Article

Digital Finance and County Ecological Performance—New Evidence from China Counties

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Abstract: As a new product that combines finance and digital technology, digital finance is of great significance to the governance of the ecological environment. Based on the panel data of 2128 counties in China from 2014 to 2020, the fixed effect model and a panel threshold model are established, and the direct impact, heterogeneity, and transmission paths of digital finance development on ecological environment quality are empirically analyzed. The results demonstrate that the progress of digital finance has a significant negative effect on ecological environmental performance, and robustness tests support this conclusion. Additionally, industrial agglomeration and structural transformation are crucial mechanisms through which digital finance hinders ecological environmental performance. Moreover, the adverse influence of digital finance development on the ecological environment is particularly pronounced in densely populated areas, county-level cities, and non-poverty-stricken counties. Fourthly, based on the development level of digital finance itself, digital finance has a double threshold effect on the performance of county ecological environment. When digital finance is at a low level and a high level, its negative impact on eco-environmental performance is the greatest. Between the low level and the high level of digital finance, digital finance has the greatest negative impact on the performance of the ecological environment. Finally, suggestions are put forward to promote the green development of digital finance, foster balanced regional development, and expedite industrial transformation in underdeveloped regions.

Keywords: digital finance; eco-environmental performance; heterogeneous characteristics; transmission mechanism

1. Introduction

Environmental pollution, climate change, and ecological destruction pose threats to human health and survival and have far-reaching impacts on social and economic development. They hinder the sustainable utilization of resources, disrupt social stability, and impede future development. Since the reform and opening in 1978, China has experienced rapid economic growth, with its regional gross domestic product (GDP) consistently ranking among the highest globally. However, this extensive economic model has also resulted in severe environmental problems. Despite the government’s efforts to strengthen environmental pollution control through policies and regulations, China still faces significant challenges. According to the Global Environmental Performance Index in 2022 [1], the comprehensive environmental index of China ranks 160th in the world. In its 2022 Bulletin of Ecological Environment in China [2], the Ministry of Ecology and Environment highlighted that although the national ecological environment quality has improved, the foundation for further improvement remains unstable. The difficulty of achieving continuous improvement is evident, and the transition from quantitative to qualitative improvement in ecological environment quality has yet to be completed. Therefore,
environmental governance has become a crucial task for China. Further enhancing ecological management and implementing more effective measures are necessary to promote the coordinated development of the economy and the environment. Only by doing so can China achieve sustainable development objectives. The study shows that ensuring the long-term sustainable development of ecology is the primary aspect of sustainable development [3].

As the core factor of social production and modern economic operation, finance plays a vital role in reducing transaction costs, accelerating the flow of factors, and guiding social capital from industries with high pollution, high energy consumption, and excess capacity to cleaner production industries [4]. It is also an essential regulatory tool for government departments to save energy and reduce emissions [5]. Focusing on building a green financial policy framework and leading the green economic transformation and development will inevitably become an effective means of environmental governance. However, traditional finance is a form in which traditional financial institutions (such as banks, securities companies, insurance companies, etc.) provide financial products and services through offline channels. Its essential feature is that it is “too poor to love the rich”, which may make it difficult for medium and small enterprises and other low-income groups to obtain financial resources [6], thus making it difficult to fully play the role of financial energy conservation and emission reduction. Digital finance is a new feature of economic development, which rises with the development of digital technologies such as the Internet, big data, and cloud computing. By promoting information sharing and lowering the threshold for obtaining financial resources, digital finance addresses the issues of high transaction expenses and inadequate financial resource availability in traditional finance. It fills the service gap that conventional financial institutions cannot cover [7], providing financial help for start-ups and small and medium-sized micro-groups and further enhancing the energy-saving and emission-reduction effects of finance.

Although the relationship between digital finance and environmental pollution has been discussed in the literature, there is still no unanimous conclusion. Then, from the county perspective, does the development of digital finance improve or reduce ecological performance? What is its influencing mechanism? Is there a nonlinear relationship between the development of digital finance and the ecological performance of counties? In order to answer the above questions, based on the panel data of 2128 counties and cities in China from 2014 to 2020, this paper discusses the influence of digital finance development on county ecological performance by constructing a panel double-fixed-effect model, discusses its action mechanism by using the intermediary effect model, studies the nonlinear relationship between digital finance and county ecological performance by using a panel threshold model, and deeply studies the heterogeneity of digital finance on county ecological performance. The research shows that from the county perspective, the development of digital finance reduces ecological performance, and industrial agglomeration and structural transformation are the main influencing mechanisms. In densely populated, county-level cities and non-poverty counties, the negative impact on the ecological environment is even greater. This study provides a solid empirical basis and decision-making reference for better playing the role of digital finance in pollution reduction.

The innovations and contributions of this paper are as follows: First, this paper finds for the first time that the development of digital finance has reduced the ecological environment performance at the county level in China. In the past, most of the research focused on China province and explored how the development of digital finance can improve environmental quality. However, there is little research on the degradation of environmental quality caused by the development of digital finance, and there is no research and analysis on the impact of the development of digital finance on the ecological environment at the county level. As the most basic administrative unit in China, it is of great significance to discuss the relationship between digital finance and county ecological environment for realizing the ecological environment from “quantitative change to qualitative change”. Therefore, taking China county as the research object, this paper discusses how the development of digital
finance can reduce the quality of the ecological environment, thus filling the research gap between digital finance and environmental quality. Secondly, different from the previous studies on carbon dioxide, industrial wastewater, waste gas, and solid waste, this study refers to the research of Chinese scholars and takes county PM2.5 and vegetation coverage data as key indicators and dependent variables of empirical research, which supplements the research on digital finance and environmental governance. Thirdly, taking industrial agglomeration and structural transformation as mechanism variables, this paper expounds on how digital finance affects the ecological performance of counties, enriching the existing theoretical research. Fourthly, in the aspect of heterogeneity, this paper discusses the impact of digital finance on ecological performance from the aspects of population density, urban grade, and economic differences. Fifthly, in order to avoid possible endogenous problems, this paper takes the development degree of digital inclusive finance of each county-level administrative unit and the nearest county in the same prefecture-level city as the instrumental variable. Finally, combined with the reality of China’s development, some suggestions were put forward to improve the ecological environment of the county.

The rest of this paper is organized as follows. The Section 2 introduces the literature review. The Section 3 includes the theoretical framework and research hypothesis. In the Section 4, the variables are explained, and the econometric model and data source are explained. In the Section 5, the empirical results are described. Finally, the research results are provided, and targeted suggestions are put forward.

