a time trend and a cross-product term of the control variables to account for the potential time-dependent effects of the environmental footprint's influencing factors. There is a strong inverse relationship between financial inclusion and the Environmental footprint. First-order autocorrelation. This

study's disquiet terms may display heteroskedasticity or autocorrelation due to the sample's lengthy time frame, which prevents them from adhering to the assumption of spherical perturbation. Because of this, OLS is no longer considered the best unbiased linear estimator. This study addressed the potential effects of autocorrelation and heteroskedasticity by using the generalized least squares (GLS) method.

Table 6. Additional robustness tests of financial inclusion effects.

| VARIABLES | Variable replacement | Sample exclusion | Time trend of the control variables | First-order autocorrelation |
|---|---|---|---|---|
| FI | −6.264** | −4.068*** | −2.262** | −0.600*** |
| | (-2.486) | (-2.064) | (-2.644) | (-4.260) |
| Controls | YES | YES | YES | YES |
| Region | YES | YES | YES | YES |
| Year | YES | YES | YES | YES |
| Observations | 280 | 244 | 280 | 280 |
| N | 40 | 28 | 42 | 42 |
| R-squared | 0.462 | 0.440 | 0.640 | |

This graph examines the interdependent dynamics of digital financial inclusion, GDP growth, and carbon emissions from 2000 to 2023. The X-axis displays the growth of digital financial inclusion in different areas from 2000 to 2023. On one side of the Y-axis is GDP growth, while on the other is carbon emissions tracking. Greater digital financial inclusion is associated with quicker GDP growth, according to the graph. There is a trade-off between economic development and environmental sustainability, as digital finance promotes economic activity while also contributing to increased carbon emissions. This pattern highlights the potential negative ecological impacts of rapid economic growth driven by digital banking, prompting vital concerns about striking a balance between economic growth and environmental protection. The Figure calls for more sustainable development models that incorporate both ecological and financial objectives.

### *Heterogeneity analysis*

The development of online finance and its impact on the environment are the main points of this paper. Environmental preservation is an example of a public virtuous since it has positive effects on people's lives generally. Yet, unanticipated events may interfere with the efficient allocation of resources, leading to wasteful levels of consumption and pollution. One effective method for dealing with wasteful resource allocation and fighting environmental deterioration is to use external limitations and guidance. Even while online finance has helped with "financial exclusion," it has also created a new issue called the "digital divide." This segmentation reduces the efficiency of financial inclusion, as only a select few individuals and places can enjoy digital rewards. When we use natural resources and release pollutants into the environment, we leave what is called an Environmental footprint. Before delving into the various effects of digital financial progress on environmental impact, this research first examines the external limits. It takes several factors into account, including the resources, environmental constraints, and the government's ability to rule digitally. Additionally, it investigates how digital finance is affected by the "digital divide" issue.

