Digital Economy Development, Industrial Structure Upgrading and Carbon Emissions—A Case Study of Beijing-Tianjin-Hebei

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ABSTRACT. The "Dual Carbon" goal has started a new era of the green and low-carbon path, and with the deepening of a new round of technological revolution and industrial transformation, the linkage between the digital economy and low-carbon transformation has become the focus of academic attention. Can the digital economy promote low-carbon development while promoting high-quality economic development in China? Adopting the panel data of 13 cities in Beijing-Tianjin-Hebei between 2011 and 2017, this paper investigates the impact of digital economy development on carbon emissions and its action mechanism via the fixed-effect model. The results suggest that digital economy development effectively suppresses carbon emission intensity in the Beijing-Tianjin-Hebei region, and industrial structure upgrading plays an important mediating role in the process.

Keywords: Digital Economy Development; Industrial Structure Upgrading; Carbon Emissions

1 INTRODUCTION

During the decades of reform and opening-up, Chinese economy has grown by leaps and bounds, achieving remarkable achievements, but at the same time, the problems of resource shortage and environmental pollution became increasingly serious. China has become the largest energy consumer and carbon emitter. Finding ways to coordinate the relationship between economic development and the environment to promote high-quality development has become an issue.

Meanwhile, the scale of Chinese digital economy reached 3.92 billion yuan in 2020, accounting for 38.6% of the GDP, and has become a new driving force for high-quality economic development, playing an important role in promoting green development and ecological civilization[1]. With the proposal of the "Dual Carbon" goal, carbon emission reduction has been a focus of the issue. Studies show that environmental regulation and improving innovation efficiency can conduct to carbon emissions reduction. Is the booming digital economy favorable to meet the carbon emission reduction targets? If so, what is the mechanism of action?

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Clarifying the issues not only contributes to enriching research on the digital economy but also has practical significance for promoting green development and achieving the Dual Carbon goal. Taking the Beijing-Tianjin-Hebei urban agglomeration where the scale of the digital economy accounts for more than 10% of China as an example, this research calculates the index of digital economy development in 13 cities from 2011 to 2017 and investigates the impact and the action path of digital economy development on urban carbon emissions theoretically and empirically.

2 LITERATURE REVIEW AND HYPOTHESIS

2.1 Digital economy development and carbon emissions

The digital economy development curbs carbon emissions in many ways. From the government's perspective, the widespread use of cloud computing and big data can realize the environmental data's dynamic monitoring such as pollution emissions and air quality by the government[2], thus improving the accuracy and effectiveness of government supervision. Meanwhile, the government can effectively control the total emissions through the digital operation of the carbon emissions trading market[3]. For enterprises, the application of digital technology can guide the efficient allocation of energy by optimizing the governance technology of terminal emissions, real-time monitoring, and analysis of energy data [1]. On the other hand, it can take full advantage of innovation's promoting effect of energy efficiency with the support of digital finance[4], thereby reducing carbon emissions. Additionally, the digital economy breaks the constraints of time and space, saving energy consumption caused by these factors in production [3], thereby promoting energy efficiency and restraining carbon emissions.

Therefore, this paper proposes hypothesis H1: The digital economy development can contribute to reducing carbon emissions.

2.2 Digital economy development, industrial structure upgrading, and carbon emissions

The digital economy promotes the upgrading of the industrial structure in two ways: on the one hand, the digital economy corrects the problem of factor misallocation by alleviating the information asymmetry between the supply and demand [5], and improves the rationalization of the industrial structure by increasing market effectiveness through information technology [6]. On the other hand, the digital industry with permeability and diffusion breaks the boundary between industries[7] to promote inter-industry integration, and generates new industries and new formats.

Besides, studies confirmed that industrial structure upgrading can effectively reduce carbon emissions from different perspectives. Pang et al. discussed the impact of industrial structure and regional innovation on carbon emissions in Jiangsu Province, and found that the optimization and upgrading of industrial structure and the enhancement of regional innovation capabilities are conducive to emission reduction[8]; from the perspective of the whole country, Zhao et al. conclude that the industrial structure upgrading contributes to carbon emission reduction[9]. While the total amount of CO_2 emissions in China is gradually rising, the digital economy can accelerate the industrial structure upgrading through technological penetration and industrial integration, to enhance the efficiency of resource allocation, and restrain carbon emissions intensity[10].

Therefore, this paper puts forward hypothesis H2: The digital economy development reduces carbon emissions by accelerating industrial structure upgrading.

3 DATA AND METHODOLOGY

3.1 Model Settling

In order to explore the impact of digital economy development on carbon emissions, this paper established the basic model as follows:

$$lnce_{it} = \alpha_0 + \alpha_1 dige_{it} + \alpha_2 X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where $lnce_{it}$ is the explained variable which represents the carbon emission intensity of city i in period t; $dige_{it}$ represents the digital economy development index; the vector X_{it} indicates control variables; μ_i and δ_t refers to individual and time fixed effect; ε_{it} represents random disturbance term.