2. Literature Review

The early research on environmental problems primarily focused on the relationship between economic growth and environmental pollution. One prominent hypothesis in this regard is the Environmental Kuznets Curve (EKC), which posits an inverted U-shaped relationship between economic growth and environmental pollution. As research progressed, the financial sector began to be included in environmental studies, believing that finance could contribute to economic development and ecological improvement by mobilizing idle capital, optimizing resource allocation, and promoting industrial transformation, thereby achieving a “win-win” outcome [8]. With the diversification of financial development, academic circles have gradually deepened their understanding of the relationship between finance and the environment. Scholars initially paid attention to the influence of finance on the hypothesis of the Environmental Kuznets Curve (EKC) and then gradually turned to discuss the relationship between finance and environment, including the influence of financial institutions on environmental policies and the influence of environmental risks on financial markets. In recent years, with the rise of digital finance, academic circles began to analyze the impact of digital finance on the environment, including the energy consumption in digital currency and the application of blockchain technology in environmental governance, and the research content has been continuously enriched. It can be predicted that with the continuous innovation of the financial industry and the increasingly prominent environmental problems, the research on the relationship between finance and environment will be more in-depth and extensive.

2.1. Traditional Finance and Ecological Environment

Academic circles continue to debate the connection between traditional finance and the environment. Three main perspectives have emerged in this discourse.

Firstly, some researchers argue that the development of traditional finance has improved environmental quality by promoting new energy development and technological innovation [9–11]. For instance, Dogan et al. [9] found that financial development reduced environmental degradation based on macro data from renewable energy countries between 1985 and 2011. Lv et al. [10] analyzed panel data from 30 provinces in China from 2003 to 2017 and concluded that financial development can effectively mitigate environmental pollution through technological innovation. Similarly, Rahman et al. [11] examined data
Secondly, some studies suggest that traditional financial development harms the ecological environment by promoting investment activities and economic growth. Hafeez et al. studied data from 52 countries participating in the Belt and Road Initiative (OBORI) from 1980 to 2016, confirming that financial development can exacerbate environmental degradation [12]. Acheampong analyzed macro data from 46 sub-Saharan African countries between 2000 and 2015, revealing that economic development increased carbon emissions [13]. Jiang et al. conducted a comprehensive study involving 155 countries and found that financial products significantly raised carbon emissions, particularly in developing countries [14]. Zaidi et al. utilized data from 21 OECD countries between 2004 and 2017 to demonstrate that the development of inclusive finance exacerbated environmental pollution by increasing carbon emissions [15].

Thirdly, there is a view of a nonlinear relationship between financial development and the ecological environment. For example, Acheampong found a nonlinear relationship between the development of financial markets and the intensity of carbon emissions based on the panel data of 83 countries from 1980 to 2014 [16]. This relationship shows different characteristics in countries at various stages of financial development.

With the continuous development of society, the basic characteristics of traditional finance have exposed some deficiencies [17]. Especially in promoting pollution reduction, the role of traditional finance is limited to a certain extent. As a result, scholars have suggested the need for innovation in finance. For instance, some studies have highlighted that in cases where the economy is minor and environmental issues are not significant, then green technology primarily relies on introducing and imitating advanced foreign technologies. In such situations, traditional finance can generally fulfill the financing requirements and contribute to pollution prevention and emission reduction through financial guidance and technological advancements [18,19]. However, as the traditional economy grows, the demand for green high-tech industries is expected to increase. These industries possess characteristics such as high risks in technology research and development, substantial capital requirements, and extended return periods. It becomes challenging for traditional finance to meet the financing needs of such industries. Therefore, it is necessary to change business philosophy, innovate financial tools, promote the development of green high-tech industries, and promote economic transformation.

### 2.2. Digital Finance and Ecological Environment

In recent years, the rapid development of digital finance has not only accelerated digital transformation and product innovation within the traditional financial industry but also sparked increasing interest among scholars in understanding its relationship with the ecological environment. Although there is limited research on the impact of digital finance development on the environment, there are varying perspectives on the matter.

One perspective argues that the advancement of digital finance can play a role in alleviating pollution by lowering information expenses, alleviating financial limitations, and fostering technological innovation and structural transformation within businesses [20–22]. For instance, Shi et al. [20] conducted an empirical analysis using data from 30 provinces in China between 2011 and 2019. They found that strengthening environmental supervision and improving digital inclusive finance can alleviate ecological pollution. Similarly, Xiong et al. [21] analyzed panel data from Chinese provinces between 2011 and 2019, confirming that digital finance significantly affects industrial pollution control. Wan et al. [22] utilized macro data from 273 prefecture-level cities in China between 2010 and 2017, revealing a vital negative connection between digital finance and the discharge of pollutants. They suggested that digital finance has the potential to reduce pollutant discharge through technological innovation, structural adjustment, and efficient capital allocation.

The second viewpoint indicates that the advancement of digital finance has a negative impact on the ecological environment. Wang et al. conducted a microscopic study using from Australia between 1990 and 2020 and found that financial development contributed to a reduction in pollution emissions.
household follow-up survey data in China and found that digital finance promoted carbon emissions, leading to environmental degradation. However, their analysis did not consider the contribution of other entities, such as enterprises, to carbon emissions [23]. Similarly, Ozturk et al. examined macro data from 42 countries participating in the “Belt and Road Initiative” from 2007 to 2019 [24]. They found that increased digital finance inclusiveness often resulted in a significant rise in pollution emissions, leading to a deterioration of the environmental quality in the economies involved in the initiative. However, their study needed to differentiate between developed, developing, and underdeveloped countries within the Belt and Road Initiative.

In contrast, the third perspective posits that the relationship between the development of digital finance and the ecological environment is still being determined. Qin et al. analyzed data from seven emerging economies between 2004 and 2016 and found that the influence of digital finance on carbon emissions varied across different quantiles [25]. This suggests that the relationship between digital finance and the environment is complex and context-dependent.

Generally speaking, scholars have different views on the impact of digital finance development on the ecological environment. Some studies believe that digital finance can reduce pollution, while others believe that digital finance will aggravate environmental problems. Other studies have shown that the relationship between digital finance and the ecological environment is uncertain. Further research is needed to deeply understand the influence of digital finance on the ecological environment. At present, the literature has comprehensively analyzed the relationship between digital finance and ecological environment, but there is still room for expansion: First, the research on the impact of digital finance on ecological environment mainly focuses on the provincial and municipal levels, while the evidence at the county level is still lacking. In order to fully understand the impact of digital finance on the ecological environment, this paper must bring the county into the scope of research. Only in this way can we fully understand the influence of digital finance on the ecological environment and provide a more accurate basis for the formulation of relevant policies. Therefore, taking county as the research object is of great significance to enrich the research field of digital finance’s impact on the ecological environment. Secondly, the literature about the impact of digital finance on the ecological environment is scarce, and the existing research mainly relies on social survey data, which is different in applicability and representativeness. At present, no scholars have used macro-panel data to carry out related research. Therefore, this study selects the macro-panel data of China county for the first time, aiming to explore the impact of digital finance on the ecological environment. Through in-depth research on the relationship between digital finance and environmental pollution, this study hopes to fill the research gap in this field. Thirdly, when discussing the heterogeneity of digital finance in the ecological environment, we should start with the inclusiveness of digital finance in poverty-stricken areas with vast land and sparse population. However, the existing research mainly focuses on the provincial and municipal scales, and the discussion between the east, the middle, and the west cannot fully reflect the micro-scale situation. Therefore, this study intends to discuss the heterogeneity of digital finance in the ecological environment from the perspectives of population density, poverty-stricken counties, and urban grades. This research method is helpful in understanding the influence of digital finance on the ecological environment in different regions more comprehensively.

