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Research Analysis on the Impact of China's Digital Economy Development on Carbon Emissions

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Abstract: The global economy has been transformed by the digital economy (DE). This study deeply explores the relationship between DE development and its impact on carbon emissions, which is not straightforward. By synthesizing multiple papers, this article aims to discuss key issues under climate change's background and sustainable development. Through the study of various econometric models, including the Spatial Durbin Model. There is spatial dependence and spillover effects of digital economic activities on carbon emissions are revealed in this paper. The primary findings suggest that DE and carbon emissions are not linear and have an inverted U-shaped curve. Data centers and network infrastructure have increased energy consumption, which may result in carbon emissions from the digital sector's initial growth. After reaching a certain threshold, the DE appears to help reduce carbon emissions. This research provides comprehensive insights for policymakers, industry leaders, and academic researchers, advocating for a balanced approach to the development of the DE. At the same time, environmental sustainability should be given priority, and digital technology should be fully utilized to promote economic growth.

Keywords: Digital Economy, Carbon Emissions, Green Finance.

1. Introduction

Maintaining rapid economic growth while achieving low-carbon development has become an urgent issue recently. The digital economy (DE) has been instrumental in creation of an ecosystem for green development by influencing economic growth rate, industrial structure, and resource utilization efficiency [1]. The DE concept was introduced in the 1990s and has since transformed the world economy. In many countries, the economic development brought about by the DE has even surpassed that of traditional industries. Data resources are a key factor of production in the DE, and emerging industry models that rely on data resources are thriving globally [2]. The development of the DE has given rise to various virtual economic models, greatly promoting the current world's industrial transformation and capacity acceleration. However, the current development inevitably leads to issues such as resource shortages, improper emission of pollutants, and global warming, which have become hidden dangers for sustainable development.

Digital finance and carbon emissions are currently being studied by many researchers. Researchers used multiple perspectives to examine the digital finance development's impact on carbon emissions through the construction of different models [3]. Research taking China as an example, based on the vast geography of China, researchers have divided it into three parts: the western, central, and eastern

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regions [4]. With geographical spatial differences as control variables, they consider the development of digital finance in different areas, while studying the potential relationship between local carbon emissions [5]. Digital finance's development of has led to the creation of local green industries, which can help reduce local industrial carbon emissions from both a theoretical and practical standpoint. Nevertheless, this has resulted in new problems, like high-carbon emission industries migrating to neighboring areas. This is not entirely per the objectives of green development.

China is at the forefront of developing the DE, and its carbon emissions in various regions have been affected to varying degrees. From this perspective, studying the impact of the DE on carbon emissions is beneficial for promoting economic development and achieving green finance development. This paper starts from the research on the impact of the DE development on carbon emissions, combines the manifestations of this impact in various fields, and summarizes the causes and processes of the impact. By synthesizing a variety of current proposals, this paper aims to provide effective suggestions for government decision-making.

2. Overview of the DE

2.1. Development History

The spread and application of computer technology is responsible for the emergence of the DE. The emergence of e-commerce and the digital economy was sparked by the popularity of computers and smartphones in the 20th century and the widespread use of the internet. At the beginning of the 21st century, cloud computing services and big data technology facilitated the transformation of traditional business decision-making and business models towards the DE. Since 2010, platform-based economic models and the sharing economy have emerged, changing traditional consumption and production methods and further advancing the digital transformation and upgrading of the economy. Technological changes brought about by the DE have played a key role in influencing energy consumption [6]. Energy consumption and energy utilization efficiency affect carbon emissions by changing the pace at which human actions emit carbon dioxide and other greenhouse gases into the atmosphere, thereby impacting the climate and altering the human living environment.

2.2. Current Status

At present, the DE has emerged as a significant catalyst for economic expansion in most countries worldwide, with different regions actively promoting the digital transformation of their economies. The fusion of digital technology with the tangible economic sector is being promoted gradually by leveraging the benefits of extensive datasets and a variety of application contexts. Emerging technologies have become an important factor of production for nations, which are developing these technologies to provide momentum for the modernization and enhancement of conventional sectors. New industries, business models, and the digital economy can generate forms that serve as innovative drivers for contemporary economic growth.

