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Research on the Influence Mechanism of Digital Economy on Carbon Emissions in the Yangtze River Delta Urban Agglomeration

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Abstract

Under the new development pattern, the digital economy has become a new engine to promote green economic development and achieve the goal of " double carbon " . This project uses the panel data of 26 cities in the Yangtze River Delta in China from 2012 to 2019 as a research sample. First , it constructs a three-level index evaluation system for the digital economy development level of the Yangtze River Delta urban agglomeration, and combines the entropy weight -TOPSIS method to comprehensively measure the urban digital economy. The level of economic development; secondly , using the two-way fixed effect model to analyze the impact of digital economy development on regional carbon emission intensity, and on this basis, the carbon emission intensity of the Yangtze River Delta urban agglomeration is analyzed for spatial heterogeneity ; finally , using the differential GMM Methods The potential factors affecting carbon emission intensity were regressed, and the endogeneity problem was further tested. This project explores the development of digital economy to promote carbon emission reduction, and aims to provide reference for how to achieve the " dual carbon " goal as scheduled while ensuring stable economic growth in China, and to formulate low-carbon development policies that are compatible with high-quality economic development.

Keywords

Digital Economy; Carbon Emission Reduction; Spatial Heterogeneity Analysis.

1. Introduction

With the development of a new round of technological revolution and industrial transformation, the digital economy has become an important engine for promoting green economic development and achieving sustainable development goals (World Economic Forum, 2018). In China, as the center of economic development gradually gathers in urban agglomerations, the Yangtze River Delta urban agglomeration is an important engine and demonstration area for national economic development, and the role of digital economy in its development has attracted much attention (Dong Chee-hwa, 2019).

At the same time, addressing climate change and reducing carbon emissions has become a global consensus, and achieving carbon neutrality and carbon emission reduction goals has become the direction of efforts of all countries (United Nations, 2015). The development of the digital economy has an important impact on carbon emissions, and it can reduce carbon emissions by improving resource utilization efficiency and promoting clean energy transformation (International Energy Agency, 2020).

In this context, this study aims to explore the impact mechanism of the digital economy of the Yangtze River Delta urban agglomeration on carbon emissions. By analyzing the panel data of 26 cities in the Yangtze River Delta from 2012 to 2019 , we first constructed a three-level index evaluation system for the digital economy development level of the Yangtze River Delta urban agglomeration, and used the entropy weight-TOPSIS method to evaluate the urban digital economy development level. Comprehensive measure (Zhu, et al., 2020 ; Li, et al., 2018). Secondly, we used a two-way fixed effect model to analyze the impact of digital economy development on regional carbon emission intensity, and further analyzed the spatial heterogeneity of the carbon emission intensity of the Yangtze River Delta urban agglomeration (Wang & Zhang, 2019; Liu, et al . , 2021). Finally, we use the differential GMM method to conduct regression analysis on the potential factors affecting carbon emission intensity to further test the endogeneity problem (Arellano & Bond, 1991 ; Blundell & Bond, 1998).

The goal of this study is to explore how the development of the digital economy can promote carbon emission reduction, and provide reference for the Yangtze River Delta urban agglomeration to achieve carbon emission reduction goals as scheduled while maintaining stable economic growth. At the same time, we hope to provide empirical analysis support for formulating low-carbon development policies that are compatible with high-quality economic development (National Development and Reform Commission, 2020 ; Ministry of Ecology and Environment, 2018).

Under the current wave of global digitalization and the urgent need for carbon emission reduction, this study is of great significance for deepening the understanding of the relationship between the digital economy and carbon emissions and their role in achieving sustainable development goals. By studying the typical region of the Yangtze River Delta urban agglomeration, we can provide experience lessons and policy recommendations on carbon emission reduction from the development of the digital economy from an empirical perspective, and contribute to promoting green transformation and sustainable development in China and the world.