3. Theoretical Analysis and Research Hypothesis Development

Digital finance is a combination of traditional finance with digital technologies such as the Internet, big data, and cloud computing, which forms the further development of financial services. Digital financial services, such as digital payment and online credit, are environmentally friendly. For example, financial institutions can provide credit products directly to enterprises and consumers through online platforms, which improves their access to funds. The development of digital finance has a direct influence on the performance
of the ecological environment, mainly in two aspects. On the one hand, the development of digital finance can loosen the financing restrictions of enterprises and promote the expansion of production capacity. This means that enterprises can more easily obtain funds to invest in new production facilities and equipment, thereby improving production capacity. However, it may also bring more energy consumption and pollution emissions because the increase in production capacity usually means more production activities and energy consumption, which will have a reduced impact on ecological environment performance. On the other hand, relaxing the restrictions on consumption budget can stimulate commodity consumption. This means that consumers can obtain loans or credit more easily, thus increasing their purchasing power. However, it may also lead to more resource consumption and environmental pressure because consumers may buy more goods and services and increase resource consumption and waste emissions, thus reducing ecological and environmental performance. Based on the above analysis, we propose hypothesis 1: The development of digital finance has reduced the ecological environment performance.

3.1. Industrial Agglomeration Channel

Digital finance, utilizing technologies such as big data, mobile networks, and artificial intelligence, offers enterprises expanded financing options and improved liquidity, consequently facilitating enterprise development [26]. Moreover, digital finance provides efficient payment and settlement services that can reduce operating costs, enhance competitiveness, and attract more enterprises to enter the same industry, fostering industrial agglomeration effects. As capital continues to flow into rural areas and with the relocation of industries, an increasing number of enterprises establish factories in rural regions. While eco-agricultural enterprises and cooperatives have become primary recipients of capital in rural areas, it is essential to note that there are also polluting industries, such as processing plants and electronic factories. These enterprises often relocate to underdeveloped regions, as they may face stricter environmental regulations in more developed areas and urban centers [27]. However, the slow pace of economic development and lower levels of industrialization in underdeveloped regions might lead local governments to prioritize short-term economic gains over environmental concerns. This could result in allocating digital financial resources to highly efficient yet environmentally detrimental enterprises, further exacerbating local ecological pollution issues. Based on the aforementioned analysis, we propose hypothesis 2: Industrial agglomeration facilitated by digital finance exacerbates ecological environment pollution.

3.2. Structural Transformation Channel

The development of digital finance serves as a comprehensive reflection of the financial development level in society, and its integration with various industries can impact the direction of industrial structure [28]. For one thing, digital finance has facilitated the rapid advancement of new technologies, formats, and business models by utilizing platform users’ information, market-oriented application of information technology, innovative management practices, and integration of business models. This has further accelerated the upgrade of the industrial structure [29]. However, it is crucial to remember that these new technologies, formats, and business models may have adverse environmental effects. For instance, the growth of e-commerce, driven by digital finance, has led to increased logistical operations, packaging, and related activities, resulting in heightened resource consumption and environmental pollution.

For another, digital finance plays a crucial role in mitigating information asymmetry between the financial sector and market participants by leveraging consumer data obtained through mobile payment platforms. This empowerment enhances the financing capacity of traditional enterprises and enables them to maximize resource acquisition during the innovation process. This, in turn, promotes technological innovation within traditional enterprises and accelerates the optimization and upgrading of traditional industries [30]. However, during this upgrading process, these industries may adopt more efficient production
methods with a more significant environmental impact. For example, digital finance promotes the development of intelligent manufacturing, which often involves substantial energy and raw material requirements, making waste management in the manufacturing process more challenging. Based on the aforementioned analysis, we propose hypothesis 3: Digital finance intensifies ecological environmental pollution through industrial structure reform.

In order to summarize the above theoretical analysis, Figure 1 shows the conceptual mechanism.

![Figure 1. Theoretical framework diagram.](image)

### 4. Research Design

#### 4.1. Model Setting

In order to verify the relationship between county digital finance and ecological performance, this paper uses the two-way panel fixed effect model to conduct benchmark regression analysis [31]. The advantage of using panel data analysis is that it provides more degrees of freedom, which can increase the sample size and statistical power. Compared with traditional longitudinal research methods, panel data provides a more flexible research method, especially when controlling and adjusting various factors. In addition, panel data is usually complete data, and there is no missing data like cross-sectional data, thus reducing measurement error. Therefore, panel data analysis provides researchers with a more accurate and reliable database, which is helpful for a deeper understanding of the characteristics and laws of the research objects. The advantages of the fixed effect model are as follows: First, the two-way fixed effect model can comprehensively consider the causal relationship and the reverse relationship, thus studying the influence between variables more comprehensively. Secondly, the model can solve the endogenous problem; that is, the results of the model are influenced by unobservable variables. The two-way fixed effect model can solve the endogenous problem more effectively by controlling the individual fixed effect and the time fixed effect. Third, the model can consider regional heterogeneity and time heterogeneity. Through the regional fixed effect and time fixed effect, the two-way fixed effect model can reflect the heterogeneity of region and time and improve the interpretation and prediction ability of the model. In addition, in order to better explore the relationship between individuals, this paper also carried out county-level cluster analysis. The model is as follows:

\[
Y_{it} = \alpha + \beta \text{Index}_{it} + \gamma \text{Control}_{it} + \varphi_i + \mu_t + \epsilon_{it}, \tag{1}
\]

Among them, \(i\) and \(t\) represent the region and year, respectively; \(Y_{it}\) is the explained variable, indicating the level of ecological performance; \(\text{Index}_{it}\) is the core explanatory variable, showing the development level of digital finance; \(\text{Control}_{it}\) represents the control variables; \(\alpha\) is the regression coefficient; \(\varphi_i\) stands for regional fixed effect; \(\mu_t\) stands for time-fixed product; \(\epsilon_{it}\) is a random disturbance term.
To further identify the mechanism, this paper refers to the research of Chen et al. [32] and constructs an intermediary effect model, including the intermediary variable $M$:

$$M_{it} = \alpha_1 + \alpha_2 Index_{it} + \alpha_3 Control_{it} + \varphi_{i1} + \mu_{t1} + \varepsilon_{it},$$  \hspace{1cm} (2)

$$Y_{it} = \beta_1 + \beta_2 * Index_{it} + \beta_3 M_{it} + \beta_4 Control_{it} + \varphi_{i2} + \mu_{t2} + \varepsilon_{it},$$  \hspace{1cm} (3)

Among them, Formulas (2) and (3) are intermediary effect testing procedures, with $M_{it}$ representing intermediary variables, including industrial agglomeration (LQ) and structural transformation (IS), and the meanings of other variables are the same as Formula (1). Similarly, the intermediary effect model is fixed in time and region and clustered at the county level. The specific test steps are as follows: Firstly, test the coefficient $\beta_1$, and if it is not significant, stop the intermediary effect test. Secondly, for the test coefficients $\alpha_2$ and $\beta_3$, if both are significant, further test $\beta_2$; if $\beta_2$ is effective, the mediation effect is substantial. If $\beta_2$ is not practical, it is a complete mediation effect; if at least one of $\alpha_2$ and $\beta_3$ is not significant, the Sobel test is conducted, and whether this test is substantial determines whether the mediation effect is significant.

