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Harmonizing the Digital Economy and Green Development: Challenges, Strategies and Pathways to Achieve the Double-Carbon Goal

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Abstract

This paper delves into the multiple dilemmas faced by the digital economy in the process of realizing green development. First, the rapid development of the digital economy has led to the aggravation of the carbon emission problem, especially in areas such as artificial intelligence, where the demand for a large amount of arithmetic power has brought about huge energy consumption, and the current power production that mainly relies on fossil fuels makes it difficult to control carbon emissions. Second, the carbon data management system has not yet been perfected, with a single access to data and insufficient regulatory mechanisms, leading to difficulties in accurately assessing carbon emissions. Thirdly, the imperfection of the carbon trading system hinders energy conservation, emission reduction and clean energy development of enterprises, and there is an urgent need to establish a more sound carbon emissions trading market. In addition, the lack of independent innovation capability, insufficient complex talents and the greening level of the industry have yet to be improved also pose challenges to the sustainable development of the digital economy. In order to address these issues, the paper puts forward specific paths and recommendations in terms of technological innovation, institutional framework and multifaceted collaboration, with a view to realizing the organic integration of the digital economy and the goal of "double carbon".

Keywords: digital economy, green development, carbon emissions, multifaceted collaboration, sustainable development

1. Introduction

The president has clearly stated that "the development of digitization has an important impact on the country, and it is a key choice for us to seize the strategic opportunities brought about by technological innovation and industrial reform". "The document presented at the 20th National Congress of the Communist Party of China (CPC) further elaborated on "accelerating the process of digitization in order to promote its deeper integration into actual production", suggesting that the promotion and implementation of digital technology is vital and necessary to raise the overall quality level in the country. In addition, the "Draft Outline of the 14th Five-Year Plan" also sets out the goal of accomplishing emission reductions within the next ten years - that is, to achieve a reduction in carbon dioxide emissions of more than 45% - and this policy has been incorporated into the new version of the Five-Year Plan, which has been reviewed and approved by the Politburo of the Central Committee of the Communist Party of China. This policy has also been included in the new version of the five-year plan adopted by the Political Bureau of the CPC Central Committee. At the same time, the Fifth Session of the 19th CPC Central Committee also made special mention of "building an economic system with green, low-carbon and recycling development", and pointed out that the concept of building an ecological civilization should permeate all aspects of economic and social activities.

With the development of the digital economy in depth, the information factor is mixed with the traditional manufacturing element and influences the output of society, thus promoting a series of systematic transformations of the industrial structure; this phenomenon contributes to the reduction of barriers to communication and the consumption of useless material at all stages of business activity, which is in line with the objective of "doing

both". This is in line with the objective of "doing both". It is important to emphasize that the "two together", i.e., the new era of technology as the main tool and environmental protection, has come to the fore. How to combine these two trends together to improve efficiency has become one of the urgent problems to be solved. While implementing the new development concept, the organic integration of digital technology and energy saving and carbon reduction has become a necessary way to achieve sustainable development, and an excellent opportunity to promote the continuous upgrading and optimization of industrial structure.

2. Literature Review

In recent years, relevant research in the field of digital economy has gradually become a hot spot in academic research. By combing through the literature, it is found that the literature related to this paper mainly develops along the three aspects of the carbon emission reduction effect of the digital economy, the carbon emission reduction effect of industrial structure optimization, and the role of industrial structure optimization in the carbon emission reduction effect of the digital economy.

Foreign scholars earlier conducted research on the environmental impact of the digital economy, and found that the Internet economy can increase energy intensity and thus reduce carbon emissions (Romm, et al., 2000). Subsequently, domestic related studies have gradually increased.

As for the carbon emission reduction effect of digital economy, (Zhang Chuanbin, 2023) pointed out that digital economy plays a significant inhibiting effect on carbon emission intensity; at the same time, considering the regional heterogeneity, this effect is more significant in the eastern, middle and western cities, non-resource-oriented cities and more developed cities. The development of digital economy will promote the continuous decline of carbon intensity and total carbon emissions, especially on the per capita carbon emissions show an inverted U-shaped effect, therefore, the appropriate scale of digital economy development is favorable to the decline of carbon emissions, but excessive digital economy development may instead increase carbon emissions (Bai Lifei, 2023). Digital trade economy significantly reduces the intensity of carbon emissions in China (Xie Huijiang et al., 2023).

