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Research on the Mechanism and Countermeasures of Promoting Carbon Reduction Through the Development of Digital Economy

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Abstract

Compared with the traditional economy, the digital economy can effectively improve the green level and quality of industrial development, enhance the ability of industrial development to reduce carbon emissions, and form the coupling and interaction between the development of the digital economy and the improvement of carbon emissions through industrial technology upgrading, market-oriented mode transformation and other methods. Combining the mechanism of digital economy development promoting carbon emission reduction, taking the specific practice of Xinxiang City in Henan Province as an example, this paper conducts a systematic study on the countermeasures of digital economy development promoting carbon emission reduction capability, and proposes to promote the optimization of enterprise production and development reform elements with digital technology as support, in order to provide effective reference for the exploration of high-quality transformation and green development of market economy entities in China.

Keywords

Digital economy; carbon reduction; green development.

1. Introduction

Climate warming is a common environmental challenge facing the international community. According to the IPCC report, the average global temperature in 2010-2015 increased by 1.1 ° C compared to the pre-industrial revolution period (1850-1,900 years), and by the end of the century, the temperature will further increase by 1~5.7 ° C [1]. Increasingly frequent human activities have led to an enhanced greenhouse effect, and carbon dioxide from fossil fuel consumption and land use change has contributed about 70% of the surface warming since the Industrial Revolution [2]. Continuous global warming has brought about a series of negative impacts, such as frequent flooding disasters, aggravated water shortage, reduced biodiversity, and more extreme climate events, which have transformed ecological problems into social and economic problems. In order to slow down climate warming, from the construction of "two-oriented society" to the road of green development, reducing carbon emission has become an international consensus and important issue. China's carbon dioxide emissions have been at a high level for a long time. In 2022, China's carbon emissions increased by 5.3% year-on-year, accounting for 30.9% of the global total carbon emissions [3], and the situation of emission reduction is grim. The proposal of the "double carbon" goal will elevate the low-carbon transformation of China's economy to a new height. The "14th Five-Year Plan" period is a key window period to achieve carbon peak. With the iteration and update of the new generation of information technology, the digital economy has become an engine of high-quality development through penetration effect, scale effect and network effect, and has brought new opportunities for carbon emission reduction by restructuring factor allocation, reshaping economic structure and restructuring industrial life. So what role does the digital economy play in reducing carbon emissions? The development of digital economy promotes carbon emission reduction.

What is the mechanism? What is the path to win-win progress of digital economy and carbon emission reduction?

According to the existing literature, the exploration of carbon emission reduction mechanism starts from the decomposition of factors of carbon emission change. Scholars identify the driving factors of carbon emission change by using decomposition models such as Kaya identity, LMDI, GD MI and STIRPAT, and find that output scale and capital scale promote carbon emission. Investment carbon intensity, output carbon intensity, energy intensity and fixed asset investment efficiency have a promoting effect [4,5]. The general consensus reached by existing studies confirms the contribution of energy efficiency improvement and energy structure adjustment to carbon emission reduction. However, due to the energy rebound effect caused by the changes in the behavior of market players, the impact of technological progress on carbon emission presents a dual nature of decreasing and increasing [6]. At the same time, relevant empirical studies have verified that trade openness, financial technology, and environmental regulation have significant carbon emission reduction effects (CAI Lihui et al.,2020; Hu Jinyan, Zhang Xiaofan,2023; Hu Zhuancheng,2022), while R&D investment, economic agglomeration, clean energy development and carbon emissions show a complex nonlinear relationship, and the effects on carbon emission reduction are different in different development stages (Lin Boqiang, Bin,2020; Xu Bin et al.,201 9; Shao Shuai et al.,2019). As policy analysis theories and tools become more and more mature, scholars use differential model to evaluate the carbon emission reduction effects of relevant policies and find that innovative city pilot policies [7], smart city pilot policies [8], carbon trading policies [9] and green fiscal policies [10] can significantly reduce carbon emission levels.

