Academic Journal of Management and Social Sciences
ISSN: 2958-4396 | Vol. 5, No. 2, 2023

Enabling Carbon Emission Reduction in Digital Economy: A Study on Action Mechanism and Impact Mechanism

Ying Zou

School of Statistics and Applied Mathematics, Anhui University of Finance and Economics, Bengbu, China

Abstract: With the rapid development of digital technology, digital economy has gradually become the main driving force of the world's economic development in the post-epidemic era and a new engine to promote China's economic and social development.Under the above background, this research group found that there is still much room for improvement in the existing research on digital economy measurement and its impact on carbon emission through discussing the relevant research on digital economy measurement, carbon emission and the impact effect and mechanism of digital economy on carbon emission at home and abroad. Therefore, this research group will be based on the above-mentioned space for improvement and go in three steps: firstly, to construct the index system of high-quality development of digital economy in each province through sorting out the existing literature; Secondly, to calculate the high-quality development of digital economy and carbon emission in each province through entropy method, compare the similarities and differences existing in the development level of different provinces, and analyze the possible reasons for such similarities and differences, and then verify the spatial correlation existing in the development of each province by using globalMoran's I and localLISAcluster map; Finally, on the basis of confirming the spatial correlation between the high-quality development of digital economy and carbon emission, the spatial econometric model is adopted to calculate the impact degree of digital economy on carbon emission reduction in each year, and control variables are introduced to calculate the impact mechanism of digital economy on carbon emission reduction from2011 to 2021 byusing baseline regression model, so as to provide an optimized path for improving the high-quality development of digital economy and promoting carbon emission reduction.

Keywords: Digital Economy; Carbon Emission; Entropy Method.

1. Introduction

Digital economy has become a new engine to promote China's economic and social development. According to China Digital Economy Development Report 2022, the scale of China's digital economy will reach 45.5 trillion yuan in 2021, accounting for 39.8% of GDP, maintaining a high growth rate of 16.2%. At the same time, in the face of global climate change problems caused by the continuous rise of carbon emissions in various countries and the serious threat posed by the surge of greenhouse gases to human life systems, China has proposed carbon peak and carbon neutral targets. In 2020, China has proposed two goals to reduce carbon emissions: the first is that carbon emissions will not continue to grow after 2030, and the second is to achieve carbon neutrality by 2060. This important decision is a positive response to the global strategy of energy conservation, emission reduction and sustainable development, a measure in line with the world development trend and China's basic national conditions, and a positive commitment conducive to basic interests. This not only demonstrates China 's responsibility for promoting the construction of a community of human destiny, but also reflects that China has taken a brand-new path for the world to control climate change and seek harmonious development between man and nature. The Fourteenth Five-Year Plan for National Economic and Social Development and the Outline of Vision Goals by 2035 also put forward digital economy, new energy, innovation and other elements as key pillars to achieve the goal of carbon neutrality. It can be seen that digital economy is an important tool to promote sustainable economic development and an inevitable requirement and important support for realizing the goal of "double carbon". For producers, taking the road of green development is an inevitable requirement for high-quality and sustainable development of enterprises. Digital transformation helps to promote the transformation of production mode, which is embodied in the effective integration of new generation digital technologies such as big data, artificial intelligence and blockchain with traditional production technology, improvement of production process flow, improvement of operation efficiency of each part, optimization of production process management mode, and effective promotion of energy conservation and emission reduction of enterprises. For consumers, digital transformation is helpful to promote lifestyle change. In the process of smart city construction, digital means have been applied in various life scenarios such as transportation, urban governance, environmental protection and energy, which improves the convenience of life, but also realizes energy conservation and emission reduction in life scenarios, and promotes more efficient, low-carbon and environmental protection of urban operation. Therefore, it is necessary to find an effective path for digital economy to assist the goal of "double carbon", which requires measuring the development status of digital economy in China at the present stage, predicting the development trend of carbon emission in various regional departments, and then accurately judging and mastering the relationship and mechanism between digital economy and carbon emission, so as to achieve targeted and good results.

