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Research on the Impact of Digital Finance on Green Economic Efficiency

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Abstract: This paper uses the super-efficiency SBM model to measure the green economic efficiency of 30 provinces (municipalities directly under the central government or autonomous regions) in China. By constructing a spatial Durbin model with time-fixed effects, it analyzes the impact of digital finance on the development of green economic efficiency. The results show that: there are significant regional disparities and obvious spatial dependence between digital finance and green economic development; the impact of digital finance on green economic efficiency presents a U-shaped curve.

Keywords: Digital Finance; Green Economic Efficiency; Spatial Econometrics.

1. Introduction

Driven by scientific and technological innovation, digital finance serves as an important engine for social development, while a sound ecological environment provides the foundation for the sustainable development of the economy and society. In the process of rapid economic growth, problems such as environmental pollution and resource waste have become prominent, and China is actively promoting the transformation of its industrial structure toward green and low-carbon development. As a comprehensive indicator, green economic efficiency can be adopted to evaluate the degree of matching between regional economic development and environmental and resource costs. This paper focuses on the impact of digital finance on green economic efficiency and puts forward corresponding policy recommendations.

2. Literature Review

In the literature on the effects of digital finance development, X Song (2017) pointed out that the development of digital finance can narrow the income gap [1]. L Bang & J Zhang (2019) analyzed that the development of digital inclusive finance can reduce corporate financing costs [2]. TANG Wen-jin, LI Shuang & TAO Yun-qing (2019) found that the impact of digital finance on industrial structure upgrading exhibits a nonlinear relationship, and the effects vary across regions [3].

In studies on the influencing factors of green economic efficiency, LI Yan-jun & HUA Min (2014) found that urban economic development promotes green efficiency, while the proportion of the secondary industry in GDP, the level of financial development, and the investment rate inhibit it [4]. GONG Yuan-yuan (2018) constructed a panel threshold model to analyze the heterogeneous impact of environmental regulation on green economic efficiency, showing that only appropriate environmental regulation can promote green economic efficiency [5]. Sahibjamal RUZI & DENG Feng (2021) used the spatial Durbin model to empirically conclude that human capital agglomeration helps improve green economic efficiency in local cities [6].

In the literature on the impact of digital finance on green economic efficiency, Wang Xing & Zhao Wenna (2021) found that financial development has a nonlinear relationship with green economic efficiency, which is negative first and then positive [7]. JIANG Hong-li & JI Peng-cheng (2022) constructed a benchmark dynamic panel model and empirically showed that the impact of digital finance on urban green economic efficiency is characterized by inhibition first and promotion later, and the secondary indicators of digital finance have different directional effects on urban green economic efficiency [8].

At present, most domestic and foreign studies on the relationship between digital finance and green economy adopt traditional econometric methods such as nonlinear regression and dynamic panel regression, leaving obvious research gaps. Therefore, this paper introduces a spatial econometric model to conduct a supplementary study on their relationship.

3. Measurement and Analysis of Green Economic Efficiency and Digital Finance

3.1. Measurement and Analysis of Green Economic Efficiency

This paper takes panel data of 30 provinces (or autonomous regions, municipalities directly under the central government) in China from 2011 to 2019 as the research object to measure inter-provincial green economic efficiency. Relevant data are mainly obtained from the China City Database, China Macroeconomic Database in the EPS Database, and regional statistical yearbooks. In addition, data of Xizang, Hong Kong, Macao and Taiwan are excluded due to the lack of official statistics.

The indicator system for green economic efficiency includes non-resource input indicators (labor force, capital stock), resource input indicators (energy consumption), desired output (gross regional product), and undesirable outputs (industrial "three wastes"). Using Maxdea software, this paper adopts the super-efficiency SBM model with constant returns to scale and undesirable outputs to calculate the green economic efficiency of 30 provinces from 2011 to 2019. A higher value of green economic efficiency indicates a higher level of green economy development, and the value of 1 represents the national average.