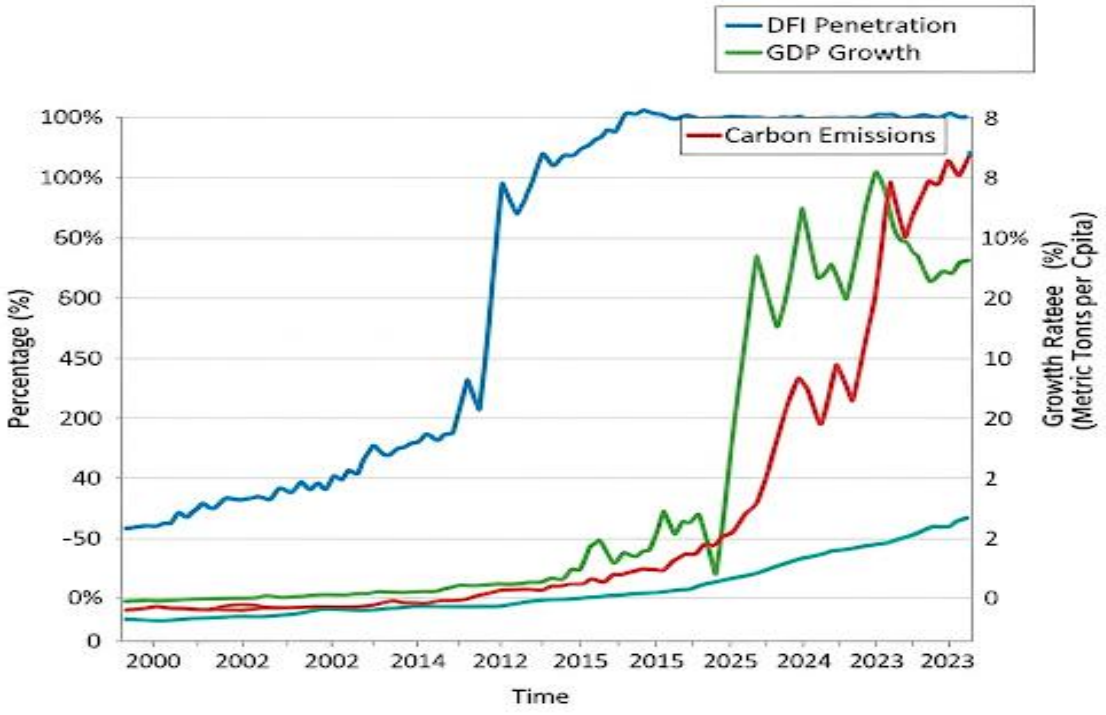


Figure 4. Correlation of Digital Financial Inclusion, GDP Growth, and Carbon Emission Trends 2000-2023.

Regional economic growth is heavily influenced by the Chinese government, which intervenes heavily in th heavily. Also, when it comes to market engagement, the Chinese government is in a prime position to support economic growth in the area. They complement one another in the growth of financial inclusion and the government's ability to regulate digitally. A more digitally perception government is necessary since the rise of the digital economy has affected human lifestyles and productivity to a significant degree. To effectively address public challenges, this calls for the adoption of a more proactive and efficient form of governance. The government must embrace the transformations introduced by the digital era and proactively integrate information technology and systems into its governance practices. This can only be achieved by implementing a horizontal organisational structure that fosters open communication between people and their government. The government's adoption of this policy would reduce economic friction and transaction costs, while enhancing the digital financial environment. This research evaluates the impact of several competences on financial inclusion after an assessment of the government's management of digital governance. Currently, social media serves as the primary channel via which public administrations disseminate information to the populace. The vast user base of online social networking sites, information can be quickly and easily shared and discussed in real-time. Consequently, they have grown into a powerful instrument that governments throughout the world may use to establish digital governance and distribute up-to-date policy data. This study examines the state of digital governance in China by analyzing Weibo, the country's most popular social media site, and calculating the number of official microblog accounts relative to 10,000 users in different regions. Additionally, before regression analysis, the sample is divided into two subsamples, with the government's digital governance skills' median value serving as the separating border.

Undoubtedly, every single regression coefficient for financial inclusion passes the 10% significance threshold. When comparing the two groups, the financial inclusion regression coefficient is much more significant in those with excellent digital governance skills than in those with low capacities. The full realization of financial inclusion advantages is contingent upon the government enhancing its digital governance capacities. By enhancing the government's digital governance capabilities, we can streamline

government service procedures, eliminate economic roadblocks, raise the bar for public goods provided by government agencies, put an end to pollution and excessive resource consumption caused by outside forces, and foster an economic climate that is both fair and efficient. The subsequent improvement of the ecological environment is made possible by the efficient deployment of digital financial resources.

Table 7. A primary aspect of Heterogeneous assessment.

| VARIABLES | High digital governance capacity | Low digital governance capacity | High Environmental restrictions | Low Environmental restrictions |
|---|---|---|---|---|
| FI | −2.080** | −0.846* | −4.288** | −2.802*** |
| | (-2.824) | (-2.820) | (-2.646) | (-4.686) |
| Controls | YES | YES | YES | YES |
| Region | YES | YES | YES | YES |
| Year | YES | YES | YES | YES |
| Observations | 286 | 04 | 204 | 286 |
| R-squared | 0.462 | 0.466 | 0.646 | 0.246 |
| N | 42 | 22 | 20 | 22 |