2. Theoretical Analysis and Research Hypothesis

2.1. Empirical Analysis of the Impact of Digital Economy on Carbon Emissions and Regional Heterogeneity

2.1.1. Digital Economy, Industrial Structure and Carbon Emission Intensity

At present, there have been many studies on the development of the digital economy to promote the optimization and upgrading of the industrial structure. The relevant research results show that the development of the digital economy has accelerated the speed of industrial transformation and promoted the transformation of China's industrial structure to a high-level and rationalized transformation. Generally speaking, the development of the digital economy It has significantly promoted the transformation and upgrading of China's urban industrial structure (Li Zhiguo, 2021). However, the energy demand of the three industries varies greatly. The traditional manufacturing industry is one of the main sources of carbon emissions in China, and the general law of the optimization path of the industrial structure is the transformation from the primary industry to the secondary industry, and then to the tertiary industry. Optimization and upgrading can slow down the growth rate of energy consumption, promote the optimization of energy structure, and contribute to the realization of carbon emission reduction (Zhao Yuhuan, 2022). Based on this, we believe that the optimization and upgrading of industrial structure is an important way for the digital economy to promote the reduction of regional carbon emission intensity.

In summary, the relevant hypotheses are put forward as follows:

Hypothesis H1: The development of the digital economy can significantly reduce regional carbon emission intensity.

Hypothesis H2: The development of the digital economy reduces regional carbon emission intensity with regional heterogeneity.

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Hypothesis H3: Digital economy can reduce regional carbon emission intensity by optimizing industrial structure.

2.1.2. Model Construction

Based on hypothesis H1, in order to verify the impact of the digital economy development of the Yangtze River Delta urban agglomeration on the regional carbon emission intensity, the model is constructed as follows:

$$CEI_{it} = a_0 + a_1 DIG_{it} + a_j \sum X_{jit} + \mu_i + \delta_t + \varepsilon_{it}$$

In the above formula, i represents the province, t represents the year, CEI_{it} represents the carbon emission intensity of each city, a_0 is a constant term, DIG_{it} represents the level of digital economy development of each city, and a_1 represents a regression coefficient, X_{jit} representing a set of control variables. , μ_1 , δ_t represents the individual and time fixed effects, and ε_{it} represents the error term.

Based on hypothesis H3 , this paper adopts the stepwise regression method to construct the intermediary effect model as shown below. Model 3 is constructed to test the impact of digital economy on industrial structure, and Model 4 is constructed to test the impact of digital economy and industrial structure on carbon emission intensity.

$$ER_{it} = \theta_0 + \theta_1 DIG_{it} + \theta_j \sum X_{jit} + \mu_i + \delta_t + \varepsilon_{it}$$

$$CEI_{it} = \beta_0 + \beta_1 DIG_{it} + \beta_2 ER_{it} + \beta_j \sum X_{jit} + \mu_i + \delta_t + \varepsilon_{it}$$

2.1.3. Variable Selection

Explanatory variable: carbon dioxide emissions per capita. In view of the large differences in the level of urban development and population, the total amount of carbon emissions cannot represent the level of technology utilization and energy efficiency of a city, so the per capita emissions of carbon dioxide are used here, that is, the ratio of the city's carbon emissions and population ratio.

Core explanatory variable: comprehensive score of digital economy development. This article is divided into three dimensions of digital infrastructure, digitalization and industrialization, and digital HP finance. And according to the actual content of the variables and the availability of data collection, relevant subdivision secondary indicators are set to establish a digital economy evaluation system (see Table (1): This article uses the entropy method to process data for this indicator system. The final unified variable obtained is defined as the digital economy index (comprehensive score of digital economy development).

Control variables: (1) GDP per capita: the ratio of urban GDP to urban population; (2) financial support: the ratio of government expenditure to GDP; (3) environmental pollution index: choose the city's industrial sulfur dioxide emissions (4) Energy consumption index: coal consumption.