The new round of scientific and technological revolution and industrial transformation are accelerating, and the vigorous rise of the digital economy has received continuous attention from the academic community. Early studies defined the digital economy as an economic model that presents the flow of information in a digital manner (Tap scott,1996). With the human society gradually entering a new stage with digitalization as the main symbol, the connotation of digital economy is constantly enriched. The 14th Five-Year Plan for the Development of the Digital Economy clearly states that the digital economy takes data resources as the key element, modern information networks as the main carrier, and the integrated application of information and communication technologies as an important driving force, and promotes a new economic form that is more unified in fairness and efficiency. The operation of digital economy is the application of Internet, big data, cloud computing, Internet of Things, artificial intelligence, machine learning and other technologies in the production, exchange, distribution and consumption links. This market model of investment and operation of new technology-led manufacturers and macro-control of the government will change human economic choice behavior, improve the efficiency of social resource allocation, and trigger production and life style and production Industrial ecological change [11]. The positive promotion of efficiency [14], industrial innovation efficiency [15], and further focus on the environmental effects of the digital economy.

Existing studies have shown that the development of digital economy can not only significantly reduce the emission of various environmental pollutants in cities [16], but also compress the development space of energy-intensive and high-emission industries through the crowding out effect, forcing the green transformation of industrial structure [17]. However, it is unclear whether the resource saving effect of digital technology can exceed the environmental footprint generated by the operation of digital equipment and remote data processing, which makes the long-term impact of digital technology on the environment difficult to predict [18]. For example, some scholars believe that although the application of ICT can improve energy efficiency, it will further expand energy demand and lead to the rapid growth of power consumption [19]. The relationship between digital technologies and carbon emissions is relatively complex due to the energy rebound effect [20]. Similarly, empirical studies have also shown that there is an inverted U-shaped relationship between artificial intelligence technology and carbon emissions, and only when the level of artificial intelligence technology reaches a certain threshold, its carbon emission reduction effect will gradually become prominent [21].

To sum up, existing studies have reached a certain consensus on the driving factors of carbon emission reduction, revealed the important application of digital economy development to macroeconomic operation, and began to pay attention to the impact of digital economy on green development, which provides rich and profound insights for this research. Although existing studies implicitly assume that digital technologies can achieve environmental benefits, they mostly take the application of digital technologies such as the Internet or artificial intelligence as the starting point, and have not yet effectively clarified the impact path and direction of the digital economy on carbon emission reduction. The research on the interpretation of carbon emission reduction mechanism in the digital economy and the identification of carbon emission reduction effect need to be further expanded. Based on this, this paper introduces the digital economy into the analysis framework of carbon emission impact factors, and evaluates the carbon emission reduction effect of the digital economy from the theoretical and empirical levels. The possible marginal contributions are as follows: (1) Clarify the "digital economy" The internal mechanism of "→ green technology progress → Carbon emission reduction" explains the path logic of carbon emission reduction caused by the development of digital economy through the driving factors of carbon emission change; (2) Instrumental variable method was adopted to identify the causal relationship between digital economy development and carbon emission reduction on the basis of overcoming endogeneity, and combined with transmission mechanism test, regulatory effect test and heterogeneity analysis

The carbon emission reduction effect of the digital economy provides a more reliable and robust empirical reference.

2. Theoretical basis and research hypothesis

2.1. Digital economy operation and carbon emission change

The operation of digital economy is a market operation mode with big data as the basic analysis element, Internet as the operation platform, and artificial intelligence as the operation means, and its most significant role is to realize efficient allocation of resources (He Da 'an,2020). On the one hand, the resource allocation effect of the digital economy can not only improve the utilization efficiency of factors in the production sector and reduce the dependence of the production process on energy sources, but also promote the evolution and upgrading of the industrial structure from labor and capital intensive to technology and digital dense integration by replacing and eliminating high-polluting and energy-consuming industries, and improve the low-carbon degree of economic growth. At the same time, promote capital investment from the traditional infrastructure field represented by "iron and public infrastructure" to the new infrastructure field with high technology content and strong market-oriented orientation, and improve the degree of low-carbon fixed asset investment (Shao Shuai et al.,2022). Therefore, the operation of the digital economy reduces carbon emissions by reducing energy intensity, output carbon intensity and investment carbon intensity. On the other hand, the growth of the scale of digital economy can improve the total output level. Under the condition that economic growth is difficult to get rid of the dependence on fossil energy consumption, the expansion of output scale will lead to more energy consumption and corresponding carbon emissions, which means that the output effect brought by the development of digital economy will increase carbon emissions. To sum up, digital economy can promote both decreasing and increasing carbon emission, and the relative strength of the two determines whether the development of digital economy can produce carbon emission reduction effect. Based on the above analysis, this paper proposes the following hypothesis:

H1: If the effect of digital economy on carbon emission reduction is stronger than that of promoting carbon emission increase, then digital economy is conducive to carbon emission reduction, and vice versa.