As previously stated, environmental quality and financial development are causally related. Investment strategies and returns are affected by environmental constraints. More severe environmental regulations usually result in better conservation efforts, which in turn need more funding and better project management. The impact of digital currency on reducing environmental impact may therefore be amplified. We want to learn more about the diverse impacts of digital financial development on the environmental footprint by conducting this research with varying degrees of environmental limitation in mind. Environmental regulations control each area to varying degrees, as measured by pollution fees to industrial value-added ratios. The ratio measures the ecological spending relative to the industrial value added, and a larger one suggests that the area has more severe environmental regulations. According to the median degree of environmental restriction, the sample is split into two categories: one with few restrictions and another with significant restraints. This disaggregation is used by collective regression analysis. The significance test ended successfully, with all financial inclusion regression coefficients passing at the 5% significance level. Also, compared to the group with fewer environmental restrictions, the one with considerable limits had a much higher regression coefficient value of -3.187. These results suggest that areas with stricter ecological regulations may see increased demand for digital finance.
This has the potential to increase the effect of financial inclusion on resource allocation, make green projects more accessible, improve the local ecology, and reduce environmental damage.
Geographical Human Development Index may be broadly categorized as "clean" or "non-clean" depending on the degree to which natural resources are distributed throughout various areas. A region's economic growth is apparently stunted when natural resources are abundant, according to the resource curse hypothesis. This is mainly because of the crowding-out effect and the Dutch disease impact. Considering the "Dutch disease effect," places with an abundance of resources are more inclined to expand economic growth by being the ones to process them first. The rationale for this is that they get an advantage over their competitors due to the lower cost of resources. However, this leads to excessive resource usage, which in turn increases the ecological impact. Another consequence of resource over-reliance is the "crowding out effect" that happens when the energy sector becomes the dominant component of the industrial system. The current economic pattern of both clean and non-clean sectors is

reinforced when a single industrial facility draws significant investment and labor to the area, eventually displacing other environmentally responsive enterprises. As a result, the Environmental footprint becomes even larger. With varying degrees of available resources, this study aims to analyze the distinct implications of digital financial development on the environmental footprint. The amount of coal, oil, and natural gas that may be hypothetically recovered is used to estimate the resource awards of regions. The next step is to run a regression analysis after sorting the data into groups based on the median. Also, those in the richer support will feel the effects of digital finance more acutely than those in the poorer support. This outcome demonstrates that the development of financial inclusion helps to combat the "resource curse" and encourages resource-rich countries to change from environmentally damaging to ecologically sustainable Human Development Index. In the long run, this lessens the ecological effect and lowers the environmental expenditure per unit of output.

Table 8. The second assessment of the Heterogeneity study.

| VARIABLES | High resource endowments | Low resource endowments | High digital access | Low digital access | High digital usage | Low digital usage |
|---|---|---|---|---|---|---|
| FI | −4.824*** | −0.288* | −2.848* | −0.284 | −2.628** | −0.622 |
| | (-4.246) | (-2.642) | (-2.822) | (-0.622) | (-2.204) | (-2.288) |
| Controls | YES | YES | YES | YES | YES | YES |
| Region | YES | YES | YES | YES | YES | YES |
| Year | YES | YES | YES | YES | YES | YES |
| Observations | 240 | 240 | 260 | 220 | 240 | 240 |
| R-squared | 0.402 | 0.228 | 0.406 | 0.240 | 0.486 | 0.264 |
| N | 28 | 28 | 42 | 28 | 26 | 24 |

At this time of incredible technological advancement, the digital gap is rising to the level of a significant concern. A digital gap is especially noticeable in these two areas. One measure of digital technology access disparity is the fact that not everyone has the same opportunities to use computers, phones, and the internet. Both the national plan for the growth of the digital economy and the standard of the country's technological infrastructure are involved. Another issue is the disparity in people's use of digital technologies, including the internet, phones, and software. Various academic disciplines make diverse use of digital technology to varying degrees, which contributes to the observed variation in utilization levels. You can't take part in digital finance unless you can access and use digital networks. When comparing rural and urban locations in China, there is a massive disparity in the accessibility of digital resources. According to research, if there is a digital gap, then only certain areas will be able to obtain the benefits of digitization. So, digital finance's positive impact on the ecosystem would be diminished, and regional development would be more fragmented.

This study examines how the digital divide impacts the operation of financial inclusion via empirical research. This research starts by evaluating the extent of internet penetration to ascertain the accessibility of digital technologies. The sample is then categorized into two groups based on the mean value. Data shown in columns (3)–(4) of Table 8 indicate that in areas with greater internet penetration, the negative correlation between digital financial expansion and environmental impact is more pronounced. Statistical significance is attained at the 10% level with a regression coefficient of -1.838 for the connection. A supplementary statistic for assessing competency with digital technologies is the proportion of the

population with a bachelor's degree or above relative to the total population. Individuals with a greater number of years of education tend to use phones and other technical gadgets more often. Regions with enhanced potential for digital consumption may address the environmental footprint challenge via digital financial advancement. Recognizing and bridging the digital divide is crucial to fully utilising the efficiency of online banking. Attaining environmental equity is more challenging when digital financial resources are inequitably allocated and inefficient across regions, exacerbated by the "information gap" and "knowledge segregation" resulting from the digital divide.