As shown in Table 1, only Shanghai, Beijing and Hainan had green economic efficiency greater than 1 in 2019, indicating leading green development levels and fewer resources and environmental problems; all other provinces were below 1, suggesting economic inefficiency. Compared with the values in 2011, the three leading regions also achieved large increases, while Heilongjiang, Shanxi and other regions witnessed a slight decline in green economic efficiency, which requires special attention. As can be seen from Table 2, provinces ranking high in green economic efficiency are mostly eastern coastal provinces, while central and western provinces rank relatively low, with higher environmental costs of development.

Table 1. Changes in Green Economic Efficiency of Each Province

Province	2011	2019	Change	Province	2011	2019	Change
Beijing	0.3907	1.0857	0.6949	Henan	0.1840	0.2374	0.0534
Tianjin	0.2983	0.2529	-0.0455	Hubei	0.2177	0.2916	0.0739
Hebei	0.1858	0.1656	-0.0202	Hunan	0.2125	0.2581	0.0456
Shanxi	0.1920	0.1839	-0.0082	Guangdong	0.3339	0.4042	0.0703
Inner Mongolia	0.1439	0.1850	0.0410	Guangxi	0.1770	0.1925	0.0156
Liaoning	0.1484	0.2020	0.0537	Hainan	0.2137	1.1268	0.9131
Jilin	0.1472	0.1745	0.0273	Chongqing	0.1922	0.2970	0.1048
Heilongjiang	0.1693	0.1667	-0.0026	Sichuan	0.1838	0.2511	0.0673
Shanghai	0.3642	1.0325	0.6683	Guizhou	0.1560	0.2004	0.0444
Jiangsu	0.2689	0.4137	0.1448	Yunnan	0.1738	0.2177	0.0440
Zhejiang	0.2545	0.3446	0.0900	Shaanxi	0.1970	0.2391	0.0421
Anhui	0.1934	0.2490	0.0555	Gansu	0.1514	0.1528	0.0014
Fujian	0.2582	0.3374	0.0792	Qinghai	0.1209	0.1338	0.0129
Jiangxi	0.1962	0.2418	0.0457	Ningxia	0.1375	0.1450	0.0075
Shandong	0.1833	0.2210	0.0377	Xinjiang	0.1774	0.1781	0.0007

Table 2. Average Value and Ranking of Green Economic Efficiency by Province

Province	Mean	Rank	Province	Mean	Rank
Beijing	0.6361	1	Shandong	0.2021	16
Shanghai	0.5693	2	Henan	0.2013	17
Guangdong	0.3730	3	Yunnan	0.1921	18
Jiangsu	0.3307	4	Guangxi	0.1805	19
Tianjin	0.3229	5	Guizhou	0.1758	20
Hainan	0.3181	6	Hebei	0.1725	21
Zhejiang	0.2939	7	Shanxi	0.1710	22
Fujian	0.2864	8	Xinjiang	0.1665	23
Hubei	0.2470	9	Liaoning	0.1650	24
Chongqing	0.2457	10	Jilin	0.1627	25
Hunan	0.2330	11	Heilongjiang	0.1623	26
Shaanxi	0.2150	12	Inner Mongolia	0.1562	27
Jiangxi	0.2125	13	Gansu	0.1419	28
Anhui	0.2122	14	Ningxia	0.1349	29
Sichuan	0.2116	15	Qinghai	0.1211	30

3.2. Measurement and Analysis of Digital Finance

This paper adopts the widely used Digital Inclusive Finance Index in academic circles to measure digital finance. The index covers three dimensions: breadth of coverage, depth of use, and degree of digitalization. It is characterized by accessibility, sustainability and comprehensiveness, and can well reflect the development level of digital inclusive finance. As shown in Table 3, the digital inclusive finance index of each province also presents a stepped distribution among eastern, central and western regions. The spatial pattern of green economy and digital finance is highly similar, which preliminarily indicates that digital finance has an impact on green economic efficiency.