In studies on the impact of improving the quality of industrial development on climate change, some scholars have argued that scientific and technological innovation can facilitate the upgrading of production capacity and the shift to more efficient and environmentally friendly renewable energy sources in place of traditional petroleum and coal fuels; furthermore, economic development can lead to increased consumer preference for green products and thus result in more greenhouse gases being dissipated. Other researchers have found that if the development of industries is stable and smooth, this will also have the effect of limiting the release of SOx and CO_2; therefore, they emphasize the importance of internal constraints in order to advance the process of air purification.

In the carbon emission reduction effect of the digital economy, the digital economy promotes the green transformation of the economy through the "factor allocation effect" of data elements and the "technological innovation effect" of digital technology, which is expected to help reduce carbon emissions and improve the efficiency of carbon emissions (Feng Ziyang et al., 2023). The digital economy can effectively reduce carbon emissions by optimizing industrial structure and improving total factor productivity. These two aspects are the main ways for digital economy to reduce carbon emissions (Bai Lifei, 2023). In terms of the conduction path, the digital trade economy reduces the intensity of carbon emissions in China by promoting the upgrading of industrial structure, technological progress and the improvement of energy consumption structure (Xie Huiqiang et al., 2023). The digital economy affects carbon emission intensity by optimizing the industrial structure, i.e., the digital economy reduces carbon emission intensity by promoting both the advanced industrial structure and the rationalization of the industrial structure, and has different impacts within different thresholds.

3. The Development of the Digital Economy has Played an Important Role in China's Progress Towards Achieving the "Double Carbon" Goal

The progress of the digital economy under the "double-carbon" strategy needs to rely on advanced digital technologies, such as big data, the Internet of Things and artificial intelligence, to achieve its goal of reducing greenhouse gas emissions, so as to break through the technological barriers between digitization and environmental protection, and to achieve simultaneous enhancement of economic gains, social benefits and the social environment. In recent years, the Chinese government has been actively implementing the "double-carbon" policy and developing the digital economy, and the connection between the two has become increasingly close, and the use of digital means to maintain the ecological environment and create wealth has become a common understanding of society. In fact, our country has adopted a series of measures at to effectively promote the development of digital green integration.

Existing research has confirmed that the development of a digital economy has obvious low-carbon effects. From the perspective of production, the digital economy effectively connects all aspects of production, strengthens production coordination through digital management, effectively realizes cross-border integration and resource sharing, improves energy use efficiency, promotes the transformation and upgrading of traditional industries (Wang & Cheng, 2023), and realizes the goal of energy saving and carbon reduction. The digital economy itself has a knowledge spillover effect and a technology impact effect, which helps realize the comprehensive innovation, penetration and application of information technology, breaks down the barriers to the dissemination of knowledge, technology and information, improves the speed and efficiency of the dissemination of knowledge, technology and information within and between regions, enables local enterprises to update their original technical knowledge base with advanced knowledge and technology from other regions, and promotes the development and diffusion of technological innovation. diffusion, boosting enterprises in industries that are the main sources of carbon emissions to realize cleaner and smarter production, and improving the efficiency of carbon emissions by strengthening governance on the emission side (Yang Gangqiang et al., 2023). For example, Chang'an Automobile has optimized the intelligent design of its products by using digital technologies such as artificial intelligence, which has led to a 7-10% reduction in the weight of the vehicle while maintaining the same performance, with a corresponding 6-8% reduction in the fuel consumption rate, as well as a reduction in carbon dioxide emissions by as much as 13%. Digitalization breaks through the traditional industry layout mode, combining the intermingling of digital and physical fields, redefining the scope of traditional industries, and realizing the advantages of industry chain collaboration based on "virtual concentration", helping to build the industry's standard framework and precise management of energy resources, which all contribute to a significant reduction in the rate of carbon emissions. This will help to significantly reduce the rate of carbon emissions.

From a consumer perspective, the digital economy has enhanced public awareness of environmental protection through the use of digital media, such as video clips, to promote environmental concepts. Digital technology tools can be utilized to match energy supply with user needs and to market green goods to customers, thereby improving the shopping experience. A study has shown that the adoption of digital technologies can reduce greenhouse gas emissions by about 13 to 22 per cent, even if total energy consumption remains stable.

