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The Impact of China's Digital Economy on Carbon Emissions: Evidence from 30 Province's Data

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Abstract: China's digital economy is expanding rapidly, and its relationship to carbon emissions is a frequent topic of discussion. To study this topic, we chose 30 provinces, except Tibet, Tai Wan, Hong Kong, and Macau, found data related to the digital economy from China Statistical Yearbook and sorted them to panel data. Based on these provinces' panel data from 2009 to 2019, this essay uses a multiple regression analysis model to examine how the digital economy affects carbon emissions, and divides the 30 provinces' data into two groups by time to study the impact of the digital economy's development in carbon emissions. In this process, we use STATA. In this paper, we choose software industry investment and the number of Internet access ports as two quotes from the digital economy because the digital economy relies heavily in the Internet. From the model, it is clear that the digital economy can help decrease carbon emissions, and by analyzing the first 5 years' data from 2009 to 2014 and the data from 2014 to 2019, we found that carbon emissions may rise with the development of digital economy, but as it continues to develop, this effect will disappear. In the end of this paper, based on our findings, we suggest government enlarge the investment in developing digital economy-related industries such as the software industry and the information transmission industry.

Keywords: digital economy, carbon emissions, software industry

1. Introduction

In the recent 10 years, the booming growth of the digital economy has made it a hot topic in all walks of life in China. At the same time, the date of the emission peak promised by our country is approaching, so carbon emissions and other issues related to environmental protection have come into the public's view, and the digital economy has also been proven to provide positive benefits for green urban development [1]. Between 2020 and 2023, there was a growing body of research on this issue. A study by Liu Zhixiong and Li Yanfei proved that the digital economy could positively affect the environment by influencing infrastructure effects [2]. And as we know, infrastructure construction and operation account for a large part of carbon emissions in each place. But others argue that since the digital economy relies heavily on networked devices, it will increase electricity consumption, resulting in carbon emissions from the increased demand for electricity [3].

Based on a reading of the previous paper, we list some of how the digitization of the economy impacts carbon emissions:

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The growth of digital industries can be facilitated by the digital economy, this will help upgrade the industrial structure and then carbon emissions are reduced. A study by Chen Xiao has found that while the digital economy is closely related to high-quality economic development, it also lends a helping hand to industrial structural upgrades [4]. Another study also provides data to support this view [5].

The digital economy can reduce coal consumption, increase robot use, and promote a low-carbon economy. When it reaches maturity, it will also lead to a rise in innovation efficiency. It improves energy utilization efficiency, hiring rates, scientific and technological innovation, and other factors [5-8]. The upgrading of rural consumption structures as an intermediary function brought on by the expenses of the digital economy may decrease carbon emissions [9].

In addition, while trade in digital services in the digital economy can facilitate industrial transformation, it can also eliminate less efficient technologies by promoting the tertiary sector of the economy's development, making the industrial structure more advanced and reducing carbon emissions [10].

Most of the articles in the literature we read demonstrate that expansions of the digital industry will reduce the release of carbon by encouraging industrial structure modernization. However, as mentioned in the previous section, some studies also show that carbon emissions will increase as the digital economy grows. Some have discovered that in the beginning stages of digital economic development, growth will be the largest [7]. And in another paper, researchers have found that the emergence of the digital economy will increase the release of carbon as the outcome of the urbanization of consumption patterns [11].

Investment in businesses such as information transmission, software, and computer services, as well as the Number of Internet access ports, were the two indicators that we used to determine the stage of growth of the digital economy so that the influence that the digital economy has on carbon emissions could be studied. Below, we will refer to investments in businesses such as computer services, information transmission, and software as "investments in digital economy-related industries" together. According to the concept of the digital economy presented in the G20 Digital Economy Development and Cooperation Initiative, the growth of the digital economy is inextricably linked to the growth of the services provided by networks. We can identify the level of internet development in a number of different provinces by using the quotation that we have chosen. We will also seek to establish the impact of the digital economy on carbon emissions at various stages of its growth. This will be done by splitting the data according to different periods.

2. Research Hypothesis

The effect of the digital economy on carbon emissions is somewhat different from that of the traditional economy. Information technology and digital production mode can optimize the production process and reduce energy and resource consumption, thus reducing carbon emissions and improving resource utilization and efficiency. Mobile communication, cloud computing and other services in the digital economy make it possible for people to live and work in different places, reduce the traffic flow of people and goods, and reduce the carbon emissions of transportation. Sharing economy, sharing platforms and other modes in the digital economy can make full use of resources, reduce waste and redundancy, and also reduce the exploitation and consumption of natural resources, thus producing an emission reduction effect on the environment. Online consumption and e-commerce in the digital economy reduce the energy and resources consumed by the physical stores of traditional retail, and also reduce the traffic flow and energy consumption generated by traditional shopping methods. Based on this theory, we put forward our first hypothesis:

H0: In general, as the digital economy develops, carbon emissions will decline.