Intermediary variables: In the input part, financial science and technology expenditure is regarded as capital investment, and the number of employees in scientific research and technical service industries is regarded as human input. In the output part, the number of green invention patent authorizations and the number of green invention patent applications are combined as the output. The unguided envelope model with variable returns to scale in the SBM-DEA operation is used to measure the final score, which is used as an intermediary variable for green innovation efficiency.

Table 1. Digital Economy Evaluation System

Level 1 indicators	Secondary indicators	Indicator description
digital infrastructure	Internet users per 100 people	Internet penetration
	Number of mobile phone users per 100 people	mobile phone penetration
Digitalization and Industrialization	Proportion of computer service and software practitioners	employment in the digital industry
	Total Telecom Services Per Capita	Utilization of digital industrialization
	Postal services per capita	Industrial digital utilization
Digital HP Finance	Mobile device penetration	Degree of Digital Industrialization Transformation
	Mobile Internet usage per capita	Output and performance of the digital economy
	Proportion of population using mobile network to resident population	The breadth of coverage of the digital economy

3. Analysis of Empirical Results

3.1. Mediating Effect Regression Results

Table 2. Model regression results

	(1)	(2)	(3)	(4)
	ce	ce	cgl	ce
dig	-0.0374 ***	-0.278 ***	-0.397 ***	-0.216 ***
	(0.0312)	(0.0386)	(0.0377)	(0.0329)
sdig	0.0487	-0.00138	0.0328	-0.00478
	(0.0335)	(0.0312)	(0.0398)	(0.0366)
cgl	0.123	-0.547 ***	0.0988	-0.512 ***
	(0.128)	(0.132)	(0.124)	(0.134)
enco	-0.297 ***	-0.652 ***	-0.377 ***	-0.543 ***
	(0.0342)	(0.0365)	(0.0329)	(0.0388)
gov	0.163	-0.547 ***	0.126	-0.537 ***
	(0.136)	(0.122)	(0.124)	(0.129)
ind	-0.525 ***	0.121	-0.547 ***	0.111
	(0.0325)	(0.0347)	(0.0376)	(0.0321)
pgdp	0.0258	0.0237	0.027	0.03135
	(0.0398)	(0.0383)	(0.0321)	(0.0329)
er	-0.525 ***	-0.547 ***	-0.0328	-0.00478
	(0.132)	(0.146)	(0.0378)	(0.0346)
Constant term	0.117	-0.547 ***	0.0968	-0.592 ***
	(0.129)	(0.134)	(0.125)	(0.134)
sample size	2080	2080	2080	2080
R square	0.398	0.432	0.332	0.198

The results of the Hausman test show that this paper should use the fixed effect model for regression estimation. Table 2 shows the regression results of the model. Column (1) of Table 2 is the regression result of the carbon emission that only considers the one-time item of the

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digital economy. The result shows that the digital economy is positively promoting carbon emissions, but this result only passes the 5% significance test, indicating that the impact of the digital economy on carbon emissions may not be linear. Column (2) of table 2 puts the primary term and the square term of the digital economy in the same model to explore the impact of the digital economy on carbon emissions. The results show that the coefficient of the primary term of the digital economy is 0.081, and the coefficient of the square term is -0.008, and the two the coefficients have all passed the 1% significance test, and Hypothesis 1 in this paper is established. The effect of the digital economy on carbon emissions manifests as an inverted U-shaped nonlinear relationship that first promotes and then suppresses. This result is consistent with the conclusion of Miao Junjun et al. (2022). This is due to the fact that in the early stages of the development of the digital economy, whether it is the construction of new digital infrastructure or the optimization of the production process of energy companies to improve production efficiency, a large amount of resources will be consumed, thereby promoting the growth of carbon emissions. After the facilities are completed, the energy saving and emission reduction effect of the digital economy will exceed the positive promotion effect on carbon emissions, thereby negatively inhibiting carbon emissions.