2. Research Status

2.1. A Study on Correlation of Digital Economic Measurement

The concept of digital economy was first proposed by Tapscott Don, who believed that digital economy is an economic system based on ICT technologies such as Internet infrastructure, e-commerce, B2B, etc.(Tapscott,1999), then digital economy research gradually became the focus of attention of scholars, narrow sense of digital economy mainly from information communication technology and individual high degree of digital industry development (Wu Yilin and Wang Tianqi, 2021), early summarized as information technology and e-commerce (Brent, 1999;Moulton, 2000; Jiang Qiping, 1998). With the penetration of digital technology into all fields of economic society, people's understanding of digital economy breaks through the limitations of information communication and electronic commerce. Broadly speaking, digital economy is a new economic form brought by digital technology after industrial and agricultural economy. (Bo 2004; Li Changjiang 2017; He Xiaoyin 2005; Yang Xinming 2017). In the field of digital economy, the existing research mainly focuses on the economic and social benefits brought by digital economy besides covering the nature of digital economy itself. Digital technology, through its connection with industrialization and intelligence, not only enables traditional industries to drive the transformation and upgrading of industrial structure, influences the change of entrepreneurial innovation process and infiltrates management analysis, but also has a positive impact on inclusive economic growth (Liu Yang, 2021; Zhang Xun, 2029). There are also a few scholars who focus on the environmental effects of the digital economy. Existing studies have shown that the development of digital economy has reduced emissions of pollutants such as industrial wastewater, dust and sulfur dioxide (Guo Feng, 2022), which has helped the government to improve environmental governance efficiency while significantly improving urban air quality (Xu Weixiang, 2022).

The research methods and contents of digital economic measurement are different in the world, among which the research results of added value measurement and related index compilation are the most abundant. Value added measurement research. Porat(1977) was the first to put forward the method of measuring the added value of knowledge economy and information economy. Since then, some international organizations and national government agencies have carried out more in-depth research, among which the representative mature research results are the research of the US Bureau of Economic Analysis (BEA)(Barefoot et al., 2018), which defines the digital economy into three categories: digital enabling infrastructure, e-commerce and digital media. Research on the compilation of relevant indicators. Internationally, OECD has formed a relatively complete set of digital economic statistical indicators; Eurostat has compiled digital economic and social indicators. In China, the China Academy of Information and Communication (2017) compiled a set of digital economic indexes, which can reasonably and comprehensively reflect the national conditions of China's digital economic development. The national digital competitiveness evaluation system constructed by Wu Yilin (2019) contains ten digital economy-related elements and has been compared internationally. At the same time, some scholars have also examined the economic effects of digital economy, such as how digital economy affects economic growth (Zhao Tao et al., 2020; Jiang Song, 2020; Guo Meichen and Du Chuanzhong, 2019), total factor growth rate (Huang Qunhui, 2019; Guo Jiatang, 2016; Yang Huimei, 2021), industrial structure (Zhang Yuzhe, 2019; Shen Yunhong, 2020; Jiao Shuaitao, 2021), technological innovation effect (Han Xianfeng et al., 2019; Wen Jun et al., 2019; Han Lu et al., 2021), etc. At present, the research on digital economy measurement is fruitful, but the accurate measurement of digital economy still needs further study. There are still further improvements in specific weight setting, index selection and comprehensive index evaluation method. According to the development of digital economy and industrial differentiation issued by the National Bureau of Statistics at this stage, the evaluation system of digital economy measurement should be established for different levels.

2.2. Carbon Emissions Related Research

Current estimates of carbon emission levels focus on total carbon emissions (Peng Shuijun et al., 2015; Wu Yinyin et al., 2021;Yue, 2017), carbon emission intensity (Shao Shuai et al., 2019; Cheng Yeqing et al., 2013; Zhao Yuntai et al., 2013; Sun Yaohua et al., 2012; Wang Shaojian and Huang Yongyuan, 2019) and carbon efficiency (Wang Yong and Zhao Han, 2019; Hu Jianbo et al., 2021; Li Lin and Zhao Heng, 2021), the measurement perspective is mainly industrial (He Xiaogang and Zhang Yaohui, 2021; Lin Xueqin et al., 2021; Sun Pengbo and Ge Liming, 2021), Agriculture (Gao Ming and Song Hongyuan, 2015; He Yanqiu et al., 2021; Tian Yun and Wu Haitao, 2020), construction industry (Yu, 2016;Qian, 2017), tourism industry (Sun Yuhuan and Yang Guangchun, 2020; Huang Heping et al., 2019), transportation industry (Yang Wenyue and Cao Xiaoshu, 2018; Zhang Jin, 2021) and other carbon emission industries. The analysis of carbon emission factors mainly includes economic factors (Xiao Hongwei and Yi Danhui, 2014; Shao Shuai et al., 2019; Zhou Jieqi and Wang Tongsan, 2014; Ren Xiaosong et al., 2020), foreign trade (Tang Zhipeng et al., 2014), industrial structure (Han Feng and Xie Rui, 2017; Yuan Yuan, 2016; Yu Zhiwei et al., 2017), energy consumption (Cheng Yeqing et al., 2013; Zhang Wei and Zhu Qigui, 2013), urbanization expansion (Zhang Tengfei et al., 2016), etc. At present, abundant theoretical basis and experience have been accumulated in the research on carbon emission, which provides useful experience and reference for the research on "double carbon" target.