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Carbon emissions may be positively correlated to the digital economy. The rapid digitization of the economy and the popularity of electronic products mean that there is also an increasing number of waste electronic products, which negatively influence the environment, including pollution of soil, water and air quality. Technologies like big data analytics and cloud computing require huge amounts of energy and equipment support. Although cloud computing can make better use of resources, storage, load balancing, backup, and so on, all require a lot of computing and storage equipment, which consumes a lot of energy and emits more and more carbon. Services such as e-commerce and logistics in the digital economy require rapid delivery and the construction and operation of logistics and storage facilities, which also require significant energy and resource support. Thus comes our second hypothesis:

H1: At a certain stage of the digital economy's growth, it will increase carbon emissions.

3. Research Design

3.1. Variable Declaration

3.1.1. Explained Variables

The explained variable in this paper is carbon emission.

3.1.2. Explain Variables

This article will analyze the consequences of the digital economy on the impact of carbon emissions on information transmission, the use of software and computer service quotas as an interpretation variable, and the number of Internet access ports in each province. Investment quotas in the computer service and software industries represent the power of digital economies. In addition, a number of Internet access ports reflects the highlight of the digital society.

3.1.3. Data Sources

The panel data for each province from 2010 to 2019 are selected from the China Statistical Yearbook.

3.2. Model Building

STATA was utilized for panel data analysis. In addition, the multiple regression analysis model is applied to investigate the consequences of the digital economy on carbon emissions. This investigation aims to determine the extent to which the digital economy influences carbon emissions. This paper adopts linear model regression:

$$lny = alnx_1 + blnx_2 + C \tag{1}$$

Where y is carbon emission; x1 is the data of investment quota of information transmission, computer service and software industry; a is the coefficient after logarithm of data of investment quota of information transmission, computer service and software industry; x2 is the number of Internet access ports; b is the coefficient after logarithm of data of Internet access ports.

3.3. Analysis of Empirical Results

Based on 2011-2019 panel data of 30 provinces, except Hong Kong, Macao, Taiwan, and Tibet Province, a panel vector autoregressive model was constructed based on information transmission, investment quota of computer service and software industry, number of Internet access ports and carbon emission

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4. Tested Result Section

4.1. Baseline Regression Analysis

Table 1: Random effects or mixed regression.

	Var	SD = sqrt(Var)		
	ln carbon emissions	0.612199		0.782431
	e	0.014471		0.120294
	u	0.378087		0.614888
Test:	Var(u) = 0			
		chibar2(01)	=	1058.98
		Prob > chibar2	=	0

Table 2: Random effects model regression.

ln crabon emissions	Coefficient	Std. err.	z	P>|z|	[95% conf. interval]	
ln investment	-0.0140164	0.0077954	-1.8	0.072	-0.0292951	0.0012623
ln numbers of ports	0.113815	0.0196706	5.79	0	0.0752614	0.1523686
_cons	4.878074	0.1590841	30.66	0	4.566275	5.189873
sigma_u	0.61488758					
sigma_e	0.12029424					
rho	0.96313736	(fraction of variance due to u_i)				

Table 3: Hausmann test.

	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	FE	RE	Difference	Std. err.
ln investment	-0.0124526	-0.0140164	0.0015638	0.0005172
ln number of Internet access port	0.1070385	0.113815	-0.0067764	0.0020362
_cons	4.917634	4.878074	0.0395594	.

In this article, the logarithmic value of carbon emissions is described as a variable. On the basis of provincial-level data from China, hybrid regression employs fixed effects models and random effect models to validate the model. This article uses the amount of carbon emissions as an interpretive variable. According to the results of table 1 and table 2, the random effects model is chosen. The final model selection is determined by the Hausmann test. In table 3, b is consistent under H0 and Ha, obtained from xtreg; B is Inconsistent under Ha, efficient under H0; obtained from xtreg, using the formula:

$$chi2(3) = (b-B)' \ [(V\_b - V\_B)^\wedge(-1)](b-B) \tag{2}$$

we learn that

$$Prob > chi2 = 0.0029 \tag{3}$$

And as the result of table 3, with the use of the original hypothesis is accepted and the fixed model is chosen.

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Using panel data from Chinese provinces, mixed regression, a fixed effects model, and a random effects model were used to validate the model. In this paper, the mixed regression model and the fixed effect model are used, respectively. Table 1 demonstrates that the P value was significantly less than 0.01, so the fixed effect model was selected. Then, we use respectively the mixed regression model and the random effects model.

4.2. Model Result Analysis

Table 4: Result base on panels of 2010-2019.

2010-2019	(1)	(2)	(3)	(4)
	OLS	FE_robust	FE	RE
ln investment	-0.0895	-0.0125	-0.0125	-0.014
	(0.0506)	(0.00947)	(0.00765)	(0.0078)
ln numbers of ports	0.542***	0.107**	0.107***	0.114***
	(0.14)	(0.031)	(0.0194)	(0.0197)
_cons	2.254**	4.918***	4.918***	4.878***
	(0.8)	(0.203)	(0.109)	(0.159)
N	300	300	300	300
R-sq	0.303	0.152	0.152	

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table 5: Result base on panels of 2010-2014.

