The Impact of Digital Economy on Regional Carbon Emissions

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Abstract—China is currently transitioning to a digital economy. Simultaneously, "carbon peaking" and "carbon neutralization" are significant challenges at this stage. What the digital economy can do to help reduce carbon emissions is an urgent topic that needs to be addressed. However, empirical research on the digital economy and carbon emissions remains limited. In light of this, this paper examines the impact of digital economy development on regional carbon emission intensity and its mechanism using provincial panel data from 2011 to 2018.After undergoing a number of robustness tests, it is discovered that the growth of the digital economy has significantly decreased the intensity of local carbon emissions. The degree to which the digital economy has affected carbon emission intensity varies.

Keywords-Digital economy; Carbon emission intensity; Energy structure

1. Introduction

Currently, academia has conducted a significant amount of insightful research on the effects of the development of the digital economy on economic and social development. The rapid development of the digital economy generally encourages the promotion of high-quality employment, the advancement of green and high-quality industrial development, the enhancement of urban development effectiveness, the encouragement of regional economic growth, the encouragement of mass entrepreneurship, and the advancement of high-quality development. Examine how the growth of the digital economy has affected the well-being of society [1].

Based on the previous research, it is possible to roughly divide the closely related research to this paper into the two categories below. The first category is research on carbon emissions, which focuses mainly on calculating the levels of carbon emissions in various regions and industries and examining the factors that influence carbon emissions. Literature in the second category focuses primarily on the digital economy and its financial ramifications. such as the capacity of the digital economy to support productive manufacturing, inclusive growth, and high-quality employment. The impact of the digital economy on the environment is not often discussed in articles, though [2]. The impact of blockchain on the environmentally friendly development of industry and the impact of digital finance on greenhouse gas emissions have both been the subject of numerous studies. The relationship between carbon emissions and the digital economy has received even less research than that of other topics. A few academics have talked about the theoretical impact of the digital economy's expansion on carbon emissions.

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The following are the contributions that this paper makes to the field. To begin, in terms of research, this paper focuses on the impact of the digital economy on the intensity of carbon emissions from the perspective of potential environmental effects. This is in contrast to the majority of studies, which only focus on the impact of the digital economy on high-quality development, productivity, inclusive growth, and employment. Secondly, in terms of research, this paper focuses on the impact of the digital economy on the diversity of employment opportunities. Second, in terms of the research content, this paper takes into account the effects of spatial variation as well as the influence of digital economy characteristics on benchmark regression results.

2. Literature Review and Hypotheses

The development of a regional carbon market will be trending in the future due to the significance of reducing carbon emissions. Many nations and regions have tried to implement regional carbon trading at this time [3]. For instance, cooperation between the carbon markets in Quebec, Canada, and California began in 2008. China formally launched its national carbon market in December of that year. In China, there are currently eight carbon trading pilot projects. A future work plan now includes creating a national carbon market.

The academic community has given unprecedented attention to the digital economy as a new driving force in recent years. Because its primary purpose is to investigate the dividends that can be reaped from the digital economy, this study places a strong emphasis on the effectiveness of technological innovation, production efficiency, high-quality development, and high-quality employment. As a direct result of the "double carbon" goal, the academic community has begun to focus more attention on the ways in which the digital economy can contribute to the reduction of carbon emission. There are three primary points of view. By improving the energy grid and bringing obsolete technology up to date, the digital economy has the potential to cut carbon emissions in local communities. Utilization of and advocacy for the promotion of internet-based digital technologies result in significant reductions in carbon emissions [4]. Second, the growth of the Internet, information technology, and other industries closely related to it has led to a sharp rise in the consumption of electric power energy, which in turn has led to an increase in the amount of carbon emissions produced in the region. This points to the possibility that the digital economy will result in an increase in carbon emissions [5]. Third, there is a connection between carbon emissions and the digital economy, but it is not a linear one [6].

In conclusion, despite the fact that the body of research is fairly extensive, there are still a great many open questions: To begin, the term "digital inclusive finance" is currently used when referring to the process of measuring the digital economy; however, the meaning of this term is relatively broad, and the measurement of the digital economy is still an area that is actively being researched and developed. This study makes use of panel data from 276 Chinese prefecture-level cities between the years 2011 and 2019. This is the point at which the originality and significance of this paper become most readily apparent. By conducting theoretical analysis and empirical tests on the relationship, this paper contributes to the relevant research that has been done on the nonlinear relationship that exists between the digital economy and carbon emissions. In the research design for this study, the instrumental variable approach was used to address potential endogenous issues and determine the causal link between the digital economy and carbon emissions. This finding has some application in the process of policy development.