3.2. Intermediary Mechanism Analysis

This paper constructs an intermediary model with local government competition as the intermediary variable, where formula (2) is the regression estimation of digital economy on local government competition, formula (3) is the regression estimation of digital economy and local government competition on carbon emissions, and the regression result is Column (3) and column (4) of Table 2 . It can be seen from column (3) that the impact of the digital economy on local government competition is a U -shaped nonlinear relationship that first suppresses and then promotes . This may be because the dividend effect brought about by the early digital economy development has also increased public awareness of environmental protection. The Internet The development of information has improved the scope and efficiency of information dissemination, and the gathering of public appeals has formed strong supervision pressure and public opinion pressure, thereby forming a crowding out effect on industries with high energy consumption and high pollution in the region, reducing local government tax sources, and weakening local governments. For the performance of public goods and public services, reduce the strength of local governments to compete for factor resources. The improved efficiency and information transparency brought about by the digital economy in the later period, as well as the good business environment generated by the construction of digital government, have increased the attractiveness of local governments to capital and other factor resources, and promoted the inflow of high-quality foreign capital. Therefore, the competition between the digital economy and local governments shows a U- shaped nonlinear relationship that first suppresses and then promotes . From the results in column (4), it can be seen that the coefficient of the first term of the digital economy is positive and the coefficient of the second term is negative, and both are significant at the level of 1% , indicating that the effect of the digital economy on carbon emissions is an inverted U- shaped effect that first promotes and then suppresses Non-linear relationship, where the coefficient of local government competition is -2.160 , and it passes the 5% significance test. At the same time, column (4), the coefficients of the first-order term and the square term of the digital economy decreased compared with those without intermediary variables, and the absolute values of the regression coefficients of both decreased. Therefore, these two points show that the digital economy indirectly affects carbon emissions through the intermediary variable of local government competition, which confirms Hypothesis 2 in this paper.

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3.3. Endogeneity Test

Considering that urban low-carbon transformation may be disturbed by various factors, there is an endogenous problem between the development of digital economy and carbon emission reduction. For this reason, on the basis of regression, this paper further uses the per capita postal service of each city as an instrumental variable for regression to alleviate the above problems. The results show that the instrumental variables and exogeneity tests pass, indicating that the selected instrumental variables are appropriate.

3.4. Evaluation Results and Regional Differences

First, the development of the digital economy has promoted the upgrading and transformation of the industrial structure. Traditional industries with high carbon emissions, such as heavy industry and traditional manufacturing, are gradually transforming into digital and intelligent industries. This transformation can reduce energy consumption and waste emissions, thereby reducing carbon emissions.

Second, the rise of the digital economy has changed the way people live and work. The application of digital technology has allowed many jobs to be carried out online, reducing carbon emissions from transportation and commuting. At the same time, the digital economy has also promoted the development of the sharing economy, such as shared travel and shared accommodation, effectively utilizing resources, reducing excessive consumption and waste, and helping to reduce carbon emissions.

In addition, the digital economy also promotes the intelligent management of energy and the improvement of energy efficiency. Through digital technology and data analysis, energy supply and use can be controlled and managed more precisely, reducing energy waste and loss, thereby reducing carbon emissions.