2.2. Digital economy, green technology progress and carbon reduction

Green technology refers to the general term of technology, process or product that can reduce the ecological environmental load and improve the efficiency of resource utilization. The progress of green technology is manifested in the enhancement of green technology innovation ability at the input end and the improvement of green total factor productivity at the output end. On the one hand, the positive impact of digital economy on green technology innovation and green total factor productivity has been confirmed by existing literature (Wang Fengzheng et al.,2021; Zhou Xiaohui et al.,2021). The application of digital technology promotes the transformation of green technology R&D decision-making from experience-driven to data-driven, and helps enterprises judge the direction, potential and path of green technology innovation through information mining and demand forecasting. The deep integration of digital technology and traditional financial service formats can not only reduce the threshold and cost of obtaining financial services, but also track the capital flow and utilization, weaken the adverse selection and moral hazard caused by information asymmetry, and provide sufficient financial resources and effective financing channels for green technology innovation. At the same time, the digital economy can break through the limitations of time and space, and is conducive to strengthening cooperation and exchange and collective learning between research and development entities, thereby reducing the risk and sunk costs of green technology research and development, and improving the efficiency of green technology innovation. In addition, the digital economy has the typical characteristics of high innovation, strong penetration, and wide coverage. By reducing search and matching and transaction costs, correcting factor allocation distortion, improving the green value creation ability of factors, and promoting the iterative innovation of key common technologies, it can improve technical efficiency and advance cutting-edge technologies, and promote the increase of green total factor production rate. On the other hand, the direction of technological progress determines the environmental results of economic activities, and the progress of green technology is an important support for solving environmental problems (Lu Yang,2012), and promotes carbon emission reduction by controlling increment and storage. Green technology is widely used in enterprise production and residents' lives, which can promote advanced energy-saving and clean production processes to replace old, energy-intensive and high-pollution production processes, promote the green transformation of industrial structure and the green upgrading of energy consumption, and green technology progress in the energy field can accelerate clean energy, renewable energy, and new energy The development and utilization of sources is conducive to the low-carbon transformation of energy consumption structure, reducing resource and energy consumption from the production and consumption sides, reducing carbon emissions on the supply side and the demand side, and realizing source control. In addition, the progress of green technology can effectively control the cost of decarbonization, provide necessary technical support for the research and development and application of carbon dioxide capture, utilization and storage technology, and enable the end management of carbon emission reduction. Based on the above analysis, this paper proposes the following hypothesis:

H2: The development of digital economy generates green technology progress through green technology innovation effect and green total factor productivity effect, thus promoting carbon emission reduction.

3. Research Design

3.1. Model Setting

In order to verify whether the digital economy can promote carbon emission reduction, this paper builds the following benchmark model:

$$COC_{it} = \alpha_0 + \alpha_1 dig_{it} + \sum_{p=1}^{n} \theta_p X_{it} + \mu_i + \lambda_i + \varepsilon_{it}$$

In the formula, subscripts i and t represent provinces and years respectively. The explained variable coc is the regional CO2 emission, the core explanatory variable dig is the regional digital economy development level, and X it is the set of control variables. ui is the region fixed effect,λt is the time fixed effect,εit is the random error term. θp is the estimated coefficient of each control variable, and α1 is the influence coefficient of the digital economy on carbon emissions. If α1 is negative and passes the significance test, it indicates that the carbon emission reduction effect of the digital economy is significant.

3.2. Variable selection and description

3.2.1. Explained variables

Carbon dioxide emissions (coc). Based on the carbon emission data provided by the MEIC model platform [22], carbon emissions were divided into five levels: less than 100 million tons, 100 million to 300 million tons, 300 million to 500 million tons, 500 million to 700 million tons, and more than 700 million tons. Arg Gis software was used for visual display (see Figure 2). Overall, China's total carbon emissions rose from 9.694 billion tons in 2013 to 10.775 billion tons in 2021, with an average annual growth rate of 1.23%. The level of carbon emissions is not obvious, and about half of the provinces have carbon emissions between 100 million and 300 million tons. The spatial distribution of carbon emissions is "high in the north and low in the south". The difference of carbon emissions between the north and the south climbed from 1.026 billion tons in 2013 to 1.462 billion tons in 2021, and the Matthew effect of the north-south gap has intensified.