This study aims to investigate the potential nonlinear relationship between digital finance and ecological performance levels. To mitigate any potential subjective bias in the estimation results caused by arbitrary regional divisions, this study adopts the Hansen [33] threshold effect regression method to determine the precise threshold. The panel threshold model is constructed as follows.

$$Y_{it} = \delta_0 + \delta_1 * Index_{it} * I (Index_{it} \leq \gamma_1) + \delta_2 * Index_{it} * I (\gamma_1 \leq Index_{it} \leq \gamma_2) + \cdots + \delta_n * Index_{it} * I (\gamma_{n-1} \leq Index_{it} \leq \gamma_n) + \delta_{n+1} Control_{it} + \varphi_{i} + \mu_{t} + \varepsilon_{it},$$  \hspace{1cm} (4)

$Index_{it}$ represents the threshold variable, and $I()$ represents the indicator function. If the expression in parentheses is correct, then $I()$ takes 1; otherwise, 0; ... is the threshold value of $Index_{it}$ to be estimated. The remaining variables are the same as those in the previous section. Digital finance is not only a threshold but also a threshold effect variable; $\gamma_n$ is the threshold value, and the control variable is the same as the benchmark regression setting.

4.2. Variable Selection

4.2.1. Explained Variables

Eco-environmental performance (Ecoenp) is a comprehensive measure that reflects the quality and efficiency of the eco-environment, the cleanliness of economic and social production and life, and the potential for green development. To ensure the accuracy of the evaluation results and consider the availability of county-level data, this study adopts the entropy method used by previous scholars to measure eco-environmental performance [34–36].

The methodology is as follows: Firstly, each county’s afforestation area and smog pollution (PM2.5) are normalized, treating the afforestation area as a positive indicator and smog pollution as a negative indicator. Secondly, the weight of each index is calculated using the entropy method, which helps to determine the importance of each hand in the overall assessment. Finally, the comprehensive score is calculated by applying the weight values to each index, resulting in an index that reflects the performance of the ecological environment.

Using this approach, the study aims to provide a comprehensive measure of eco-environmental performance at the county level, considering both positive and negative aspects of the environment. This methodology allows for a more accurate assessment of the ecological performance of each county and facilitates the comparison and analysis of different regions.

The specific steps are as follows:

Step 1, standardize the original data:
Standardization of positive indicators:
\[
X_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}, \quad i = 1, 2, \ldots, n, \quad j = 1, 2, \ldots, m
\] (5)

Standardization of negative indicators:
\[
X_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})}, \quad i = 1, 2, \ldots, n, \quad j = 1, 2, \ldots, m
\] (6)

This paper uses standardized numerical translation to solve the logarithm problem involved in entropy method operation.

Step 2, calculate the proportion of the \( j \)-th index.
\[
Y_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \quad (0 \leq Y_{ij} \leq 1), \quad i = 1, 2, \ldots, n, \quad j = 1, 2, \ldots, m
\] (7)

Step 3, calculate the information entropy value \( e_j \) and the information utility value \( d_j \).
\[
e_j = -K \sum_{i=1}^{m} Y_{ij} \ln Y_{ij}, \quad 0 \leq e_j \leq 1, \quad i = 1, 2, \ldots, n, \quad j = 1, 2, \ldots, m
\] (8)

where \( K \) is a constant, \( K = \frac{1}{\ln m} \).
\[
d_j = 1 - e_j, \quad 0 \leq d_j \leq 1, \quad j = 1, 2, \ldots, m
\] (9)

Step 4, calculate the index weight of the \( j \)-th index.
\[
\omega_j = \frac{d_j}{\sum_{j=1}^{m} d_j}, \quad 0 \leq d_j \leq 1, \quad j = 1, 2, \ldots, m, \quad \omega_1 + \omega_2 + \cdots + \omega_j = 1
\] (10)

The fifth step is to calculate the ecological performance level, and the specific formula is as follows:
\[
A_i = \sum_{i=1}^{n} \omega_j X_{ij}, \quad 0 \leq A_i \leq 1, \quad i = 1, 2, \ldots, n, \quad j = 1, 2, \ldots, m
\] (11)

4.2.2. Core Explanatory Variable
This study uses a normalized digital financial index to indicate county digital finance. The calculation formula:
\[
Index_{it} = \frac{\text{digital financial index}_{it}}{100}
\] (12)

4.2.3. Mediator Variables

Industrial agglomeration: In this paper, referring to the practice of Fan et al. [37], \( LQ \) is used to measure the level of county industrial accumulation, and the calculation formula is:
\[
LQ = \frac{\text{The ratio of non-agricultural output value to total output value in a county}}{\text{Ratio of national non-agricultural output value to total output value}}.
\] (13)

The larger the \( LQ \), the higher the degree of non-agricultural industrial agglomeration in this county.
Structural transformation: Drawing on the research of Zheng et al. [38], industrial structure upgrading (IS) is adopted to measure the structural change, and the calculation formula is as follows:

\[ IS = W_1 \times 1 + W_2 \times 2 + W_3 \times 3 \] (14)

\( W_1, W_2, \) and \( W_3 \) are the proportions of the primary, secondary, and tertiary industries in GDP, respectively.

4.2.4. Control Variables

To control the other factors that may affect the quality and efficiency of the local and regional environment, we refer to relevant research and select the following control variables [35,39]:

The savings rate (Sav) is measured by the ratio of deposit balance to the total population at the end of the year. The increase in the household savings rate also means that people will pay more attention to future economic development, environmental protection, and sustainable development, thus putting pressure on enterprises’ pollution emissions and urging enterprises to pay more attention to environmental protection measures and reduce pollution emissions.

Financial credit (Fin) is expressed by the ratio of the year-end loan balance to the GDP of financial institutions. The improvement of traditional financial development level means that financial institutions and markets are more mature and developed, which will provide more financial support and financial tools for environmental protection. Through traditional financial channels, environmental protection projects can obtain more capital investment, thus promoting the development and popularization of environmental protection work.

The financial resources of the government (Gov) are measured by the proportion of fiscal expenditure to county GDP. The greater the government intervention in the market, it usually means that the government has more policy tools and resources to promote the improvement of the environment.

The market demand (Mar) is measured by the ratio of the total retail sales of consumer goods to the total population. The higher the consumption level of residents, the more goods and services they buy, and the greater the environmental pollution.

