Research on the Impact of Digital Finance on the Development of Green Logistics

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Abstract**—**To reveal the mechanism of digital finance in promoting the high-quality development of green logistics, this paper measures the development level of green logistics based on panel data from 30 provinces (autonomous regions and municipalities) in China. A benchmark regression model is used to investigate the impact of digital finance on green logistics, and single-threshold panel regression is employed to analyze the nonlinear promoting effect of digital finance on green logistics at different development stages. The empirical results show that digital finance significantly enhances the development level of green logistics in the local area. When the level of digital finance is below the threshold, its marginal promoting effect on green logistics is relatively weak. When it exceeds the threshold, the promoting effect is significantly enhanced. The impact of different control variables on green logistics varies due to regional heterogeneity.

Keywords**—***Digital Finance, Green Logistics, Threshold Effect*

I. INTRODUCTION

A. Research Background

With the proposal of the "dual carbon" goals, China's logistics industry is facing dual pressures of "reducing carbon emissions and increasing efficiency" and "transformation and upgrading". Green logistics advocates achieving a "double reduction" in energy consumption and pollution emissions throughout the entire process of transportation, warehousing, and distribution through technological innovation, management optimization, and resource conservation, thereby balancing economic, environmental, and social benefits. The latest statistics show that the carbon emissions from the logistics industry account for approximately 30% of the national total, leaving huge room for pollution reduction and efficiency improvement. Digital finance, relying on digital technologies such as big data, cloud computing and blockchain, extends traditional financial services towards inclusiveness, convenience and intelligence. It can not only reduce financing costs and enhance the efficiency of risk management, but also break information asymmetry and achieve precise allocation of capital and technological elements to green logistics projects. Current research mostly focuses on the relationship between the digital economy and green development or between finance and industrial upgrading. Few studies start from the perspectives of digital finance and green logistics to explore the nonlinear relationship between the two. Against the backdrop of the transformation towards high-quality economic development, exploring the relationship between digital finance and green logistics development holds significant practical value for promoting the realization of high-quality economic growth.

B. Literature review

The academic community has conducted extensive research on green logistics. The majority of scholars' research focuses on the deficiencies and countermeasures in the development of green logistics, how to enhance the efficiency of green logistics, and the development mechanism of green logistics. Xu Chaoyi and Li LA[1] (2023) analyzed the dynamic evolution characteristics and driving factors of the coordinated development of green logistics and green economy. Lin Boqiang and Tan Ruipeng[2] (2019) found that economic agglomeration has an inverted U-shaped impact on the overall green economic efficiency. That is, when the degree of agglomeration is relatively small, it promotes the green economic efficiency, but when the degree of agglomeration exceeds a certain specific value, it will show an inhibitory effect. Chen Tang and Chen Guang[3] (2021) found that the digital transformation innovation environment and human capital investment, under economic characteristics, have a promoting effect on the upgrading of industrial structures both within and outside the region. As an important direction of the supply-side structural reform in finance, digital inclusive finance has a significant positive promoting effect on the high-quality development of the circulation economy, as verified by Huang Shiwang[4] (2023).

In conclusion, there is a considerable amount of literature on the factors influencing the development of the logistics industry, but relatively few on digital finance and green logistics. This paper analyzes and explores the intrinsic relationship between digital finance and the development of green logistics by constructing a threshold regression model.

II. COMPREHENSIVE EVALUATION INDEX CONSTRUCTION

A. Carbon emission measurement

1) *Data Sources:*

The data are sourced from "China Statistical Yearbook", "China Energy Statistical Yearbook", "China Science and Technology Statistical Yearbook", as well as statistical yearbooks of various provinces and cities.

2) *Carbon emission calculation method:*

The IPCC carbon emission coefficient method refers to multiplying the energy consumed in the production of a certain product by its carbon emission coefficient to obtain its carbon emissions. Moreover, the IPCC assumes that the carbon emission coefficient of a certain energy source remains constant. Based on this, the carbon emission calculation formula for the direct energy consumption method of China's logistics industry can be obtained as:

$$CO_2 = EC_k \times \beta_k (NCV_k \times CEF_k \times COF_k \times 44/12) \quad (k = 1,\ 2,\ \cdots,\ n) \tag{1}$$

In the formula, CO_2 represents the total carbon dioxide emissions of the logistics industry. k represents the KTH type of energy. EC_k represents the consumption of the KTH type of energy consumed by the logistics industry. B_k represents the standard coal conversion coefficient of the KTH type of energy. NCV_k represents the average lower calorific value of the KTH energy source. CEF_k represents the carbon content per unit calorific value of the KTH type of energy. COF_k represents the carbon oxidation rate of the KTH type of energy. 44/12 is the molecular weight of carbon dioxide. The standard coal coefficients and carbon dioxide emission coefficients of various energy sources are shown in Table 1.