At present, life cycle assessment method, carbon emission coefficient method and input-output method are three main methods for CO2 emission estimation. Zhu Qin et al.(2012) adopted the input-output method to calculate the carbon footprint of consumer goods in China. Deng Guangyao (2018) et al. calculated the carbon emissions of energy consumption from the perspective of industry by combining the input-output table and energy consumption data, and found that the emissions of electricity and heat production and supply industries were significantly larger than those of other industries. In contrast, the input-output method can not only estimate implied carbon emissions, but also measure carbon emissions at the industry sector level, facilitating comparison of carbon emission differences between industry sectors (Liu Zi et al., 2015).

2.3. A Study on the Effect and Mechanism of Digital Economy on Carbon Emissions

Some foreign studies show that digital technology plays a certain role in environment: in the new round of global technological and industrial transformation, the popularization of information technology has important marginal utility (Vu, 2011;Anseret, 2021); digital economy with information technology at its core provides new impetus for intelligent environmental management (Kjaeret, 2018;Usmanet, 2021); the pervasive penetration and popularity of the digital economy in energy consumption and environmental protection helps to address issues such as declining environmental carrying capacity and species scarcity (Junioret, 2018;Rehmanet, 2021); and the digital economy has great potential for improving the ecological environment (Murad, 2020). Domestic research mostly focuses on the economic benefits of digital economy, such as digital economy enabling high-quality development, digital economy and total factor productivity, digital economy and high-quality employment, etc. A few studies involve the relationship between blockchain and green development (Li Shaolin, 2021), and the impact of digital finance on pollution reduction (Xu Zhao, 2021). Specific research on the relationship between digital economy and carbon emission: Guo Feng et al.(2021) showed that the development of Internet can improve environmental quality by promoting technological progress and effectively reduce pollution emissions in the region; Wu Yingjie et al.(2021) found that the impact of digital economy on SO2 emissions was promoted first and then suppressed through empirical research; A small number of scholars have explained how the development of digital economy affects carbon emissions from a theoretical point of view. For example, Chen Yongwei (2021) believes that digital economy mainly realizes carbon emission reduction through two paths: "increment reduction" and "destocking". Wu Qi (2021) believes that digital economy can promote green and low-carbon development from three aspects: improving resource utilization efficiency, reducing energy consumption of traditional industries and solving financing problems. However, such articles only discuss the impact of digital economy on carbon emissions in a superficial way. Lack of strong experience and data support.

3. Empirical Study

3.1. Explanatory Variables

In terms of carbon emission research, we refer to the research of Lv Jingye et al. (2022) and Li Qun et al.(2023), and finally choose the ratio of actual GDP and carbon dioxide emission of carbon emission efficiency land area. The data are from China Statistical Yearbook and China Carbon Accounting Database. Some missing data are supplemented by interpolation. This paper calculates the carbon emission efficiency of 29 provinces and cities except Xinjiang and Xizang from 2011 to 2021. Among them, from the time trend, the overall level of Yangtze River Delta urban agglomeration is higher than that of other regions, and the development level of eastern region is higher than that of western region. Among them, Beijing, Shanghai, Jiangsu, Zhejiang, Guangdong indicators are far ahead of other provinces. It can be seen that the level of carbon emission in China is still in a polarized state, and the carbon emission efficiency in most parts of China has increased in recent years.