Table 3. Average Value and Ranking of Digital Inclusive Finance Index by Province

Province	Mean	Rank	Province	Mean	Rank
Shanghai	264.1810	1	Jiangxi	195.3468	16
Beijing	260.1415	2	Henan	192.6748	17
Zhejiang	249.9889	3	Hunan	191.5798	18
Fujian	229.1964	4	Guangxi	191.3860	19
Jiangsu	228.9610	5	Shanxi	191.3018	20
Guangdong	228.9433	6	Inner Mongolia	189.7951	21
Tianjin	220.8176	7	Hebei	187.4852	22
Hubei	212.4335	8	Heilongjiang	187.4322	23
Hainan	206.9310	9	Yunnan	186.4347	24
Chongqing	205.0574	10	Ningxia	185.3688	25
Shandong	203.7618	11	Jilin	184.9565	26
Liaoning	202.3832	12	Xinjiang	182.1045	27
Anhui	200.7661	13	Guizhou	177.2003	28
Shaanxi	199.7190	14	Gansu	176.3238	29
Sichuan	198.5840	15	Qinghai	169.4716	30

4. Spatial Econometric Analysis

4.1. Spatial Autocorrelation Test

This paper selects the adjacency matrix (0–1 matrix). Since Hainan is an island, it is manually adjusted to be adjacent to Guangdong, that is, the corresponding value between Hainan and Guangdong in the adjacency matrix is set to 1. Based on this matrix, the global Moran's I index of green economic efficiency and digital finance index for 30 provinces in China from 2011 to 2019 is calculated, with the results shown in Table 4. To improve the validity of the spatial econometric model, data from 2018 to 2019 with low Moran's I index of economic efficiency are excluded.

Table 4. Moran's I Index of Green Economic Efficiency and Digital Finance Index

Indicator	2011	2012	2013	2014	2015	2016	2017
GEE	0.440 (3.972)	0.433 (3.925)	0.414 (3.789)	0.391 (3.631)	0.368 (3.459)	0.356 (3.398)	0.308 (3.039)
IFI	0.473 (4.130)	0.465 (4.111)	0.439 (3.926)	0.429 (3.843)	0.399 (3.596)	0.419 (3.773)	0.484 (4.320)

Note: Values in parentheses are z-statistics.

According to the calculation results, both variables show significant spatial dependence from 2011 to 2017, meaning that the development of digital finance and green economy in one province exerts an impact on that in neighboring provinces.

The positive Moran's I index indicates that the level of digital finance and green economy development in each province is positively correlated with that in other provinces, which provides a suitable basis for constructing a spatial econometric model.

4.2. Spatial Econometric Model Analysis

4.2.1. Spatial Panel Model Specification

Based on the above analysis, a region can exert a certain impact on adjacent regions through spillover effects, making spatial econometric models appropriate for this study. Spatial econometric models are mainly divided into the Spatial Autoregressive Model (SAR), Spatial Error Model (SEM), and Spatial Durbin Model (SDM). This paper selects and constructs a time-fixed effect Spatial Durbin Model (SDM) with the highest goodness of fit:

$$GEE_{it} = \alpha + \rho \sum_{i \neq j}^{n} w_{ij} \, GEE_{it} + \theta_1 IFI_{it} + \varphi_1 \sum_{j \neq i}^{n} w_{ij} \, IFI_{jt} + \theta_2 X_{it} + \varphi_2 \sum_{j \neq i}^{n} X_{jt} + \varepsilon_{it} + v_t \quad (1)$$

In the above equation: ρ denotes the spatial autoregressive coefficient measuring the degree of spatial correlation; w_{ij} is the spatial weight matrix, which is the adjacency matrix constructed in this study; ε_{it} is the error term; v_t represents the time fixed effect; GEE_{it} and IFI_{it} denote green economic efficiency and digital inclusive finance index of province i in year t, respectively; X_{it} stands for a series of control variables.

4.2.2. Variable Selection and Data Description

In addition to the aforementioned dependent variable Green Economic Efficiency (GEE) and core explanatory variable Digital Inclusive Finance Index (IFI), this paper also includes the following control variables:

Urbanization Level (UL): Urban population / Total population. On the one hand, urbanization can guide the agglomeration of human resources in regions with better development foundations and higher efficiency, thereby improving overall economic efficiency. On the other hand, it may also lead to resource waste and hinder the improvement of green economic efficiency. The simple transfer of low-skilled population may not be conducive to green economic development. The expected sign is uncertain.