In addition to the direct effect, the following steps are taking to examine the mediation effect of industrial structure upgrading between digital economy development and carbon emissions: if the coefficientα_1 in model (1) is significance, model (2) and (3) will be constructed. Regression equation (2) includes $dige$ and the mediating variable industrial structure upgrading is, and the regression equation (3) involves the three variables. The model indicates whether the mediation effect exists by texting the significance of β_1、 γ_1 and γ_2.

$$is_{it} = \beta_0 + \beta_1 dige_{it} + \beta_2 X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (2)$$

$$lnce_{it} = \gamma_0 + \gamma_1 dige_{it} + \gamma_2 is_{it} + \gamma_3 X_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (3)$$

3.2 Variable selection

3.2.1. Core Explanatory Variable

This variable is measured by the digital economy development index ($dige_{it}$). Referring to the study of Zhao et al.[11], this paper adopts the internet penetration rate, the proportion of internet workers, the related output of internet industries and mobile phone penetration rate, combined with the digital inclusive financial index to get the comprehensive index of the digital economy by Principal Component Analysis.

3.2.2. Explained Variable

Referring to the previous research of Deng and Zhang, the logarithm of the ratio of urban carbon dioxide emissions to the actual regional GDP is used to measure carbon emission intensity ($lnce_{it}$)[12].

3.2.3. Intermediary variable

In the previous research, there are many indicators to measure the industrial structure upgrading. Generally, it can be measured by the relative scale changes between industries. Economy servitization is one of the important features of industrial structure upgrading. The ratio of the tertiary industry's added value to the secondary industries indicates the degree of the industrial structure upgrading[13].

3.2.4. Control variables.

Referring to relevant literature, the control variables are as follows: ①the economic development ($lnrgdp$), expressed by the logarithm of the real GDP per capita; ②population density ($lnpd$), expressed by the logarithm of population per square kilometer; ③foreign direct investment (fdi), expressed by the proportion of actual foreign direct investment in GDP; ④Government support (gs), expressed by the proportion of general public budget expenditure in GDP.

3.3 Data Source

This paper selects the panel data of 13 cities in Beijing-Tianjin-Hebei from 2011 to 2017. The data on carbon dioxide emissions is from the CAEDs database, and the data of other variables from the China city statistical yearbook, the digital inclusive finance index is from the Institute of Internet Finance of Peking University [14]. Table 1 shows descriptive statistical results of each variable.

Table 1. Descriptive Statistical results.

variable	Obs.	mean	std. Dev	min	max
$dige$	91	-6.12e-08	0.808	-0.963	3.660
ce	91	2.427	0.982	0.234	4.459
is	91	1.022	0.781	0.516	4.166
$lnrgdp$	91	10.627	0.524	9.752	11.906
$lnpd$	91	6.188	0.727	4.547	8.960
fdi	91	0.022	0.021	0.001	0.110
gs	91	0.180	0.068	0.066	0.370

4 EMPIRICAL RESEARCH AND DISCUSSION

4.1 Baseline Regression Results

Table 2 reports the regression results in models (1) and (2), the estimated coefficients of the core explanatory variable digital economic development ($dige$) are significantly negative, which indicates that it curbs urban carbon emissions intensity, verifying the hypothesis H1.

Table 2. Baseline Estimate Results

$Variable$	(1)	(2)	(3)	(4)
	ce	ce	is	ce

$dige$	-0.151** (-2.29)	-0.140** (-2.89)	0.390*** (4.29)	-0.051** (-2.38)
is				-0.089** (-1.97)
$Year$	YES	YES	YES	YES
$city$	YES	YES	YES	YES
Obs	91	91	91	91

a. Due to space limitations, this table only shows the results of core variables.

To test the mediating effect of industrial structure upgrading, the results are in series (3) and (4) in Table 2. Based on Model (2), Model (3) verifies whether the digital economy promotes industrial structure upgrading, and the intermediary variable is put into Model (4). The regression result shows coefficients of $dige$ and is are significantly negative. Comparing the absolute value of the coefficient of the explanatory variable in the two models can confirm the existence of the mediating effect, which verifies hypothesis H2, that the digital economy development reduces carbon emissions by accelerating industrial structure upgrading.

4.2 Robustness Check

In Table 3, series (1) shows the coefficient of the digital inclusive financial index, replacing the original core explanatory variable. And the series (2) refers to the regression result of the model with one lag period of the core explanatory variable [15]. The results prove the robustness of the benchmark regression.

Table 3. Robustness test result

$Variable$	(1)	(2)
	ce	ce
$dige$	-0.179*** (-4.23)	-0.603*** (-4.10)

5 CONCLUSION

With the panel data of 13 cities in the Beijing-Tianjin-Hebei region from 2011 to 2017, this paper investigates the impact of the development of digital economy on urban carbon emissions and its mechanism. The empirical results show that digital economic development significantly inhibits urban carbon emission intensity, and industrial structure upgrading plays a significant mediating role in the process. Accordingly, the following policy recommendations are proposed:

We should take the opportunities brought by the digital science and technology revolution, to accelerate the speed and improve the quality of digital economy development. a) The government needs to strengthen the construction of digital infrastructure, and increase investment in projects such as 5G networks, big data centers, and artificial intelligence, to promote the digital transformation of the economy comprehensively. b) Based on industrial digitalization, enterprises should improve production efficiency, as well as the utilization and allocation efficiency of traditional production factors, and make full use of the carbon emission reduction effect by accelerating the industrial structure upgrading. c) While vigorously

developing the digital economy, attention should be paid to improving the energy conservation awareness and energy efficiency of enterprises, as well as to the research and development and application of energy-saving and emission reduction technologies, enhancing the emission reduction effect of technology empowerment.

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