Table 9. Assessment of mechanisms using OLS and TSLS models.

| VARIABLES | OLS | | TSLS | |
|---|---|---|---|---|
| FI | 0.802* | 4.222*** | 0.402** | 2.482** |
| | (2.884) | (4.042) | (2.244) | (2.244) |
| Wald test | | | 28.020 | 28.020 |
| Controls | YES | YES | YES | YES |
| Year | YES | YES | YES | YES |
| Region | YES | YES | YES | YES |
| Observations | 280 | 280 | 280 | 280 |
| R-squared | 0.426 | 0.880 | 0.682 | 0.268 |
| N | 42 | 40 | 42 | 40 |

Note: FI: Financial Inclusionm, OLS: Ordinary Least Squares, TSLS: Two-Stage Least Squares

## Further discussion

How do the effects of increasing access to financial services affect the environment? The natural environment not only absorbs human waste but also supplies a large portion of the energy required for social and economic development. Enhanced access to finance may augment the efficacy of green financing and stimulate the development of innovative, eco-friendly technologies. This may mitigate the adverse environmental effects by decreasing reliance on polluting energy sources and total pollution. This research examines the effects of digital financial services on the environment by analysing the transmission mechanism. Two elements are especially significant: the efficacy of green financing and technical innovations that promote environmentally sustainable behaviors. The study used Ordinary Least Squares (OLS) and Two-Stage Least Squares (TSLS) models to investigate these enquiries.

***Environmentally-focused approach to technology development***

In order to achieve sustainable growth, technical progress is crucial, with the main driver being the creation of eco-friendly technology. Spontaneous green machinery, eco-friendly manufacturing procedures, and innovative pollution prevention tools might significantly lessen our environmental impact. The results are fewer resource wastage, less environmental harm, and a smaller ecological footprint. Strict restrictions and rising expectations for improved living circumstances are driving new technology to tackle environmental concerns at a rapid pace. Technology advancements prioritizing ecological preservation are encouraged by the screening effect. Financing environmentally responsive tech advancements requires financial inclusion to meet scalability and dependability standards. Beyond what is required, it promotes and backs environmentally responsible technical innovation, which satisfies a local need and inspires a desire for such progress. Examining the dissemination of environmentally conscious technical advances is the overarching goal of this research. In order to characterize the green technological innovation direction (GT) in each area, the research uses the percentage of patents for green

innovations as a whole [22]. Green innovation research and development receive more priority in locations with higher percentages. Check out the State IP Office's patent database or the WIPO list of green patents to see what innovations have been patented in this area.

The OLS regression study considers indignity concerns like missing variables and other confounds and finds a statistically significant association between digital finance and green-biased technological innovation (r=0.801, 10% p-value). Capital resources are more readily available for digital financial development than conventional finance. Addressing the demand for such innovations in the sector successfully encourages the development of eco-friendly technology. To that end, it may help mitigate the damage people do to the environment in the area.

***Green credit effectiveness scale mechanism***

Green credit is a system that uses financial incentives to encourage and recognize business actions that lessen their impact on the environment by cutting down on wasteful usage of energy and pollutants. As a requirement for receiving credit funds, "green credit" evaluates how strictly environmental standards and ecological preservation are adhered to. It transfers funds to address the long-standing problem of production practices that harm the environment and lead to resource waste. The goal of this method is to reduce the cycle of pollution, cleanup, and restoration. When it comes to accounting and decision-making, the financial sector is starting to consider environmental and ecological concerns with the help of green credit. This fosters a positive relationship between the financial industry and the natural world, mitigating some of the unforeseen effects of expanding environmental and ecological sectors and other businesses that don't always pay off right away. Improvements in the efficiency of both the compromise and administration of environmentally aware loans, as well as a decrease in the costs associated with information recovery, are all possible outcomes of the development of financial inclusion.

Furthermore, this innovation may increase the supply of green credit and attract large quantities of capital, both of which contribute to green finance's overall efficacy. The purpose of this study is to assess the performance of the green credit scale by looking at the total amount of loans given to green businesses in that area. The effectiveness of the regional green credit scale is evaluated by using the methods outlined by Rahman et al. [42] for regression analysis: Ordinary Least Squares (OLS) and Two-Stage Least Squares (TSLS).