3.2. Explained Variables

At present, there is no international standard for the selection and measurement of digital economic indicators, and there is no unified digital economic measurement indicator as a normative guide. The Digital Economic Competitiveness Index proposed by Shanghai Academy of Social Sciences analyzes the development of the world digital economy from four dimensions: infrastructure construction, industrial scale, innovation ability and governance evaluation. The measurement of the digital economy has been the focus of attention of government agencies around the world, including DEBA (United States Department of Commerce Digital Economy Advisory Committee), OECD (Organization for Economic Cooperation and Development), BEA (United States Department of Commerce), EU (European Union), etc. However, no methodology has been widely accepted, and due to the limitations of the digital economy-related assessment methods proposed by various international organizations, their scope of application is limited.

Table 1. Measurement system of digital economic development level index

first-level indicators	secondary indicators	measurement index	index units	index attribute
Digital Economic Development Level Index Measurement	digital facilities	cable length	kilometers	+
		Internet broadband access ports	ten thousand	+
		Internet Domain Name Numbers	ten thousand	+
		Number of cell phone base stations	ten thousand	+
	Internet applications	mobile phone penetration rate	Sector/ 100 people	+
		Internet penetration rate	%	+
		Number of Internet Users	thousands of people	+
	digital industry development	Software industry revenue	wanyuan	+
		Number of employees in information services	thousands of people	+
		Output value of information service industry	100m	+
		telecom business volume	100m	+
	digital finance	Digital HP Financial Index	/	+

Based on the work of Liu Jun (2020), Liu Yang and Chen Xiaodong (2021) and other scholars, this paper constructs an indicator system of digital economy development level from four dimensions of "digital facilities", "Internet application", "digital industry development" and "digital finance" according to the requirements of scientificity, standardization and simplicity based on existing urban data, and makes empirical analysis on it, as shown in Table 1. The Digital Finance Development Level Index jointly launched by Peking University Digital Finance Research Center and Ant Financial Services Group aims to measure the popularity of digital technology in the financial field, so as to better meet the financial needs of consumers; With the continuous progress of mobile communication technology, the number of Internet users continues to grow, so the development of digital economy has realistic conditions; Digital development depends on the growth of various industries, such as: Software and information services revenue, employment, e-commerce, and production of goods.

The above data are from China Urban Statistical Yearbook, China Regional Statistical Yearbook, statistical yearbooks of all provinces and cities in China from 2011 to 2021, CNRDS "China Survey Data Service Platform" and "EPS Global Statistics". For missing single data, we used interpolation and intermediate values to fill in.

As for evaluation methods, TOPSIS model based on entropy weight is constructed. By entropy weight TOPSIS model, the weights of each index can be determined effectively, and these weights can be used to approach the ideal solution, to achieve the score and ranking of evaluation objects. Entropy weight TOPSIS method is a very effective method, it can objectively assign weights according to different indicators, and can carry out comprehensive comparative analysis, but also very easy to calculate. It can provide theoretical support for future research.

Before empirical analysis, descriptive statistics should be carried out on the data. Considering that the panel data volume of this paper is large and the overall units are many, the average and median of each data item in each year are counted from the national level to reflect the general level change trend. The results are shown in Figure1.