4.3. Data and Descriptive Statistics

In this paper, 2128 county-level units in China from 2014 to 2020 are selected as the research objects. This sample interval is selected because the starting year of updating the county digital financial index in China is 2014, and the data in 2021 and beyond are seriously missing. As the core variable, the data of the county digital finance index in this paper come from the Peking University Digital Finance Index compiled by the research group of the Digital Finance Research Center of Peking University [40]. In addition, due to the relative lack of county-level eco-environmental data in China compared with prefecture-level cities and provinces, many key environmental indicators are not made public. Therefore, this study starts from the availability of data, selects two indicators, and uses the entropy method to construct ecological performance data. Among them, the PM2.5 data are analyzed into the socio-economic data of Columbia University and the grid PM2.5 concentration average data of the application center through ArcGIS software (10.8) combined with the vector map of the administrative region. The data on the afforestation area come from the county afforestation data in the Statistical Yearbook of Forestry in China (2015–2021). Due to the lack of county-level data, this paper only uses a tool variable to test endogenous problems, and the data come from the Peking University Digital Finance Index. Other economic and social data come from the Statistical Yearbook of Counties in China (2015–2021) and the Annual Statistical Bulletin on National Economic and Social Development of Counties. In addition, in order to eliminate the interference of outliers on the results of this paper, 5% of the eco-environmental performance of the explained variables is truncated bilaterally.
Table 1 of this paper shows the descriptive statistical results and variance expansion factor values of the main variables. It can be seen that the difference between the minimum value and the maximum value of the eco-environmental performance in sample counties is 0.371, the standard deviation is 0.105, and the average value is 0.363, indicating that the eco-environmental performance among counties is significantly different, and the eco-environmental performance level is low. The minimum value of the digital finance index is 0.102, the maximum value is 1.441, and the standard deviation is 0.238, which shows that the development level of digital finance among counties is quite different. The average and standard deviation of savings rate, financial credit, government financial resources, and market demand show that there are obvious differences in the level of economic and social development in various districts and counties in China. This is also in line with the reality that there is a big gap between the economic development level between the eastern coastal areas and the western inland areas in China. The expansion factor of each variance is less than 10, indicating that there is no significant multicollinearity among variables.

Table 1. Descriptive statistics.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Meaning</th>
<th>Ods</th>
<th>Mean</th>
<th>Std</th>
<th>Min</th>
<th>Max</th>
<th>Vif</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecoenp</td>
<td>Eco-environmental performance</td>
<td>14,785</td>
<td>0.363</td>
<td>0.105</td>
<td>0.212</td>
<td>0.583</td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>Digital financial index</td>
<td>14,025</td>
<td>0.920</td>
<td>0.238</td>
<td>0.102</td>
<td>1.441</td>
<td>1.35</td>
</tr>
<tr>
<td>Sav</td>
<td>Savings rate</td>
<td>12,034</td>
<td>3.057</td>
<td>2.105</td>
<td>0.088</td>
<td>35.450</td>
<td>2.80</td>
</tr>
<tr>
<td>Fin</td>
<td>Financial credit</td>
<td>13,588</td>
<td>0.757</td>
<td>0.438</td>
<td>0.009</td>
<td>7.635</td>
<td>1.32</td>
</tr>
<tr>
<td>Gov</td>
<td>Financial resources of the government</td>
<td>14,636</td>
<td>0.290</td>
<td>0.262</td>
<td>0.005</td>
<td>3.941</td>
<td>1.31</td>
</tr>
<tr>
<td>Mar</td>
<td>Market demand</td>
<td>11,364</td>
<td>1.515</td>
<td>1.255</td>
<td>0.067</td>
<td>34.206</td>
<td>2.44</td>
</tr>
</tbody>
</table>

5. Empirical Result Analysis

5.1. Baseline Regression Result

The Hausman test is used to verify relevant research methods to verify whether the fixed effect model adopted in this study is applicable [31]. According to the result of the Hausman test, the p-value is 0.0000, so we choose the fixed effect model as the best model. Table 2 presents the benchmark regression results of a digital financial index on county eco-environmental performance. The observation results show that whether the control variables are considered or not, the influence of digital finance on the performance of the country’s ecological environment is significant and harmful at a considerable level of 1%. Every time the development level of digital finance increases by one unit, the environmental performance will decrease by 0.021 units, which shows that the development of digital finance has not improved the level of the county’s ecological environment but has aggravated the pollution of the county’s environmental environment. Therefore, hypothesis 1 put forward in this paper has been verified.

From the perspective of enterprise behavior, the development of digital finance has reduced information costs and eased the financing constraints of enterprises. However, most county-level enterprises are small- and medium-sized, and the available financial resources are relatively small, which still needs improvement compared to other prefecture-level cities. As a result, they can only obtain enough funds to maintain the regular operation of enterprises. They cannot be used to develop new products, update production processes, and increase pollution treatment equipment, thus failing to reduce the intensity of pollution emissions. From the perspective of personal behavior, the development of digital finance has promoted the popularity of electronic payment and online shopping. This has reduced the use of paper money and paper shopping bags. However, with the increase of electronic payment and online shopping, the generation of electronic waste has also increased, including discarded electronic equipment and packaging materials. This has put some pressure on the environment.
Table 2. Baseline regression results.

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index</td>
<td>$-0.022^{***}$</td>
<td>$-0.021^{***}$</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>Sav</td>
<td>$-0.003^{**}$</td>
<td>$-0.009^{**}$</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>Fin</td>
<td>$-0.009^{**}$</td>
<td>$-0.025^{***}$</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td></td>
</tr>
<tr>
<td>Gov</td>
<td>$-0.025^{***}$</td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Cons</td>
<td>$0.382^{***}$</td>
<td>$0.392^{***}$</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>Ods</td>
<td>13,920</td>
<td>9796</td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.882</td>
<td>0.893</td>
</tr>
<tr>
<td>yearfix</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>idfix</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Note: *** and ** represent the significance levels of 1% and 5%, respectively, and the values in brackets are robust standard errors with counties as cluster variables.

5.2. Robustness Test

5.2.1. Endogenous Test

This paper’s possible sources of endogeneity include the omission of relevant explanatory variables and reverse causality. On the one hand, although this study has used the two-way fixed effect model to estimate and control the appropriate variables as much as possible, there may still be the problem of missing relevant explanatory variables. On the other hand, the decline of eco-environmental performance may promote the development of local digital finance, resulting in reverse causality. To better solve the problem of reverse causality, this paper takes the following measures: First, the first-order lag term of explanatory variables is used for regression, that is, the relationship between last year’s digital finance development level (Lag-index) and the current year’s ecological performance is estimated to alleviate the problem of reverse causality [41]. Secondly, the instrumental variable method is used for regression analysis. Referring to the practice by Li et al. [42], the nearest digital inclusive finance development degree (Nearest_index) of each county-level administrative unit and the nearest county in the same prefecture-level city is manually sorted out as a tool variable. This instrumental variable is closely related to the development of digital inclusive finance in Dangxian County, and there is no direct influence channel between it and the ecological performance of Dangxian County. Therefore, this instrumental variable may be influential in developing digital inclusive finance in Dangxian County.

The regression results of the two-stage estimation method are shown in columns (1), (2), and (3) of Table 3. The results of the first stage show that the estimation coefficients of instrumental variables (Nearest_index) and explanatory variables (Index) are significant, and the $p$-value is less than 0.01, which indicates that instrumental variables have an excellent descriptive ability to endogenous variables. At the same time, this paper also carries out the Hausman test. The original assumption of the Hausmann test is that all explanatory variables are exogenous. The result shows that the $p$-value is 0, which rejects the initial hypothesis, indicating that the explanatory variable (Index) is endogenous. In addition, according to the rule of thumb, it shows that the tool variables meet the relevant conditions, and there is no problem with weak tool variables. Because the number of instrumental variables and endogenous explanatory variables is the same, there is no need for the over-identification test. After solving the potential endogenous factors, the results of the second stage show that the explanatory variable (index) has a significant negative coefficient for the significance level of 1%. This discovery confirms the validity of the conclusion of this study.
Table 3. Robustness test.