The Financial inclusion regression coefficient is still statistically significant at the 5% level. Reclamation the expenses of green investments takes a long time and has significant external repercussions. But conventional financing, which favors readily available capital and has a low-risk tolerance, does not back it up enough. There are two primary benefits to the development of computerized financial systems. Green financing may become more widely available, for starters, if it helps with social capital mobilization and encourages the use of underutilized sources. In addition, new digital tools make it easy to monitor green credit development in real-time, which improves its effectiveness while also ensuring financial stability. As a result, sustainable growth is promoted, harmful effects on the environment are reduced, and eco-friendly businesses are allowed to grow.

## Conclusions and Policy Recommendations

***Overview***

The emerging financial sector of financial inclusion is often seen as having changed our understanding of economic growth and how society and the economy operate. This concept underpins this research. This study analyses the relationship between the proliferation of digital money and the environmental impact of each province, using panel data covering all of China from 2011 to 2023. This study examines the transmission method and implications of digital financial development on sustainable development, with a particular emphasis on environmental impacts. The research is well supported by actual evidence. The per capita environmental effect of China's provinces has been consistently decreasing. The transition to digital banking has significant environmental implications, which can be mitigated. Countries with low incomes and regions experiencing considerable environmental degradation are likely to see this phenomenon more prominently. Numerous comprehensive experiments have shown the validity of

interconnectivity. Two measures must be implemented to enhance the impact of financial inclusion development on the reduction of environmental effects. Priority one: the government must enhance its oversight of digital technologies and take a leadership role in the environmental sector.
Furthermore, to bridge the digital divide, it is imperative to strive for a more equal allocation of digital resources and software. To preserve the Human Development Index over the long term, it is essential to cultivate environmentally friendly technology and incorporate sustainable financial practices. Financial inclusion may facilitate environmental benefits by accelerating the development of sustainable technology and enhancing the efficiency of green finance. This would mitigate the adverse impacts on the environment.

***Policy implications***

These policy implications stem from the aforementioned research findings. Enhanced methodologies for evaluating and allocating resources are necessary. Financial institutions should fully leverage digital technology for creating financial products, loan approval, risk management, and other related activities. To facilitate the high-quality growth of the real economy, it is essential to enhance the flexibility and precision of financial inclusion progressively. This will enhance digital financial services for the real economy, significantly contribute to sustainable development, and use the synergy between digital and green finance regarding effect and innovation potential. Advancing digital infrastructure development and promoting cooperation in digital financial growth are crucial. Expediting the advancement of state-of-the-art digital infrastructure and augmenting the capabilities and capacity of network infrastructure are very important.
Furthermore, the hardware infrastructure of the building system, encompassing internet broadband, optical fibre, and other key components, needs enhanced coordination and advancement. It is essential to secure funds for the construction of internet infrastructure in low-income areas, expedite internet adoption, and mitigate regional digital access inequities. The enhancement of the nation's governance capacity must be expedited, and digital governance must be fortified. Establishing a government that is both digital and intelligent necessitates advocating for the extensive use of digital technology to facilitate administrative operations. Furthermore, we must acknowledge the significant influence that digitalisation has had on enhancing governmental efforts for ecological and environmental conservation. The primary objectives of information technology are to enhance individual interactions within the social sphere and to provide a robust framework for gathering and assessing public feedback.

***Future Direction***

Although theoretical and experimental testing have been included in this study, several limits still need more investigation and improvement. Initially, we must address the issue of sub-footprint expansion. This research seeks to comprehensively examine the environmental effects associated with the inception of digital money. Each of the six components of the environmental footprint represents a unique ecological context in a separate situation. Building upon the first environmental footprint study, further research might investigate the extensive impacts of advancements in digital banking across several settings, primarily by assessing how these technologies have transformed ecological footprint scenarios. The fast proliferation of electronic financial metrics is the second problem. This study uses the data provided by PKU-DFIIC to examine financial inclusion metrics. Data gathered from users' financial records may illuminate some facets of the sector, although it does not provide a comprehensive view of digital currency's evolution. The rapid shift of the supply-side banking industry to digital technology is significantly influencing the advancement of financial inclusion. Digital financial indicators may see substantial advancement on the supply side shortly.

***Declaration***

**Ethics approval/declaration:** Not applicable.
**Consent to participate:** Not applicable.
**Consent for publication:** Not applicable.

**Acknowledgment:** Not applicable.
**Conflict of interest:** The authors declare no conflict of interest.
**Data availability:** Data used in the study will be provided by the corresponding author upon request.
**Author's contribution:** Abdul Ghaffar: Conceptualization, Supervision, writing—original draft preparation. Muhammad Asif: Formal analysis, software. Areeba Ejaz: Project administration. Kashif Raza: Methodology, writin, review and editing. All authors have read and agreed to the published version of the manuscript.

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