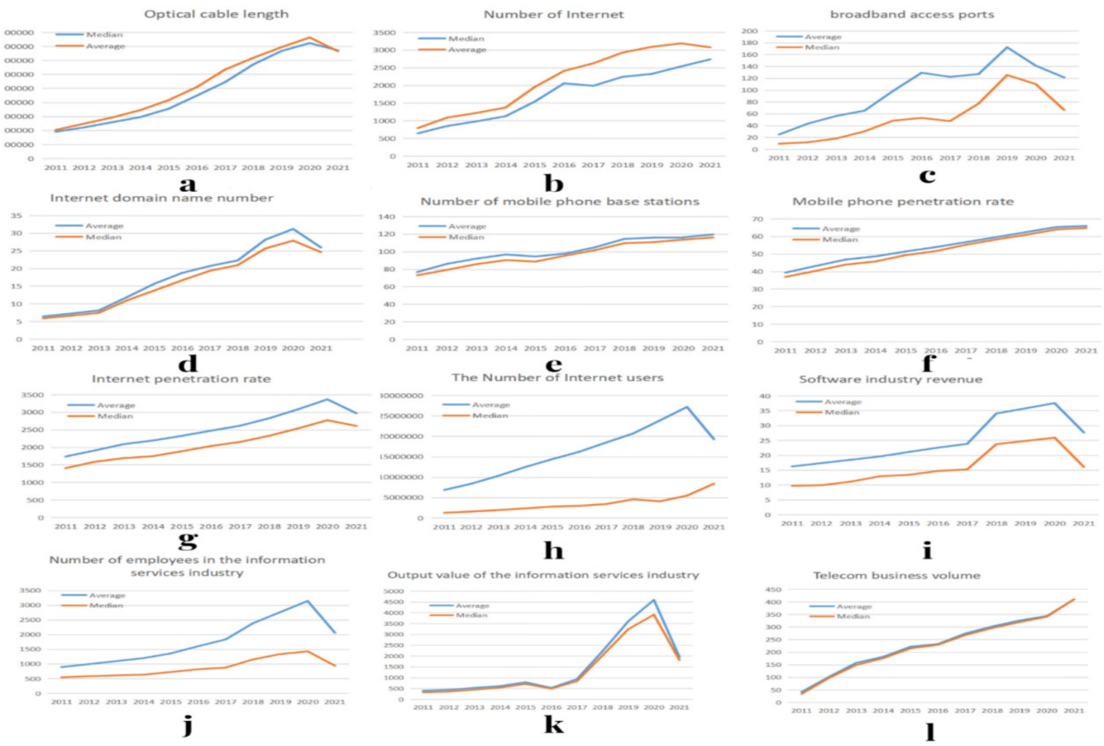

Figure 1. Descriptive statistical results of mean and median of digital economic evaluation indicators

Subgraph (a),(b),(c),(d),(e),(f),(g),(h),(i),(j),(k) and (l) represent optical cable length, number of Internet broadband access ports, number of Internet domain names, number of mobile phone base stations, mobile phone penetration rate, Internet penetration rate, number of Internet surfers, software industry revenue, number of information service industry employees, output value of information service industry, telecommunications business volume and digital HP financial index respectively. According to descriptive statistics, the general level of 12 categories of data almost all have an upward trend year by year, with time series characteristics. Among them, the difference between the mean value and median value of sub-figure (b)(c)(g)(h)(i)(j) is large, indicating that the corresponding index has Matthew effect, and the data value presents right-biased distribution; the difference between the mean value and median value of sub-figure (a)(b)(e)(f)(k)(l) is small, indicating that the corresponding data distribution is relatively even.

4. Measurement Results and Analysis

4.1. Brief Description of Baseline Regression Model

The development of digital economy provides technical guarantee for the change of carbon emission efficiency. Therefore, this paper uses Cobb-Douglas production function as the basis to express the effect model of digital economy, as shown in the following equation:

$$Y = A \times K^{\alpha} \times L^{\beta} \tag{1}$$

Where Y is the effect output of digital economy, K is capital input, L is labor input, A includes the impact of digital economy on carbon emission efficiency through technological progress, mainly including environmental regulation index, FDI level and human capital level. Therefore, it can be expressed as:

$$\mathrm{Y}=\theta \bullet \mathrm{ERI}^{\gamma_1} \bullet \mathrm{FDI}^{\gamma_2} \bullet \mathrm{HCL}^{\gamma_3} \tag{2}$$

ERI is the environmental regulation index; FDI is the level of international direct investment; HCL is the level of human capital. Benchmark regression is one of the most basic and common regression methods, and it is the basis of other regressions. According to the research requirements, a suitable reference regression model is constructed, and the results obtained by parametric regression on appropriate sample data can be called reference regression results. Benchmark regression is a nonlinear regression that can be used to evaluate the accuracy of models or data, and can also be used to calculate the parameters of variables in a benchmark regression model, thereby performing empirical analysis on the regression results. Based on (2), this paper constructs a benchmark regression model to test the impact of digital economic development on carbon emissions. The benchmark regression model constructed is as follows:

$$ECS=\beta_0+\beta_1 DIG+\beta_2 ERI+\beta_3 FDI+\beta_4 HCL+\delta_i+v_i+\varepsilon_i \quad (3)$$

ECS is a comprehensive index of carbon emission efficiency, which is obtained by measurement; DIG is the development level of digital economy, which is the core explanatory variable of this paper. β_0 is the intercept term, δ_i is the province fixed effect, v_i is the time fixed effect, ε_i is the random disturbance term.