Trade Openness (TO): Total import and export / Regional GDP. Economic openness can exert either a positive promoting effect or a negative inhibitory effect on green economic efficiency through technology diffusion and the "pollution haven" hypothesis, respectively. The expected sign is uncertain.

Environmental Regulation (ER): Urban sewage treatment rate. As an important component of the green economy, environmental regulation should directly change the development trend of the green economy. A positive impact is expected.

Human Capital (HC): Number of students in regular institutions of higher education / Total population.The improvement of human capital represents the enhancement of national quality. As the most active factor in productivity, human capital can evidently promote economic efficiency. A positive impact is expected.

Government Intervention (GI): Local government general public budget expenditure / Regional GDP.As the “visible hand”, the government can guide social and economic development at various levels. A positive impact is expected.

Financial Service Level (lnFSL): Natural logarithm of insurance density of all insurance institutions.Generally, a higher level of financial service corresponds to higher green economic efficiency. A positive impact is expected.

4.2.3. Regression Result Analysis

The estimation results of the SDM model with time fixed effects are shown in Table 5. Digital finance (IFI) and its quadratic term (IFI^2) are significantly negative and positive in both direct effects and total effects, while the indirect effects are not significant. This indicates that there is a U-shaped relationship between digital finance and green economic efficiency. That is, after digital finance develops to a certain level, it can improve green economic efficiency in the local region, while its impact on neighboring regions is not significant.

In addition, the resource waste caused by high urbanization level (UL) is not conducive to green economic development in local and adjacent regions. Trade openness (TO) improves green economic efficiency in both local and neighboring regions, as technology spillovers can enhance production and pollution control management. The improvement of human capital (HC) promotes green economic efficiency in both local and neighboring regions. The financial service level (lnFSL) has not yet matched the demand for green economic efficiency improvement.

Table 5. Estimation Results of the SDM Model

Variable	Main	Wx	Spatial	Variance	LR_Direct	LR_Indirect	LR_Total
IFI	-0.00294***	0.00137*			-0.00288***	0.00060	-0.00229**
IFI^2	0.00001***	-0.00000**			0.00001***	-0.00000	0.00001***
UL	-0.10701*	-0.17682*			-0.12101**	-0.30460*	-0.42561**
TO	0.17250***	0.08656**			0.18506***	0.21131***	0.39636***
ER	0.00063	-0.02957			-0.00190	-0.04898	-0.05089
HC	3.98406***	7.69504***			4.86211***	13.35107***	18.21318***
GI	0.00088	0.04299			0.00535	0.06511	0.07046
lnFSL	0.02496*	-0.08187***			0.01712	-0.10972***	-0.09260**
rho			0.34532***				
sigma2_e				0.00072***			

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

5. Conclusions and Policy Implications

This paper adopts the Spatial Durbin Model with time fixed effects to conduct an empirical analysis of the relationship between digital inclusive finance and green economic efficiency in 30 provinces (municipalities, autonomous regions) of China from 2011 to 2017, excluding Xizang, Hong Kong, Macao and Taiwan. The results show that:

(1) There are obvious regional differences and spatial correlations between digital finance and green economic efficiency. The development level in the eastern coastal areas is relatively high, while that in the central and western regions is relatively backward.

(2) There is a significant U-shaped relationship between digital finance and local green economic efficiency, but its impact on neighboring areas is not obvious.

(3) Urbanization level has a certain inhibitory effect on green economic efficiency, while trade openness, human capital and financial service level have a relatively significant promoting effect on green economic efficiency. Meanwhile, the above indicators have spillover effects on neighboring regions.

Based on the above research conclusions, this paper puts forward the following suggestions:

(1) Strengthen regional coordinated development, give play to the demonstration and leading role of the eastern regions, encourage the central and western regions to learn advanced experience, narrow the development gap between digital finance and green economy, and achieve regional balance.

(2) Continuously deepen the development of digital inclusive finance, promote it to cross the threshold, and give full play to its role in improving green economic efficiency.

(3) Optimize the focus of development, rationally guide the process of urbanization and reduce resource waste; strengthen the construction of trade openness, human capital and financial service level.

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