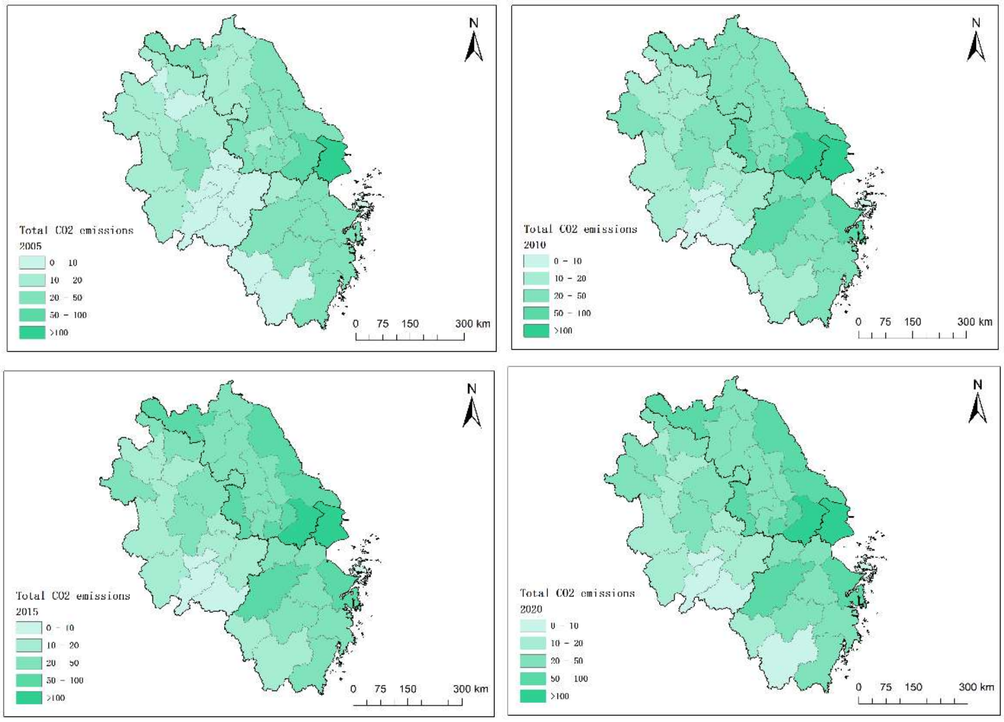

Figure 1. 2005-2020 carbon emission heat map of the Yangtze River Delta region

In general, the changes in carbon emissions in the Yangtze River Delta region can be explained by the impact of the development of the digital economy on carbon emissions. With the promotion of the digital economy, factors such as the transformation of the industrial structure

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in the Yangtze River Delta region, changes in lifestyles, and intelligent energy management have interacted, resulting in changes in carbon emission levels. This change, to a certain extent, demonstrates the potential and impact of the digital economy on carbon emission reduction and green development.

4. Conclusion and Recommendations

4.1. Conclusion

Taking the Yangtze River Delta region as an example, this study conducted an in-depth study on the impact mechanism of the digital economy on carbon emissions. The results of the study show that the development of the digital economy has had a positive impact on the level of carbon emissions. With the application and innovation of digital technology, traditional high-carbon-emitting industries have been transformed and upgraded, energy efficiency has been improved, and waste has been reduced, thereby reducing carbon emissions. The rise of the digital economy has also changed the way people live and work, reducing carbon emissions from transportation and commuting. At the same time, the development of the sharing economy has also promoted the effective use of resources and further reduced carbon emissions.

However, despite the positive impact of the digital economy on carbon emissions, there are still some challenges and problems. The rapid development of the digital economy may bring new energy demands and e-waste disposal issues, which may cause additional pressure on the environment. In addition, the digital divide and digital inequality also need to be addressed to ensure that the development of the digital economy does not exacerbate social and environmental inequalities while promoting sustainable development.

4.2. Countermeasures and Suggestions

To further drive the development of the digital economy, reduce carbon emissions and achieve sustainable development goals, here are some suggestions:

1) Formulate policy support: The government should formulate policies and regulations to encourage the development of the digital economy, and strengthen regulatory measures to ensure that the development of the digital economy meets the requirements of environmental protection and sustainable development.

2) Promote innovation and technological development: Encourage the application of innovative technologies in the digital economy, such as smart energy management systems, clean energy technologies, etc., to improve energy efficiency and reduce carbon emissions.

3) Strengthen energy management and energy conservation and emission reduction: promote the application of digital technology in energy management, improve energy use efficiency, and reduce energy waste and carbon emissions.

4) Cultivate talents and improve awareness: Strengthen the training of talents related to the digital economy and improve skills, cultivate professionals with environmental awareness and sustainable development concepts, and promote the combination of digital economy development and environmental protection.

5) Promote international cooperation and experience exchange: Strengthen international cooperation, share experience and best practices in digital economy development with other countries and regions, and jointly address global environmental challenges.

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