Table 1. Standard Coal Equivalent and CO_2 Emission Parameters for Various Energy Sources

Energy Source	**Standard Coal Equivalent (kgce per kg or m³)**	**Avg. Lower Heating Value(kJ per kg or m³)**	**Carbon Content per Calorific Value(kg C per GJ)**	**Carbon Oxidation Rate**
Raw coal	0.7143	20 908	26.37	0.94
Coke	0.9714	28 435	29.50	0.93
Crude oil	1.4286	41 816	20.10	0.98
Gasoline	1.4714	43 070	18.90	0.98
Kerosene	1.4714	43 070	19.60	0.98
Diesel oil	1.4571	42 652	20.20	0.98
Fuel oil	1.4286	41 816	21.10	0.98
Natural gas	1.3300	38 931	15.30	0.99

B. Index weight method

This paper draws on the improved CRITIC method: First, the standard deviation coefficient (the ratio of the standard deviation to the mean) is used to replace the standard deviation to eliminate the influence of dimensions; The second is to take the absolute value of the correlation coefficient to eliminate the interference of the positive and negative signs on the judgment of conflict.

Furthermore, some scholars have pointed out that although the CRITIC method can effectively comprehensively reflect the contrast intensity and conflict among indicators, it fails to take into account the degree of dispersion of the indicators. The entropy weight method precisely measures the discreteness of an index through its information entropy, thereby determining the weight. To further enhance the objectivity and scientific nature of weight calculation, this paper adopts a comprehensive weighting method combining CRITIC and entropy weight method (CRITIC- entropy weight method) to calculate the weights of high-quality development indicators in the manufacturing industry, more comprehensively and accurately reflecting the importance of each indicator.

C. Variable selection

The study selected 30 provinces, municipalities and autonomous regions in China (excluding Xizang, Hong Kong, Macao and Taiwan due to data availability limitations) as research samples. The sample period was from 2015 to 2023, and a small number of missing values were filled in by interpolation method.

Digital finance serves as the core explanatory variable (DF), and the Peking University Digital Inclusive Finance Index is used as the proxy variable for digital finance.

Green logistics was taken as the explained variable (GL), and indicators such as factor input, development scale, green development, and development efficiency capacity were selected to measure the development of green logistics in the province. The constructed indicator system includes indicators such as fixed asset investment in the logistics industry, carbon dioxide emissions in the logistics industry, energy consumption in the logistics industry, and freight volume.

The control variables selected include the degree of opening up to the outside world (the proportion of total import and export trade volume in GDP), the level of financial development (the proportion of the sum of deposits and loans of financial institutions in GDP), the proportion of the tertiary industry (the proportion of the output value of the tertiary industry in GDP), and environmental regulations (the proportion of completed investment in industrial pollution control in the added value of the secondary industry).

D. Model selection

The study uses panel data for regression. Firstly, the Hausmann test is adopted to determine the form of the constructed model. The P-value of the Hausmann test is much less than 0.05, and a fixed-effect model should be selected for regression. The following benchmark regression econometric model is established:

$$GL_{i,t} = \beta_0 + \beta_1 DF_{i,t} + \beta_2 Control_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \qquad (2)$$

Among them, the variable subscripts i and t respectively represent the data of the i-th province in the t-th year. $Control_{i,t}$ represents a series of control variables, β is the regression coefficient, μ_i and δ_t are the dummy variables of the regional fixed effect and the time fixed effect respectively, and $\varepsilon_{i,t}$ is the random disturbance term. To further examine whether the impact of the development level of digital finance on the development of green logistics has nonlinear characteristics, the following threshold regression model is constructed:

$$GL_{i,t} = \beta_0 + \beta_1 DF_{i,t} * I(DF_{i,t} \le \gamma) + \beta_2 DF_{i,t} * I(DF_{i,t} \ge \gamma) + \beta_{13} Control_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \qquad (3)$$

In the formula, $DF_{i,t}$ represents the threshold variables of digital finance. I is the indicator function, which takes a value of 1 when the conditions in parentheses are met; otherwise, it takes a value of 0. γ represents the threshold value to be estimated. The remaining variables are the same as those in formula (1). Equation (2) represents the case of a single threshold. If there are multiple threshold values, it can be extended in a similar way.