Wu employed a dynamic threshold panel model to investigate the current factors influencing carbon emissions and determined that energy consumption encourages carbon emissions [7]. However, this promotional effect decreases with the increase in policy supervision. Moreover, various factors such as technological levels and energy structures can have a nonlinear impact on carbon emissions due to the DE [8]. These views are consistent with the actual situation. Regional economic development can be significantly different, and there exists a distinct spatial interrelation among urban economic activities. Currently, scholars use the Spatial Durbin Model to analyze regional interdependence and spatial spillover effects in spatial data. This model extends the traditional Durbin model, allowing the coefficients of explanatory variables to change with spatial location and capturing spatial lag and spatial error. By establishing a fixed-effects multiple regression model, Bai

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found that the dual-carbon policy has a spatial transfer effect on carbon emissions [9]. Using an instrumental variable estimation method that satisfies the relevance and historicity of variables reduces the error in the results. Digital finance and internet technology have a technological spillover effect, which causes a spatial effect on the regional economy [10]. Local governments' imitation or competition can cause carbon emissions to spread across various regions due to the DE.

3. The Impact of the DE on Carbon Emissions

The development of the DE has a significant transformative impact on traditional industries. The energy demand of the DE, especially the reliance on data centers and network infrastructure, also brings new environmental issues. The DE can effectively decrease carbon emissions by improving operational efficiency, promoting remote work, digital products, innovative services, and optimizing energy management [11]. However, it may also hurt energy consumption. Through a comprehensive analysis of these complex factors, DE has a greater comprehension of the function in current carbon emission changes can be achieved.

3.1. Impact on the Energy Industry

The DE has simultaneously affected energy consumption on the supply and demand by promoting the digital transformation of various industries and changing people's production and lifestyle [12]. Xue constructed a linear regression equation for DE development's impact on energy consumption and conducted regression analysis by plotting a scatter diagram [12]. The result showed that, on the one hand, the DE intensified energy consumption in industries with energy demands, leading to increased carbon emissions. DE reduced carbon emissions through managing renewable energy while improving energy usage efficiency. Overall, the DE has promoted the growth of the energy industry's output value.

Li established a production function model to simulate a perfectly competitive market environment, taking into account the constraints of profit maximization and carbon emission targets [13]. An inverted U-shaped relationship between energy consumption and carbon emissions has been observed in the energy industry through empirical results. Carbon emissions' increase could occur during the early stages of DE development because of the reliance on energy-intensive industries. However, as the DE further matures and deepens, the technological innovation, energy efficiency improvement, and industrial structure optimization it brings will gradually show emission reduction effects, ultimately achieving a reduction in carbon emissions.

The DE will significantly increase carbon emissions when the DE index is below the inflection point value of 267.8 according to calculations. In 2018, the overall level of the DE in many cities increased, but it is still below the inflection point value of the inverted U-shaped line, and their carbon emissions have also increased compared to the past, indicating the universality of carbon emissions caused by the DE. In addition, the U-shaped relationship is also reflected in the spatial transference impact of the digital economy on the carbon emissions of adjacent regions., with the inflection point value being 322.9. China's proposal to achieve "carbon neutrality" involves combining renewable energy with the construction of a clean energy system, which leads to a mutually beneficial outcome that fosters both economic progress and the reduction of carbon emissions [14].

3.2. Impact on Industry

In many fields, industry accounts for a considerable proportion of energy consumption and carbon emissions. The impact of the DE on industrial carbon emissions can be reflected through spatial differences. From east to west in the spatial pattern, there is a decreasing trend in DE development level, so the emission reduction effect brought by the DE also shows regional differences. Zhang

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divided China into eight economic areas and found that the Yangtze River Middle Reaches Economic Area had a carbon emission performance that was 17 percentage points lower than the national average, which was significant [15]. China proposed the concept of dual carbon, that is, carbon peak and carbon neutrality. In the field of economics, it can be simply described as using big data to achieve rapid optimization and recycling of resources, thereby reducing industrial carbon emissions and achieving high-quality economic development [16]. Chang's analysis discovered that the calculated coefficient of the DE and carbon emission intensity is highly negative at the 0.01 level [17].

This indicates that promoting industrial transformation through digitalization can drive the industry to reduce carbon emissions. DE has an actively relationship between industrial carbon emissions, which is regulated by government support. For example, the digital government can stimulate the growth potential of the DE in the market, help the industry reduce pollution and carbon footprint through environmental monitoring systems, and in turn empower green technology innovation to support sustainable development goals [18].

3.3. Impact on Other Fields

The development and application of the DE have affected the carbon emissions of various industries to varying degrees. In addition to the two industries mentioned above, carbon emissions in manufacturing, agriculture, and other fields are also influenced by the development of the DE. Intelligent arrangements of storage and transportation routes can significantly inhibit carbon emissions for the logistics industry thanks to the DE, and DE can effectively promote the iterative upgrade of technologies applied in the logistics industry [19].

The Internet industry has a development that is dependent on the economy's development, and the union of these two often encourages green and sustainable economic development. The internet industrial development provides the DE with virtualization technology and the application of energy management systems, using various technologies such as artificial intelligence to promote economic development and a decrease in environmental pollution [20]. In turn, the development of the DE can also affect technological progress in the internet industry through investment attraction and policy support.