3.2.2. Core explanatory variables

the comprehensive evaluation index system of digital economy is constructed from four dimensions: digital infrastructure, digital industry scale, digital life application and digital production application. On the basis of non-dimensional processing of each index, entropy method is used to assign weight, and the digital economy development index and 4-dimensional sub-index are synthesized by linear weighting to measure the digital economy development level at the provincial level. As shown in the figure, nationwide, Beijing, Guangdong, Shanghai, Jiangsu, Zhejiang, Fujian and other regions lead the level of digital economy development, and there is a clear digital gap between them and Xinjiang, Gansu, Yunnan, Guizhou, Guangxi and other regions at the bottom. The southern region, represented by the Yangtze River Delta and the Pearl River Delta, has a relatively high level of digital economy development. In addition to Beijing, the northern region has a certain circle gap with the southern provinces. It can be seen that the North-South differentiation trend in the development process of China's digital economy is obvious.

Table 1 Evaluation index system of digital economy development

Target layer	Criterion layer	Index layer (unit)	Index attribute	Mean value	Standarddeviation
Development level of digital	Infrastructure	Optical cable line density (km/km^2)	Forward direction	9.448	12.416

economy		Internet access port density (per person)	Forward direction	0.534	0.208
		Number of websites per 100 companies (number)	Forward direction	50.527	10.273
	Industrial scale	Average employment in computer communications and other electronic equipment manufacturing (10,000)	Forward direction	30.186	64.833
		Computer Communications and other electronic Equipment manufacturing Main business revenue (billion yuan)	Forward direction	3534.593	7099.515
		Average number of employees in software and information technology services (10,000)	Forward direction	20.365	29.238
		Software revenue (billion Yuan)	Forward direction	1934.947	3139.413
	Life application	Mobile phone penetration rate (units / 100 people)	Forward direction	105.460	23.564
		Number of broadband Internet users per capita (households/persons)	Forward direction	0.248	0.097
		Internet penetration (%)	Forward direction	0.758	0.277
		Digital Financial Inclusion Development Index	Forward direction	348.169	64.186
	Production application	E-commerce sales (100 million yuan)	Forward direction	4458.535	6231.535
		Proportion of enterprises with e-commerce transactions in the total number of enterprises (%)	Forward direction	0.087	0.038
		Number of computers used by enterprises per 100 people (units)	Forward direction	28.103	11.698