<table>
<thead>
<tr>
<th>Variables</th>
<th>First Stage</th>
<th>Second Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Index</td>
<td>Ecoenp</td>
</tr>
<tr>
<td>Nearest_index</td>
<td>0.285 *** (0.008)</td>
<td>−0.222 *** (0.040)</td>
</tr>
<tr>
<td>Index</td>
<td>−0.222 *** (0.040)</td>
<td>0.023 ** (0.010)</td>
</tr>
<tr>
<td>Lag-index</td>
<td>−0.027 *** (0.009)</td>
<td>0.023 ** (0.010)</td>
</tr>
<tr>
<td>Cons</td>
<td>0.288 *** (0.005)</td>
<td>0.473 *** (0.018)</td>
</tr>
<tr>
<td>F</td>
<td>6752.88</td>
<td>8156</td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.901</td>
<td>0.909</td>
</tr>
<tr>
<td>yearfix</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>idfix</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Note: *** and ** represent the significance levels of 1% and 5%, respectively, and the values in brackets are robust standard errors with counties as cluster variables.

5.2.2. Substitution Variable Test

PM2.5 is a crucial indicator of air pollution, and its high concentration harms the ecosystem. Hence, this study utilizes the average annual concentration of PM2.5 as a surrogate variable, conducting a robustness test to validate its effectiveness. By doing so, the study aims to assess the impact of PM2.5 on the ecosystem comprehensively. As presented in the third column of Table 3, the results reveal a positive and statistically significant coefficient for PM2.5 at the 5% level. This suggests that the development of digital finance has indeed contributed to an increase in the average concentration of PM2.5, ultimately leading to a decline in the quality of the ecological environment. This finding further confirms the validity of the previous research conclusion.

5.3. Mechanism Analysis

The theoretical analysis describes the overall impact of digital finance on county ecological environment performance. However, it is still necessary to further study the specific channels and mechanisms of how digital finance affects county environmental performance. This paper chooses “industrial agglomeration” and “structural transformation” as intermediary variables according to the specific path of digital finance development in implementing a county ecological environment.

The significant coefficients of the second step of the intermediary analysis show that the development of digital finance has an obvious positive influence on industrial agglomeration, as shown in columns (1) and (2) of Table 4. When the digital finance index and industrial agglomeration are included in the same regression equation, the coefficients for both variables are significantly negative, indicating that industrial accumulation mediates the relationship between digital finance and the reduction of ecological impact. Similarly, the regression results in columns (3) and (4) demonstrate that structural transformation mediates the relationship between digital finance and environmental impact reduction. These findings provide support for hypotheses 2 and 3. Due to the lack of high-grade, high-quality, and high-tech industrial gathering platforms in China’s counties, the county industrial parks are mainly local small- and medium-sized enterprises and “high pollution, high energy consumption and high emission” enterprises eliminated from big cities. This situation may lead to more and more serious environmental pollution problems at the county industrial level. Although the development of digital finance in China has played a long-term and significant role in promoting the agglomeration of secondary and tertiary industries [43], it is necessary to seek a more sustainable development model for county industries. Therefore, establishing a high-grade, high-quality, and high-tech industrial
gathering platforms to attract high-tech and green environmental protection industries is the only way to realize the sustainable development of the county.

Table 4. Estimation results of the mechanism test.

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1) LQ Ecoenp</th>
<th>(2) IS Ecoenp</th>
<th>(3) IS Ecoenp</th>
<th>(4) IS Ecoenp</th>
</tr>
</thead>
<tbody>
<tr>
<td>LQ</td>
<td>-0.040 **</td>
<td></td>
<td>-0.025 ***</td>
<td></td>
</tr>
<tr>
<td>IS</td>
<td></td>
<td>0.052 ***</td>
<td>0.041 ***</td>
<td>-0.020 ***</td>
</tr>
<tr>
<td>Index</td>
<td>0.052 ***</td>
<td>-0.019 ***</td>
<td>0.041 ***</td>
<td>-0.020 ***</td>
</tr>
<tr>
<td>Cons</td>
<td>0.879 ***</td>
<td>0.427 ***</td>
<td>2.189 ***</td>
<td>0.447 ***</td>
</tr>
<tr>
<td>Ods</td>
<td>9833</td>
<td>9794</td>
<td>9834</td>
<td>9795</td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.944</td>
<td>0.893</td>
<td>0.889</td>
<td>0.893</td>
</tr>
<tr>
<td>yearfix</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>idfix</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Note: *** and ** represent the significance levels of 1% and 5%, respectively, and the values in brackets are robust standard errors with counties as cluster variables.

This paper uses the Sobel test to determine their effect proportion to study further the contribution of industrial agglomeration and structural transformation to intermediary effect. The specific calculation results are as follows: The indirect effect of industrial agglomeration accounts for 9.83% of the total impact, the indirect effect accounts for 10.9% of the direct hit, and the natural result accounts for 110.9% of the immediate effect; the indirect effect of structural transformation accounts for 4.73% of the total impact, the indirect effect accounts for 4.98% of the direct result, and the entire development accounts for 104.98% of the immediate effect. The negative impacts of digital finance on ecological performance through industrial agglomeration and structural transformation are 9.83% and 4.73%, respectively. This shows that digital finance has a more significant negative impact on environmental performance through industrial agglomeration, which provides some evidence for subsequent pollution control and emission reduction.

5.4. Heterogeneity Analysis

The results provide evidence for the negative impact of digital finance development on ecological environment performance. However, it is essential to acknowledge that the estimation results based solely on a national sample may introduce bias due to variations in population density, administrative levels, and social attributes among different counties. Therefore, this study examines the heterogeneous characteristics of digital finance development on ecological environment performance from three perspectives.

5.4.1. Population Density

In 1935, the renowned population geographer Hu Huanyong introduced the Hu Huanyong Line, also known as the Hu Line, to illustrate the disparity in population density across counties in China. The Hu Huanyong Line, stretching from the Heihe River in the northeast to Tengchong in the southwest, is a demarcation line in China [44]. Approximately 96% of the country’s population is concentrated on the eastern side of this line, while the remaining 4% is found on the western side. Considering that the population disparity between the two sides may influence ecological environment performance, this study divides the area based on the east and west sides of the Hu Huanyong Line. The regression results presented in columns (1) and (2) of Table 5 reveal that, compared to the western side of the Hu Huanyong Line, the negative impact of digital finance development on ecological environment performance is more significant on the eastern side. This disparity can be attributed to several reasons. Firstly, the level of economic development on the western side of the Hu Huanyong Line is relatively low, with a smaller population and a predominantly
agricultural and service-oriented industry. As a result, the development of digital finance has a relatively modest impact on ecological environment pollution in this region.