4. Development Trends and Challenges of the DE

4.1. Development Trends

Overall, the development trend of the DE is stable and positive. The digitalization of industries is beneficial for reducing their environmental impact. Through data analysis and smart business practices, the DE helps internet companies better understand market demands and customer needs. The digital industry has a novel structure for capitalizing on innovative advancements in the DE thanks to the significant differences in technologies, standards, and licensing models compared to traditional industries [21]. The DE continuously updates business models and social life, and the latest digital technologies are an indispensable part of innovative economic development models [22]. The DE will always be a key area of economic development in the future.

4.2. Challenges

The technological advancements brought about by the development of the DE can suppress carbon emissions. However, it is crucial to recognize that the influence of the digital economy on carbon emissions has both positive and negative aspects. The digital technology industry, while capable of cutting down on greenhouse gas emissions while fostering economic growth, is not environmentally friendly [23]. Local carbon emissions can be increased by a development in economic development.

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This in turn can increase energy demand. However, an improvement in industrial development can significantly reduce local carbon emissions. The energy demand has been increased by the development of the DE, thereby exacerbating environmental pollution [24]. Therefore, determining the optimal point of development level that matches the energy industry has become a challenge for the development of the DE.

4.3. Development Recommendations

For academic research on the impact of the DE on carbon emissions, the impacts of technological innovation, low-carbon pilot policies, and population structure on carbon emission performance are discussed through further exploration. The DE on carbon emissions causes impact, which can also be discussed by considering a high-quality economy and environmental pollution as dependent variables. In terms of policy, governments can start by digitizing specific fields and use spillover effects to promote the upgrading of other industries in the region.

By enacting policies that require industries to use clean non-fossil fuels and by constructing solar photovoltaic power stations, wind power stations, hydropower stations, and biomass energy power stations, governments can effectively intervene in carbon emission peaks. Companies should be encouraged to use seawater or natural lake water for data center cooling. According to the various levels of digital economic development in different regions, governments can provide targeted tax incentives, subsidies, and quota systems to carry out renewable energy demonstration projects and encourage community and resident participation, such as rooftop solar and community wind power. At the same time, companies should use battery energy storage systems, pumped hydro storage, compressed air energy storage, and other technologies to address the intermittency and instability of renewable energy. They should also adopt digital technologies such as smart grids, remote work, and online services.

5. Conclusion

Overall, the influence of the DE on carbon emissions is indicative of a U-shaped correlation. Currently, its effect on carbon emissions across different sectors is characterized by an initial phase of the U-shaped relationship. When the level of the DE is relatively low, it will have a slight promotional effect on local carbon emissions. This could be attributed to the region's augmented energy expenditure aimed at advancing the development of the DE, but at the same time, there is a lack of matching energy supply and demand adjustment and government supervision, leading to the promotion of carbon emissions by the DE. However, as the level of the DE increases, its role in promoting carbon emissions gradually emerges. When the advancement of the DE attains a balanced stage, the impact shifts from promotion to suppression. Urbanization and varying levels of economic development have established threshold effects. Once the pace of urbanization and the population density exceed certain thresholds, the digital economy (DE) significantly mitigates the impact on carbon emissions. Conversely, once the GDP per capita surpasses a particular threshold, the enhancing impact exerted by the DE on reducing carbon emissions. Additionally, disparities exist in the spatial influence of the DE on carbon emissions. The spatial spillover effect on carbon emissions is generated through the diffusion of technological advancements and the interplay among regional governments. Regardless of whether the spillover effect is static or dynamic, the immediate impact of the DE on carbon emissions exceeds its indirect influence.

There are some deficiencies in this paper's research. For example, this paper mentions China's dual-carbon policy and can further explore how to enable the DE to continue to supply energy in the implementation of the dual-carbon policy. Depending on the different economic development

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situations of the regions, what indicators should be adopted to determine the optimal value of the DE development level also needs further discussion.

The scholarly community ought to delve deeper into examining the effects of the DE on carbon emissions. Simultaneously, studies should explore the processes through which the DE can improve carbon emission outcomes. This includes understanding its potential to contribute to a high-quality economy and to implement effective environmental protection strategies. This paper acknowledges its limitations in research, particularly noting that the discussion regarding the role of DE in the implementation of China's dual-carbon policy lacks sufficient depth. In parallel, research efforts should investigate the pathways that the DE employs to enhance the management of carbon emissions. across various stages of economic progression. Furthermore, it is essential to consider the unique impacts that the digital economy exerts on carbon emissions within various industrial sectors.

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