III. CONCLUSIONS AND RECOMMENDATIONS

A. Benchmark regression results

In the two regressions shown in Table 2, the coefficients of the core explanatory variables are both significantly positive, indicating that regional digital finance has a significant promoting effect on the development of green logistics. This might be because digital finance has reduced the cost for logistics enterprises to obtain financial services and helped financial institutions provide more precise and convenient financial products and services to support the development of the green logistics industry.

Column (3) reports the results of the threshold regression. It can be seen that digital finance has a significant promoting effect on the development of green logistics both before and after the threshold value. However, the promoting effect of digital finance after exceeding the threshold value is slightly higher than that before the threshold value, indicating that digital finance plays different roles in green logistics at different development stages. The higher the level of digital finance, The promoting effect on the development of green logistics is also greater. The reason for the emergence of the threshold effect might be that when the development level of digital finance is relatively low, the digital financial system is not perfect and the types of digital financial products are not rich enough, and the integration with green logistics is insufficient. However, as the development level of digital finance continues to improve and the integration with green logistics deepens, it has a stronger promoting effect on green development.

Table 2. Regression Results

Variable	（1）	（2）	（3）
DF	0.0013***(4.07)	0.0035***	
$DF_{i,t} \leq \gamma$			0.0008***（4.66）
$DF_{i,t} \geq \gamma$			0.0009***（5.01）
Cons	-0.0297（-1.03）	0.0978***（2.72）	0.2137***（3.6）
Control variable	NO	YES	YES
Year/Region	YES	YES	YES
N	270	270	270
R-squared	0.425	0.687	0.756

Note: The errors in parentheses are standard errors. * * *, * *, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Robustness tests were conducted using the addition of control variables and tailing treatment. By increasing the economic level and using the total regional GDP as a measure; By performing a 1% indentation on all continuous variables. Re-conducting the regression analysis revealed that the coefficients and significance of the core explanatory variables of the two methods were basically consistent with those in the previous text, indicating that the estimation results of the aforementioned model were generally robust.

B. Conclusions

Based on provincial panel data in China, this paper empirically examines the impact of digital finance on the development of green logistics. The research findings are as follows: First, digital finance plays a significant role in promoting the development of green logistics, and this promoting effect remains significant even after the robustness test. Secondly, the level of digital finance development affects the extent to which it promotes the development of green logistics. A higher level of digital finance development significantly improves the quality of the logistics industry's development, while a lower level of digital finance has a smaller promoting effect.

C. Policy Implications

Based on the research conclusions, the following policy implications are obtained: First, accelerate the construction and application of digital finance, improve the digital finance construction system, and guide digital finance to increase its support for green logistics. Accelerate the application of modern information technologies such as big data and artificial intelligence in the financial industry, encourage innovation in digital financial institutions and products, and at the same time strengthen the supervision of digital finance to guide the development of green logistics through digital financial services. Second, formulate differentiated measures for the development of digital finance, improve the measurement system for the development level of digital finance, and build a dynamic system for digital finance to support green logistics. At different stages of digital finance development, adopt differentiated development measures to adjust the path of supporting the development of green logistics, so as to better leverage the promoting role of digital finance in the development of green logistics.

Acknowledgment

First of all, I would like to express my gratitude to the teacher for always giving me meticulous guidance and unremitting support. Whenever I encounter academic problems, my teachers always offer detailed guidance and assistance, and also give me a lot of valuable suggestions in my studies and work. I would like to express my sincere gratitude and highest respect to my teacher.

Secondly, I would like to express my gratitude to the school and my classmates. The school has provided me with the opportunity to further my studies and a good learning environment. When I am confused and upset, my classmates will also comfort and help me get through the darkest moments, giving me spiritual encouragement.

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