### Table 5. Heterogeneity estimation results.

<table>
<thead>
<tr>
<th>Variables (1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index</td>
<td>$-0.026$ ***</td>
<td>$-0.001$</td>
<td>$-0.016$ *</td>
<td>$-0.096$ ***</td>
<td>$0.043$</td>
<td>$0.017$</td>
</tr>
<tr>
<td>Cons</td>
<td>$0.415$ ***</td>
<td>$0.312$ ***</td>
<td>$0.376$ ***</td>
<td>$0.493$ ***</td>
<td>$0.360$ ***</td>
<td>$0.312$ ***</td>
</tr>
<tr>
<td>Ods</td>
<td>8333</td>
<td>1463</td>
<td>7317</td>
<td>1874</td>
<td>605</td>
<td>3705</td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.893</td>
<td>0.881</td>
<td>0.895</td>
<td>0.884</td>
<td>0.857</td>
<td>0.876</td>
</tr>
<tr>
<td>Yearfix</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Idfix</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Note: *** and * represent the significance levels of 1% and 10%, respectively, and the values in brackets are robust standard errors with counties as cluster variables.

Conversely, the eastern region has a higher population density. Although it is more inclined towards the service industry, the overall industrial scale is much larger than that of the western part, leading to heightened resource consumption and pollution emissions. Consequently, the negative impact of digital finance development on ecological environment performance is more pronounced in the eastern region. In conclusion, the study demonstrates that the negative influence of digital finance development on ecological environment performance is more significant in the eastern part. At the same time, the western region experiences a comparatively more minor impact. This discrepancy can be attributed to variations in economic development, population density, and industrial structure between the two areas.

#### 5.4.2. Administrative Level

Municipal districts, county-level cities, and counties are China’s most basic administrative units. The difference between them is that municipal districts are divided into several parts to effectively manage the city, which is close to the prefecture-level city center and integrated with the central city, increasing the development space for the main city. The county is a regional administrative division that aims to manage a certain number of rural settlements and is far from the prefecture-level city center. County-level cities are urban divisions with cities as the core, far from prefecture-level city centers, but they are better than counties in terms of population, GDP, and infrastructure. According to the different administrative levels, this paper divides the total sample into three sub-samples of municipal districts, counties, and county-level cities for regression. According to the regression results of columns (3), (4), and (5) in Table 5, the development of digital finance in county-level cities has the most significant negative impact on ecological performance compared with municipal districts and county administrative units. This may be because municipal districts, as the core areas of cities, have a higher degree of industrial cleanliness, and the development of digital finance has positively impacted the ecological environment of municipal districts and improved the quality of the environmental climate. The negative impact of the development of digital finance on the ecological environment of county-level cities may be due to the industrial transfer and accelerated urbanization process brought about by the development of digital finance, which has led to more energy consumption and environmental pollution. Therefore, in digital finance development, it is necessary to pay attention to ecological environment protection, strengthen environmental protection investment and supervision, guide enterprises to accelerate green transformation, and achieve a win-win situation for digital finance and the environmental environment.

#### 5.4.3. Social Attribute

Poverty-stricken counties, also known as national poverty alleviation key counties or national poverty-stricken counties, are a standard set by China to help poor areas,
and the demarcation standard is mainly based on residents’ average annual net income. National poverty-stricken countries are primarily concentrated in western China, especially in old revolutionary base areas, ethnic minority areas, and border areas. According to the list of poverty-stricken counties published by the Chinese government in 2020, this paper divides the total sample into two sub-samples of poverty-stricken counties and non-poverty counties for regression. According to the regression results in columns (6) and (7) of Table 5, it can be seen that the negative impact of digital finance on the ecological environment in non-poor countries is more significant than that in poor countries. This may be because poor countries provide financial support and financial services to rural areas through internet financial services, helping farmers to carry out agricultural production and develop rural industries. With the support of digital finance, farmers can better integrate into the market economy and improve their income level, thus reducing the over-exploitation and destruction of natural resources. Therefore, the impact of digital finance in poor countries is more reflected in promoting sustainable development and improving the ecological environment. On the other hand, in developed countries, the development of digital finance could lead to problems such as excessive consumption of resources and environmental degradation. Therefore, these countries must strengthen supervision and guidance to ensure a harmonious balance between the development of digital finance and the protection of ecology and environmental well-being. This will enable them to realize the dual goals of economic development and ecological protection.

5.5. Threshold Effect Test

The previous empirical results show that from the overall situation of China county, the development of digital finance has a linear inhibitory effect on the ecological environment performance. However, in view of China’s vast territory and uneven development levels of digital finance, it is very important to investigate whether there is a nonlinear relationship between the development level of digital finance and its ecological performance. Table 6 lists the results of the survey, indicating that the digital financial index has undergone a double threshold test. Table 7 shows the estimated threshold and confidence intervals, while Table 8 details the results of threshold regression. According to the regression results, the impact of digital finance development on ecological environment performance can be divided into three stages. When the digital financial index is less than 0.7591, its influence coefficient on ecological environment performance is $-0.069$. When the digital financial index is between 0.7591 and 0.9527, its influence coefficient on ecological environment performance is $-0.021$. When the digital financial index is greater than 0.9527, its influence coefficient on ecological environment performance is $-0.057$. It can be seen that when the development of digital finance is at a low level (Index $\leq 0.7591$), it has the greatest negative impact on the ecological environment performance; when the development of digital finance crosses the first threshold and is below the second threshold ($0.7591 < \text{index} \leq 0.9527$), the negative impact on the ecological environment performance is reduced; when the development of digital finance crosses the second threshold ($0.7591 < \text{Index}$), the negative impact on the ecological environment performance will decrease to a certain extent compared with the low-level stage. It can be seen that the negative impact of digital finance development on ecological environment performance presents the nonlinear characteristics of the double threshold effect.

Table 6. Threshold effect test results.

<table>
<thead>
<tr>
<th>Threshold Variables</th>
<th>Models</th>
<th>F-Value</th>
<th>p-Value</th>
<th>10% Threshold</th>
<th>5%Threshold</th>
<th>1%Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single threshold</td>
<td>694.87 ***</td>
<td>0.000</td>
<td>9.804</td>
<td>12.122</td>
<td>16.269</td>
</tr>
<tr>
<td></td>
<td>Double threshold</td>
<td>308.15 ***</td>
<td>0.000</td>
<td>10.063</td>
<td>11.562</td>
<td>15.811</td>
</tr>
<tr>
<td></td>
<td>Three threshold</td>
<td>29.28</td>
<td>0.690</td>
<td>46.597</td>
<td>51.361</td>
<td>61.816</td>
</tr>
</tbody>
</table>

Note: *** represent the significance levels of 1%.
Table 7. Estimation results of threshold values.

<table>
<thead>
<tr>
<th>Threshold Variables</th>
<th>Models</th>
<th>Threshold Estimates</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index</td>
<td>Single threshold</td>
<td>0.7591</td>
<td>0.7530</td>
</tr>
<tr>
<td></td>
<td>Double threshold</td>
<td>0.9527</td>
<td>0.9514</td>
</tr>
</tbody>
</table>

Table 8. Threshold regression results.