4.2. Control Variables

1) Urban Development Indicators (UDI). The social development of a province is measured by the proportion of urban residents to the total population of the country; this part of the information is obtained from statistical data from all parts of the country.

Environmental Regulation Index (ERI). The ratio of total investment to total investment in industrial pollution prevention and control in secondary industry output value is used to measure the degree of environmental protection supervision and management in our province.

Level of International Investment (FDI). FDI is a kind of investment mode, which is directly invested by foreign businessmen in one country into the products and services of another country, and has a considerable degree of management rights. All the information about this aspect comes from the official website.

Human Capital Level (HCL). This paper adopts a new evaluation method-"academic index", that is, using the average education level of labor force to measure the stock of human capital to reflect the level of education in the province. This part of the data mainly comes from the official website of the National Bureau of Statistics.

Descriptive statistics of the main variables of the four indicators are shown in Table2.

Table 2. Descriptive analysis of control variables

indicator description	observed values	average	standard deviation	minimum value	maximum value
UDI	319	0.5998	0.122	0.35	0.90
ERI	319	0.4846	0.524	0.00	2.59
FDI	319	5.536	1.710	-1.22	7.72
HCL	319	9.295	0.940	7.47	13.00

4.3. Analysis of Regression Results

According to the formula, regression analysis is carried out on 348 rows of sample data from 29 provinces (except Hong Kong, Macao and Taiwan, Xinjiang and Xizang) in China from 2011 to 2020. See Table 3 for regression results. According to the regression analysis in the first column of Table 3, it can be seen that with the development of digital economy, the traditional industrial production mode is being replaced by intelligent and digital mode, thus reducing the dependence on traditional raw materials such as coal and oil, and increasing the demand for electric energy. This conclusion is significant and can be used as an important reference to infer future sustainable development.

Table 3. Benchmark Regression Results

Explanatory variable: carbon emission efficiency						
variables	x	x	x_1	x_2	x_3	x_4
development level of digital economy	-0.335	-0.086	-0.074	-0.093	-0.105	-0.106
urbanization development index	-	-	0.371	0.473	0.396	0.380
environmental regulation index	-	-	-	0.119	0.122	0.122
FDI levels	-	-	-	-	0.014	0.014
human capital level	-	-	-	-		-0.010
constant	0.900	0.282	-0.022	-0.098	-0.126	0.007
province fixed effect	No	Yes	Yes	Yes	Yes	Yes
time-fixed effect	No	Yes	Yes	Yes	Yes	Yes
sample size	348	348	348	348	348	348
R^2	0.848	0.899	0.858	0.871	0.873	0.873

In column 2, we examine how the level of development of the digital economy affects the development of carbon efficiency and conclude that this driver remains important. After the analysis of the control variables in the third, fourth, fifth and sixth columns, the results show that the development level of digital economy still has a significant negative impact on the development of carbon emission efficiency, which indicates that digital economy can continuously promote the cleaning of carbon emission efficiency.

4.4. Subsample Regression Analysis

Through comparative analysis, we found that even if we try to suppress the impact on carbon emissions, there are still differences from different geographical factors that have a significant impact on the final prediction results. As the digital economy evolves, changes in carbon emissions are likely to vary significantly between regions. After systematic regional division, we divide 29 provinces into east, middle, west and northeast regions, and draw detailed conclusions through regression analysis, as shown in Table 4.

After analysis, we found that the impact of digital economy on carbon emissions varies from region to region. In these regions, only the core explanatory variables have significant effects on carbon emissions, and the effects become more significant when all control variables are considered. The study showed that, even after adjusting for stabilization factors, the level of development of the digital economy led to a significant reduction in carbon emissions regardless of the region, consistent with the overall study results. Research shows that the development level of digital economy in different regions will have different impacts on the development of low-carbon industries. In particular, the difference is more significant in Northeast China, while the difference is relatively small in other regions. Especially in the eastern and western regions, the level of development of the digital economy has a greater impact on changes in carbon emissions. First, because carbon emissions in the northeast, east and west regions are more mature than those in the central region, carbon emissions in these regions are more in line with environmental protection standards, thus making significant contributions to local energy conservation and emission reduction. Second, due to the development of digitalization, emerging energy technologies have been further developed, thus playing a positive role in promoting environmental protection. Third, since Guizhou Province is the leader of China's digital economy, Gui 'an Comprehensive Electronic Information Industrial Park, Guiyang Big Data Information Industrial Park and Gui' an Digital Economy Industrial Park in Guizhou Province and Gui 'an have strong development prospects, which will be conducive to the development of China's future digital economy level.