2010-1014	(1)	(2)	(3)	(4)
	OLS	FE_robust	FE	RE
ln investment	-0.112	0.0182	0.0182	0.0253
	(0.142)	(0.0375)	(0.0266)	(0.0269)
ln numbers of ports	0.636***	0.190***	0.190***	0.206***
	(0.149)	(0.0389)	(0.028)	(0.0283)
_cons	1.864*	4.257***	4.257***	4.126***
	(0.758)	(0.357)	-0.198	(0.224)
N	150	150	150	150
R-sq	0.405	0.295	0.295	

Table 6: Result base on panels of 2015-2019.

2010-1014	(1)	(2)	(3)	(4)
	OLS	FE_robust	FE	RE
ln investment	0.148*	-0.00215	-0.00215	-0.00155
	(0.0619)	(0.00424)	(0.00629)	(0.00671)
ln numbers of ports	0.541***	0.0983*	0.0983**	0.120***
	(0.137)	(0.048)	(0.0295)	(0.0309)

Table 6: (continued).

_cons	0.578	4.906***	4.906***	4.742***
	(0.973)	(0.362)	(0.223)	(0.26)
N	150	150	150	150
R-sq	0.378	0.086	0.086	

In accordance with the regression results shown in table 4, there is an unfavorable association between digital economy-related industries' investment and carbon emission. When the investment quota of computer service, information transmission and software industry in each province increases by one unit, carbon emission decreases by 1.25%. At the same time, the number of network ports is inconsequential. This suggests that increased investment in digital economy-related industries has helped reduce emissions. To make the experimental results more accurate, this paper carries out further analysis, grouping the data of 2010-2019 according to 2010-2014 and 2015-2019 for panel data regression analysis, to observe whether there is any difference with the results based on the panels of 2010-2019. Whether the carbon emission is inhibited first and then increased, or increased first and then inhibited. Which are shown in table 5 and table 6.

Based on our findings, it is clear that over the years 2010-2014, a boost in the investment quota of sectors connected to the digitization of the economy led to an increase in the production of carbon emissions to some degree. The number of network ports did not reach the substantial threshold of 5% needed to be considered significant. Between the years of 2015 and 2019, a boost in the investment quota of digital economy-related businesses brought about a certain degree of reduction in carbon emission; nonetheless, even at the considerable level of 5%, the number of network ports remained negligible. This demonstrates that the effect of investment quotas related to industries that are associated with the digital economy will have the influence of increasing carbon emissions to a certain level at the beginning of the process, but will thereafter suppress the increase in carbon emissions to a certain extent after the process has begun. This assumption is supported by several pieces of data, such as the fast expansion of the digital economy and the rise in carbon emissions caused by the effect of the carbon emissions that were addressed before. When the digital economy is still in its early phases of development, and has not yet achieved a particular level of growth, the ramifications of the digital economy on carbon emissions is encouraged. However, if the digital economy achieves a certain degree of maturity, it will effectively improve the sector, which will lead to a diminution in carbon emissions and further restraint of their production.

5. Conclusions

This article explores the effect that the digitization of the economy has had on carbon emissions, as well as the variables that influence the investment quotas of sectors associated with the digital economy, and whether or not the numbers of Internet access ports play a part in this influence. An artificial panel vector income model was built using thirty different province panel data sets from Tibet, Hong Kong, Macau, and Taiwan from 2011 till 2019. These data sets were utilized to develop the model. This model makes use of the information transmission industry, the computer services industry, as well as the software industry. The number of carbon emissions produced by the Internet access port, as well as those produced, are being investigated as study objectives. Thorough research was conducted to investigate the nature of the two parties' connection, and the following findings were uncovered as a result: At first, the rise in carbon emissions was caused by an increase in carbon emissions caused by an increase in the number of Internet access ports. However, this impact dissipated later. This demonstrates that our H2 is accurate. An increase in the number of network ports will not have a significant impact; nevertheless, growth in investment in sectors associated with

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the digital economy will contribute to an increase in carbon emissions during the first five years of the projected period, but will prevent an increase during the second half of the period. The expansion of the digital economy leads to a decrease in the amount of energy and resources that are used, as well as an increase in the amounts of resources that are utilized and the efficiency with which they are utilized. This, in turn, results in a reduction in the amount of carbon emissions that are produced. As a result, Hypothesis 1 (H1) is validated. The digitization of the economy is largely fueled by the gradual loosening of investment restrictions imposed on companies operating in sectors closely related to the digital economy.

Taking into consideration the earlier-presented findings, the following recommendations have been made for increasing the ramifications that the digitization of the economy has on carbon emissions: Increasing investments in industries such as information transmission, software, and computer service can promote the growth of the digital economy, accelerate its development beyond its initial stage, and reduce carbon emissions from this phase of the digital economy's life cycle. This is because such industries are essential to the ongoing expansion of the digital economy. It may be possible for the growth of industries linked to the digital economy to assist in improving industrial development and the indirect reduction of carbon emissions.

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