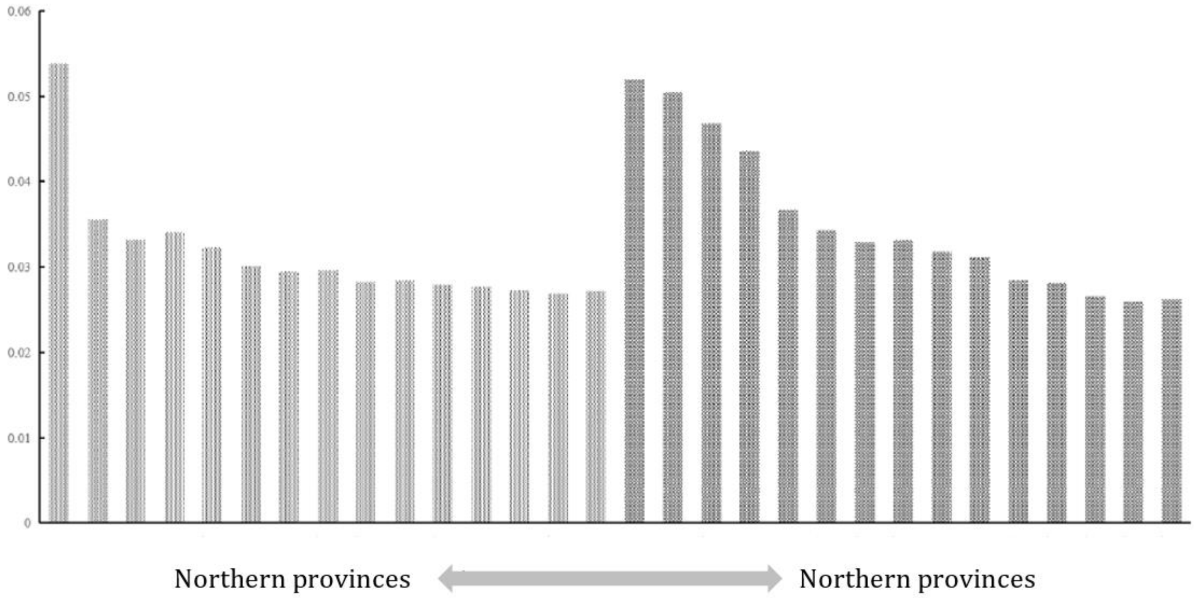

Fig. 1 Annual averages of provincial digital economy indices from 2013—2021

3.2.3. Control variables

In this paper, the following control variables are selected: (1) Economic scale (gdp), which is measured by the logarithm of the actual regional gross domestic product; (2) Investment level (inv), measured by the numerical value of regional per capita fixed asset investment; (3) Industrial structure (ins), measured by the ratio of output value of tertiary industry to secondary industry; (4) Energy intensity (ens), measured by the ratio of total regional energy consumption to regional gross domestic product; (5) Government support (gov), measured by the proportion of regional fiscal expenditure on energy conservation and environmental protection in general public budget expenditure; (6) Command-and-control environmental regulation (cer), referring to the research of Deng Huihui and Yang Luxin (2018), is represented by the word frequency of the words related to carbon emission reduction (energy consumption, low-carbon, emission reduction, carbon dioxide) in the local government work report; (7) Market-incentivized environmental regulation (mer), based on the research of Dong Zhiqing and Wang Hui (2021), the policy dummy variable of the carbon emission trading pilot is expressed. If region i is the pilot province of carbon emission trading during the period t, it is 1, otherwise it is 0.

3.2.4. Data sources and descriptive statistics

Carbon emissions data from MEIC model (cn) http://meicmodel.org. platform, digital pratt &whitney financial index from financial open research platform (https:// www.dfor.org.cn/ research/numberdata), its Its economic data are derived from 2014-2022 China Statistical Yearbook, China Industrial Statistics Yearbook, China Information Industry Yearbook, China Energy Statistical Yearbook, China City Statistical Yearbook, as well as provincial statistical yearbooks, statistical bulletins and government work reports. The statistical variables of current price were reduced to the 2013 base level, and the missing data were completed by interpolation method.

4. Conclusion

4.1. Digital economy enables carbon emission reduction

The practice and exploration of digital economy itself is the deep integration and exploration of digital and intelligent mode and economic system, and has formed a number of concrete and feasible models and concepts, relying on digital technology to provide multi-level technical

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empowerment for the transformation of urban construction, transportation, industrial production and other fields. Replace or upgrade the environment and technologies with large carbon emissions and high pollution in traditional economic fields, and strive to improve the green development and high-quality development capabilities of market players [4]. From the current development trend, relying on the digital economy to promote the optimization and upgrading of traditional industries and energy saving and consumption reduction is not only the overall trend of the development of the digital economy, but also the trend of the transformation and development of various industries. Taking Xinxiang City as an example, under the empowerment of digital economy[12], integrated exploration of carbon emission reduction has been carried out in digital city, smart library, smart transportation, digital gas station and digital upgrading of industrial industry, etc., giving full play to digital advantages, and guiding various industries and fields to explore concept upgrading, path upgrading and technology upgrading. By improving the efficiency of industrial development, Reduce carbon emissions and develop energy consumption, take carbon emission reduction as the goal, and explore the path of synergistic interaction between digital economy and industrial development.

4.2. Digital economy products help carbon monitoring

The specific effect of carbon emission reduction needs scientific assessment and research on influencing factors, as well as corresponding technical support and guarantee. At present, in the process of practice, Xinxiang City guides Internet enterprises to vigorously develop digital economy products based on the needs of carbon monitoring. On the one hand, Xinxiang City provides support for its own carbon emission reduction practice, and on the other hand, it also provides corresponding economic products and services for enterprises. Relying on blockchain, Internet of things and other technologies, carbon monitoring equipment will be incorporated into the network supervision system, forming real-time data interaction, and building a data collection, analysis, transmission and control system for carbon monitoring and carbon emission reduction, providing effective technical support for the implementation of carbon emission reduction.

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