2.1 The effect that the digital economy has on the amount of carbon emissions

The reduction of greenhouse gas emissions is primarily accomplished through the digital economy in the following three areas: To begin, the digital industry has a number of its own environmentally friendly characteristics, which means it has a smaller overall negative impact on the planet. The digital industry is dominated by the information sector, which includes Internet companies and information service providers; the level of sustainability in this sector is typically higher than that of traditional manufacturing industries. In addition, because of their robust economic viability, digital businesses have a tendency to focus more of their attention on the environmental benefits [7]. Because it is the industrial backbone of the digital economy, the digital industry can serve as an example to other industries and encourage them to reduce their carbon emissions. The traditional industry can be revolutionized by the digital sector through the adoption and development of digital technology, which will also help advance smart and sustainable development, increase sector added value, and reduce energy consumption and carbon emissions. Thirdly, the expansion of the digital economy encourages the creation of a carbon market, which in turn reduces emissions of carbon [8]. However, in order to construct a trustworthy market for trading carbon emissions, problems of a more technical nature such as monitoring, reporting, and verification of emissions need to be solved. Utilizing digital technology will undoubtedly prove to be a game-changer in terms of finding solutions to these problems. The carbon trading market can be improved by allowing companies that have high energy efficiency to sell their excess emission rights to other businesses. Carbon trading has the potential to encourage businesses to take steps that will save energy and reduce emissions. In light of the analysis presented earlier, this paper draws the following conclusions about the world.

Hypothesis H1: The growth of the digital economy has the potential to significantly cut down on the intensity of regional carbon emissions.

2.2 Economy in the Digital Age and Energy Structure

Following are three factors that, when viewed from the perspective of energy structure, have the potential to propel the transformation of the energy structure into a low carbon one: First, we need to alter the way energy is produced. The digital energy boon incentivizes the intelligent transformation of the energy production process and the modernization of the production management system of energy enterprises, which ultimately results in the actualization of energy recycling and an increase in the efficiency with which energy is utilized. Next, we will work to optimize the structure of energy consumption. Through the facilitation of technology transportation, digital businesses have the potential to aid in the reduction of energy consumption in other industries. Because of the development of the digital economy, both our method of production and our way of life have been altered. This development has also encouraged the "virtualization" and "dematerialization" of economic activities, which has resulted in a reduction in traditional energy consumption as well as carbon emissions. Third, accelerate the development of innovative sources of energy [9]. For instance, Shanghai Electric Group announced the launch of its very first industrial Internet platform in August of 2018. This platform has been utilized for the storage of energy, electric vehicles, and possibly other fields in the near and distant future. In addition to that, it has been put to use in the management and upkeep of renewable power plants like wind and solar.

Hypothesis H2: Energy structure improvement is an important mechanism for digital economy to restrain carbon emission intensity.

3. Materials and Methods

3.1 Research methods

Model for measurement. In order to conduct empirical research into the effect that the digital economy has on carbon emissions, the following model is developed in this paper based on the theoretical analysis that was presented earlier:

$$\mathrm{CEI}_{\mathrm{it}} = \alpha_0 + \alpha_1 \mathrm{DE}_{\mathrm{it}} + \beta_{\mathrm{j}} \sum X_{jit} + \mu_i + v_t + \varepsilon_{it} \quad (1)$$

Wherein CEIit represents the total carbon emissions of city I in year t. DEit refers to the digital economy development index of city i in year t, adding a square term to investigate the nonlinear impact of digital economy on regional carbon emissions.

3.2 Variables selection

Variable that has been explained: the intensity of carbon emissions (CEI)

A time series of carbon dioxide emission inventory has been created for 30 Chinese provinces, and this paper discusses the calculation method that was used to create it. The majority of the carbon emissions accounted for in the inventory come from the consumption of energy and the processes involved in manufacturing.

$$CE_{ij}^{a} = EC_{ij} \times NCV_I \times CC_i \times O_i \quad (2)$$

$$CE_{it}^{b} = EC_{it} \times EF_{it} \quad (3)$$

$$\mathrm{CE} = \mathrm{CE}^{\alpha} + \mathrm{CE}^{\mathrm{b}} \quad (4)$$

$$\mathrm{CEI} = \frac{\mathrm{CE}}{\mathrm{GDP}} \quad (5)$$

Formula (3) refers to the process related carbon emissions, and refers to the carbon dioxide generated due to physical and chemical reactions in the production process. Considering the limitation of data, and the carbon dioxide emissions caused by cement production account for about 75% of the total carbon dioxide in the production process, we mainly calculate the carbon emissions related to cement production, as shown in Formula (3), CEitb is the carbon dioxide generated by cement production; ECit is the cement production, while EFit is the corresponding cement carbon emission coefficient.

The carbon emissions of each province can be calculated by adding the carbon emissions associated with energy use and process, as shown in Formula (4), while the carbon emission intensity (CEI) is the ratio of each province's carbon emissions to its actual GDP, as shown in Formula (5).

Because the entropy method is relatively objective in evaluating the indicator table, it is used to measure the comprehensive indicators of digital economy development. The corresponding indicator system can be found in Table 1.