Table 4. Regression results of subsample

Explanatory variable: carbon emission efficiency								
variables	northeast	northeast	Eastern	Eastern	central	central	Western	Western
development level of digital economy	-1.987	-3.034	-0.108	-0.207	-0.015	-0.114	-0.104	-0.316
urbanization development index	-	2.872	-	0.590	-	1.860	-	1.203
environmental regulation index	-	0.094	-	0.195	-	0.357	-	0.507
FDI levels	-	0.058	-	0.103	-	0.187	-	0.052
human capital level	-	-0.930	-	0.021	-	0.245	-	0.086
constant	1.014	-8.130	0.268	-1.104	1.901	-5.475	1.870	-0.332
province fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
time-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
sample size	36	36	120	120	72	72	120	120
R^2	0.868	0.765	0.822	0.861	0.747	0.787	0.870	0.887

4.5. Robustness Test

(1) Replacement indicators. The explained variable carbon emission in this paper is a comprehensive index. At present, most of the existing studies focus on the change of single index such as logarithmic term, so this project plans to replace the explained variable with logarithmic term. The regression results after replacing the variables described with indices are shown in Table 5 below.

(2) instrumental variables. Although this paper has tried to limit the factors that influence the development of digital economy and carbon emission, there are still some other unobservable reasons that inevitably cause some endogenous Ness. On this basis, the main economic growth rate of our country lags a period of data as the main analysis index, this paper carried out regression analysis.

After replacing the metrics, the first to third columns of Table5show the results of the reprocessing of the data. The study shows that with the development of digital economy, the growth of carbon emissions has obvious suppression effect, and this conclusion is still obvious after using fixed province and time effect and adding all control variables. The application of digital technology and information communication services to the energy field is a new development model in the future, which has important positive significance for improving China's energy conservation efficiency and optimizing China' scarbon emission efficiency. At the same time, it plays an important role in reducing carbon emissions in China's carbon-intensive regions and promoting China's energy development.

Columns 4 to 6 of Table5show the data results after applying tool variables. The study shows that as the digital economy develops, it has a significant negative effect on the overall development of carbon emissions, and this conclusion is still very obvious after using fixed province and time effects and adding all control factors. This conclusion is consistent with our statistical analysis of the whole data and proves the robustness of our proposed benchmark regression results. Furthermore, we found that the negative impact of the data on carbon emission efficiency was more significant than that of the standard model when endogenous factors were taken into account.

Table 5. Robustness test results

Explanatory variable: carbon emission efficiency						
variables	1	2	3	4	5	6
development level of digital economy	-0.237	-0.712	-0.007	-0.219	-0.017	-0.015
urbanization development index	-	-	1.493	-	-	0.556
environmental regulation index	-	-	0.036	-	-	0.115
FDI levels	-	-	0.014	-	-	0.009
human capital level	-	-	-0.086	-	-	-0.006
constant	0.944	0.879	0.662	0.901	0.254	-0.189
province fixed effect	No	Yes	Yes	No	Yes	Yes
time-fixed effect	No	Yes	Yes	No	Yes	Yes
sample size	348	348	348	348	348	348
R^2	0.856	0.911	0.927	0.847	0.898	0.901

In general, the econometric results of both tests are consistent with those of the original regression, both in terms of additive variables and in terms of alternative models, that is, it shows an overall effect that can resist total carbon emissions and can make carbon emissions green.