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index ≤ 0.7591</td>
<td>-0.069 ***</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>0.7591 &lt; Index ≤ 0.9527</td>
<td>-0.021 ***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
</tr>
<tr>
<td>0.9527 &lt; Index</td>
<td>-0.057 ***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
</tr>
<tr>
<td>Sav</td>
<td>-0.005 ***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Fin</td>
<td>-0.008 ***</td>
</tr>
<tr>
<td></td>
<td>(0.00286)</td>
</tr>
<tr>
<td>Gov</td>
<td>-0.009</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>Mar</td>
<td>0.005 ***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
</tr>
<tr>
<td>Cons</td>
<td>0.327 ***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
</tr>
<tr>
<td>Ods</td>
<td>9863</td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.154</td>
</tr>
<tr>
<td>F</td>
<td>28.51</td>
</tr>
</tbody>
</table>

Note: *** represent the significance levels of 1%, and the values in brackets are robust standard errors.

6. Conclusions

6.1. Conclusions and Suggestions

The integration of traditional finance and modern science and technology has given rise to digital finance, which has attracted significant attention in academic research due to its potential impact on the ecological environment. Previous studies have primarily focused on the effects of traditional finance on the environment, including pollution control and emission reduction efforts [9–11]. These studies have highlighted the potential for traditional finance to exacerbate environmental pollution [12–15].

However, there needs to be more research on the impact of digital finance on the ecological environment, with most studies focusing on its potential to reduce pollution and emissions [20–22]. Little attention has been given to whether the development of digital finance may contribute to environmental pollution. Therefore, this paper aims to explore the theoretical impact of digital finance on the ecological environment and its underlying mechanisms. Empirically, the study utilizes data from 2128 counties from 2014 to 2020 to conduct empirical research and shed light on this crucial topic.

The results show that, firstly, digital finance harms the performance of the ecological environment, which aggravates environmental pollution. After considering the endogeneity, the conclusion is still valid. Secondly, the intermediary model test shows that industrial agglomeration and structural transformation are essential mechanisms. Thirdly, in the analysis of heterogeneity, it is found that digital finance has a more significant negative impact on the ecological environment in densely populated, county-level cities and non-poor counties. Finally, the threshold effect test shows that digital finance has a double threshold effect on ecological environment performance.

This paper aligns with previous research findings to some extent, but there are also notable differences in certain aspects. Wang et al. [23] conducted their research using micro-level household follow-up survey data in China, focusing on the impact of household consumption scale expansion and upgrading on carbon emissions. In contrast, this paper...
adopts a macro-level perspective by utilizing panel data at the county level in China to analyze the influence of digital finance on ecological environment pollution from an industrial standpoint.

While the findings of this paper are consistent with those of Ozturk et al. [24], it is essential to note that they measured digital finance using the number of ATMs and debit cards, which differs from the digital finance index employed in this study. Additionally, the conclusions drawn by Wan et al. contradict the findings of this paper [22]. They used the same digital finance index as this study to examine environmental pollution in China. Still, their conclusions differ due to variations in the urban dimension data and ecological indicators used. This discrepancy highlights the complexity of the relationship between digital finance and the ecological environment, which may vary depending on the research dimensions employed. Consequently, it is unreasonable to maintain a fixed viewpoint, and further investigation is warranted to gain a comprehensive understanding of this topic.

Based on these findings, we propose the following suggestions:

First, strengthening the supervision of digital finance is an important measure to protect the environment. The rapid development of digital finance has brought great impetus to economic development, but it has also brought environmental pollution and ecological damage. Therefore, digital finance should be subject to the same strict environmental laws and regulations, and the regulatory authorities should strengthen the supervision and inspection of digital finance enterprises’ environmental protection to ensure that they will not have a negative impact on the environment while developing.

Second, to promote balanced development among regions, it is necessary to support the development of digital finance in backward areas. Despite the rapid growth of digital finance in China, there still needs to be a big gap between the level of digital finance in some areas and the national average, especially in remote areas. Because the influence of digital finance on the ecological environment is polarized between districts and counties, it is necessary to strengthen the development of digital finance at the county level. The government can coordinate financial services by taking corresponding measures. For example, the local government should provide relevant financial facilities and popularize the financial knowledge of residents in poor and backward areas to improve their recognition and acceptance of digital finance and guide them to use digital financial tools.

Lastly, guiding enterprises towards accelerated green transformation is essential to achieve a mutually beneficial relationship between digital finance and the ecological environment. This can be accomplished by incentivizing and supporting companies in adopting environmentally friendly practices, such as investing in clean technologies, implementing energy-saving measures, and adopting sustainable production processes. Government policies and regulations are pivotal in encouraging and facilitating these transitions.

In conclusion, the development of digital finance exerts both positive and negative effects on the ecological environment. To harness its benefits while mitigating adverse consequences, prioritizing environmental protection in the digital finance sector is imperative. By implementing the recommendations mentioned above, we can achieve a harmonious balance between digital finance and the ecological environment, fostering sustainable development and ensuring the long-term well-being of our planet.

6.2. Limitations

Although this paper attempts to ensure the reliability of the empirical results, we must admit that our research has some inherent limitations.

First of all, this paper adopts the macro data of county-level cities without an in-depth analysis of the micro-enterprise level, and the conclusion may be one-sided.

Secondly, because the county-level financial index in China began to be updated in 2014, and the county-level economic and social data were seriously missing after 2020, this study can only choose 2014–2020 as the sample period, which is a short-term analysis and has certain limitations.
Thirdly, because the county-level eco-environmental data in China are relatively scarce compared with prefecture-level cities and provincial levels, and many key environmental index data have not been made public, this study selects two indicators to construct ecological performance data by using the entropy method from the perspective of data availability, which makes this paper possess certain limitations.

Finally, due to the lack of county-level data, this paper only uses a tool variable to test endogenous problems, which may have certain limitations in solving endogenous problems.

6.3. Future Research

In future research, several avenues can be explored to further enhance our understanding of the connection between digital finance and the ecological environment. Extending the sample period beyond 2014–2020 can provide a more comprehensive analysis of the long-term trends and dynamics between digital finance and ecological environment pollution.

Secondly, efforts can be made to gather more comprehensive and reliable eco-environmental data at the county level in China. This would enable the construction of more accurate ecological performance indicators, capturing a broader range of environmental aspects and providing a more detailed understanding of the impact of digital finance on the ecological environment.

Thirdly, exploring additional mechanisms through which digital finance influences the ecological environment can shed more light on the underlying processes. For example, studying the role of technological innovation, financial inclusion, and green financing plans can provide valuable insights for promoting the relationship between digital finance and ecological environmental pollution.

Lastly, expanding the scope of research to include other countries and regions can help validate and generalize this study’s findings. By comparing and contrasting the experiences of different countries, we can gain a more comprehensive understanding of the global implications of digital finance on the ecological environment.

By addressing these avenues, future research can contribute to a more robust and nuanced understanding of the complex connection between digital finance and the ecological environment, providing valuable insights for policymakers and stakeholders in promoting sustainable development.

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