Table 1 Indicator System of Digital Economy Development Level

Development level of digital economy	**Primary indicators**	**Secondary indicators**
	Digital industrialization	Scale of electronic information manufacturing industry
		Scale of telecommunication industry
		Scale of software industry
		Scale of information service industry
		Internet development
	Industrial digitalization	Agriculture
		Industry
		the service sector; the tertiary industry
		Digital financial inclusion

4. Results

4.1 Benchmark regression

Table 2 displays the results of the benchmark regression analysis regarding the influence of the digital economy on regional carbon emissions. This indicates that the growth of the digital economy has the potential to lower the intensity of carbon emissions, which proves hypothesis H1.

Table 2 Benchmark Regression Results

Variables	**Model 1**	**Model 2**
DE	-0.005** (0.002)	-0.005** (0.002)
PS		0.010* (0.006)
UR		001 (0.007)
FDI		-0.002 (0.006)

FT		001 (0.001)
ER		0.001* (0.000)
MAR		002 (0.001)
IS		001 (0.001)
_cons	067*** (0.001)	-0.023 (0.046)
Time fixed effect	Yes	Yes
Provincial fixed effect	Yes	Yes
N	240	240
R^2	0.539	0.566

Note: The brackets are the corresponding standard errors, and *, * * and * * * represent significant at 10%, 5% and 1% levels respectively.

4.2 Heterogeneity analysis

Heterogeneity of regional carbon emission levels

As a direct consequence of this, we carried out the sub-regional regression analysis that is detailed below. As can be seen in Table 3. When the carbon emission intensity in the east is compared to that of the central and western regions, it is found that the carbon emission intensity in the central and western regions is greater than that of the east. The east has a higher intensity of carbon emissions than the central and western regions. In comparison to the eastern regions, the central and western regions have a slower rate of economic development, a greater reliance on traditional resources, and a lower level of energy utilization efficiency. The growth of the digital economy, along with the implementation and widespread adoption of digital technology, has the potential to help market economic entities gain a deeper comprehension of the dynamics of the energy market and the price trends that affect it. In addition, the use of digital technology will assist industrial enterprises in lowering the intensity of their energy use, improving the efficiency with which they utilize energy, and reducing the amount of carbon emissions they produce.

Table 3 Regression Results by Region

Variable	**East**		**Mid-west**	
	Model 1	***Model 2***	***Model 3***	***Model 4***
DE	-0. 002	-0. 001	-0. 021***	-0. 018**

	(0.002)	(0.002)	(0.002)	(0.002)
control variable	No	Yes	No	Yes
_cons	0.064*** (0.001)	0.178*** (0.036)	0.070*** (0.001)	-0.363 (0.066)
R^2	0.945	0.647	0.736	0.283

Note: The brackets are the corresponding standard errors, and *, * * and * * * represent significant at 10%, 5% and 1% levels respectively.

5. Conclusions

According to the findings of this study, the expansion of the digital economy is associated with a sizeable cut in the intensity of regional carbon emissions. This conclusion holds true even after accounting for endogenous issues and conducting a number of other robustness tests. Based on the results of the heterogeneity analysis, it has been determined that the digital economy has a greater potential to reduce carbon emissions in the central and western regions, as well as in areas with a high intensity of carbon emissions. However, the effect of "industrial digitalization" on the reduction of carbon emissions is not reflected in this study, despite the fact that "digital industrialization" has been shown to have a more obvious carbon emission reduction effect than other dimensions of the digital economy.

Based on the findings of the research presented above, this article makes the following recommendations for public policy:

The primary takeaway from this study is that the establishment of a digital economy can be of assistance in the fight against the intensification of carbon emissions. The digital economy has the potential to bring environmental dividends and improve the social welfare level in China by reducing the intensity of carbon emissions and thereby mitigating climate change. These benefits are in addition to the economic effects that are mentioned in the classic literature. In the new era, this offers new support for accelerating the construction of a network power as well as a digital power. As a result, it is necessary to further strengthen the construction of digital infrastructure, speed up the integration of real economy and digital economy, and provide a feasible path for the realization of the "30.60" double-carbon goal.

Second, in order to make improvements to both the environment and the climate as a whole, it is important to take into account fully the regional heterogeneity of the digital economy, which affects the intensity of carbon emission. According to the empirical findings, the central and western regions benefit more significantly from the digital economy's ability to cut carbon emissions than do the other regions. The research indicates that despite the relatively high carbon emission intensity of the central and western regions, these regions have a stronger late-comer advantage in the environmental dividend brought about by the digital economy. This is due to the relatively backward digital foundation of these regions. If the digital resources are appropriately weighted toward the central and western regions, then those regions will also be able to achieve "overtaking in corners" on environmental issues, which will lead to both an improvement in the Pareto distribution and an improvement in the climate as a whole.

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