5. Conclusion and Recommendations

It can be seen from the existing relevant literature that with the understanding of "numbers" and "carbon emissions", the relationship between "data" and "energy consumption" is getting closer and closer, and "carbon" consumption is also paying more and more attention to "low carbon" and "green". ICT is a key part of the digital economy, with the effect of reducing carbon emissions, laying the foundation for achieving low-carbon, green economy development. However, in the process of data development, the use of data will not only bring positive effects, under the data drive, the relevant data will also be amplified in the data drive process, resulting in miscellaneous data. A lot of work has been done in academia on the role of the digital economy in carbon emissions, and a lot of significant research results have been obtained. More in-depth work is still needed in the work ahead. First, most of the current research has focused on the role of ICT in carbon emissions, and future research needs to extend this to the role of the digital economy in carbon emissions. Second, the existing analysis of the overall effect of "digitalization" on carbon emissions mainly focuses on "all-regional effects", while subsequent work needs to be extended to the differentiation of "digitalization" on carbon emissions. Thirdly, analyze its direct or indirect effects on China's carbon emissions, whether it is linear or nonlinear, and its possible intermediate effects. Exploring the role of digital economy in the development of carbon field in China is an important support for realizing the development of economic environment in China. By analyzing the shortcomings of the past related literature, it lays a solid foundation for the further analysis and follow-up work of the related literature.

Based on the conclusions of this paper, the following suggestions are put forward for the coordinated development of domestic digital economy and carbon emission efficiency:

At present, China's core digital technology R & D and innovation capability is still insufficient. Therefore, we should increase the proportion of investment in digital technology R & D and innovation to a certain extent, and promote the integration and development of digital technology and green technology, because the current green technology R & D cost is high and the cost recovery cycle is long, resulting in low economic benefits, which makes enterprises have insufficient motivation to get involved in this field. Therefore, the government needs to take the lead. The integration of digital technology with higher economic returns and green technology will be put on the agenda to promote its rapid development in order to better realize green development. At the same time, pay attention to the difference of digital economy development level between different regions, make full use of the advantages brought by the rapid development of digital economy in developed regions, and start to promote the development of digital economy in economically underdeveloped regions, to obtain higher economic benefits in the era of rapid development of digital economy and empower green economy development.

Make full use of the rapid development momentum of digital economy in some regions of China, encourage advanced regions and enterprises to build digital technology platforms, cooperate with surrounding areas on green development of digital technology empowerment, make good use of the radiation effect of central cities, thus driving the development of digital economy in surrounding cities, completing the integration of digital technology and traditional industries with higher quality, and contributing to green manufacturing.

Acknowledgments

Funded by the Innovation and Entrepreneurship Training Program for College Students of Anhui University of Finance and Economics (S202310378011).

References

[1] Park Y, Meng F C, Baloch M A. The effect of ICT, financial development, growth, and trade openness on CO2 emissions: An empirical analysis [J]. Environmental Science and Pollution Research, 2018, 25(30): 30708-30719.

[2] Qian Shi and Jindao Chen and Liyin Shen. Driving factors of the changes in the carbon emissions in the Chinese construction industry[J]. Journal of Cleaner Production, 2017, 166: 615-627.

[3] Wang L, Chen Y, Ramsey T S, et al. Will researching digital technology really empower green development? [J]. Technology in Society, 2021, 66: 101638.

[4] X. Zhou, D. Zhou, Q. Wang, B. Su. How information and communication technology drives carbon emissions: a sector-level analysis for China. Energy Econ., 81 (2019), pp. 380-392.

[5] Yang L, Li Z. Technology Advance and the Carbon Dioxide Emission in China-Empirical Research Based on the Rebound Effect [J].Energy Policy, 2017, (101).

[6] Y.L. Li and B. Chen and G.Q. Chen. Carbon network embodied in international trade: Global structural evolution and its policy implications[J]. Energy Policy, 2020, 139(C): 111316-111316.

[7] mr choi yueh-chau. Value Added and Contribution Measurement of Digital Economy: Historical Evolution, Theoretical Basis and Methodological Framework [J]. Journal of Qiushi, 2018, 45 (05):65-71.

[8] Dong Zhiqing, Cai Xiao, Wang Linhui. Technological progress direction, urban land use scale and environmental quality [J]. Economic Research, 2014, 49 (10):111-124.

[9] Guo Jiatang, Luo Pinliang. Does Internet Promote China's Total Factor Productivity? [J]. Managing the World, 2016 (10):34-49.

[10] GUO Meichen, DU Chuanzhong. Analysis on the mechanism and effect of ICT in improving the quality of China's economic growth [J]. Statistical Research, 2019, 36 (03):3-16.

[11] Han Xianfeng, Song Wenfei, Li Boxin. Can the Internet become a new kinetic energy for improving regional innovation efficiency in China? [J]. China Industrial Economics, 2019 (07):119-136.