Digital technology plays an important role in environmental regulation by integrating a wide range of data, such as geographic information, air pollution information and energy loss information, to realize the monitoring and accounting of the whole life cycle of carbon emissions. This helps provide timely feedback on environmental changes to regulators so that the state of the environment can be assessed and appropriate policy measures can be formulated. According to the Opinions on Complete and Accurate Comprehensive Implementation of the New Development Idea and Doing a Good Job in Carbon Peak and Carbon Neutrality issued by the Central Committee of the Communist Party of China (CPC) on October 24, 2021, it is required to push forward the in-depth integration of new-generation information and communication technologies with green and low-carbon industries. In recent years, the policy system for promoting the digital economy to achieve the "double-carbon" goal has been continuously improved, for example, the Peak Carbon Action Plan by 2030 issued by the State Council calls for the promotion of digitalization, intelligence and green integration in the industrial sector, and the Central Committee for Cybersecurity and Informatization issued the "14th Five-Year Plan", which calls for the promotion of the integration of new-generation information and communication technologies with green and low-carbon industries. National Informatization Plan of the 14th Five-Year Plan" issued by the Central Committee for Network Security and Informatization proposes accelerating energy conservation and emission reduction of information technology in various fields, and the "Implementation Plan for Peak Carbon in the Industrial Sector" jointly issued by the Ministry of Industry and Information Technology, the National Development and Reform Commission, and the Ministry of Ecology and Environment calls for accelerating the application and promotion of digitized and low-carbon solutions, etc., which provides a strategic guidance for the development of digital low-carbon. Meanwhile, driven by the policy, the relevant digital infrastructure has been rapidly deployed and developed by leaps and bounds." During the "13th Five-Year Plan" period, China has successfully built the world's largest mobile communication network system, set up more than one and a half million 5G base stations, realized access to more than 200 million 5G devices, and completed the planning of the national integrated data center, and formally implemented the plan of "East Counts, West Counts". Today, more than 450 large and medium-sized data centers have been put into operation, with a computing capacity of more than 1,400 trillion Eflops, providing a solid foundation for us to realize our "double-carbon" strategy.

Nordhaus, winner of the Nobel Prize in Economics in 2018, emphasized that mankind should choose a green development path that takes into account both economic growth rate and climate protection, and the development of the digital economy has an obvious enabling function for the realization of the goal of "double-carbon", so the

development path of the digital economy is expected to become a green development path that takes into account both economic growth rate and climate protection. Therefore, the development path of digital economy is expected to be a green development path that balances economic growth rate and climate protection.

4. Dilemmas Facing the Green Development Path of the Digital Economy

The digitalization of industries puts forward the requirements of digitalization and sustainable development for the transformation and upgrading of traditional industries, and the digital economy is the main means to achieve the goal of "double-carbon", but under the current goal of "dual-carbon", the digital transformation of industries is still faced with many challenges.

4.1 The Carbon Footprint of the Digital Economy Needs to be Urgently Addressed

The digital economy is under tremendous pressure in the face of the growing challenge of energy conservation and emission reduction. For example, the demand for arithmetic power, a key supporting force for the digitalization process, is showing a rapid upward trend. This is not only driving a significant increase in overall energy consumption, but is particularly evident in the development of AI-led digital industries. Global data storage is predicted to increase to 163 ZB by 2025, while technologies like generative AI require massive amounts of data and large-scale model training, further increasing the need for powerful arithmetic. However, high-performance computing power often brings a large amount of energy consumption, a study shows that by 2035, the energy use of a single supercomputer center could be as high as 500MW, the size of which is almost equal to the power generation capacity of half a nuclear power plant. At the same time, most electricity is still supplied by traditional fossil fuels such as oil and coal, but the proportion of renewable energy used in contrast is unsatisfactory, so the problem of climate warming is becoming more and more serious as the demand for arithmetic power continues to expand. Furthermore, the competition for arithmetic power due to the efficient advancement of digital technology has led to an accelerated rate of updating digital products, and the resulting e-waste is increasing day by day, becoming one of the major sources of pollution from solid waste, such as the large amount of e-scrap generated by the Bitcoin trading platform.

4.2 Carbon Data Management Platforms and Systems are not Yet Complete

At present, China still has some problems in utilizing digital technology for carbon data governance. First, the data acquisition channels are relatively single, and the acquisition and assessment of enterprises' digital carbon footprints mainly rely on information voluntarily disclosed by enterprises. Most enterprises are unwilling to disclose their carbon footprints directly, but are only willing to disclose indicators such as the total amount of electricity used by data centers or the utilization rate of power sources. Second, there is a lack of an effective regulatory mechanism, and China has not yet established a carbon emission constraint system. Some enterprises may falsify data and issue false certificates in order to gain profit, which affects the orderly promotion of the peak carbon compliance and carbon neutrality strategy. Thirdly, the accurate quantification of carbon data still needs to be improved, including the difficulty of data acquisition and application, as well as the lack of uniformity in the source and quality of data, which has led to the failure to effectively measure the differences in carbon emissions between different industries.

4.3 Carbon Trading System is not Yet Perfect

Since the National Development and Reform Commission (NDRC) issued the Circular on Launching Carbon Emission Right Market Trials in 2011, more than twenty provinces and cities in China have either completed or are completing the construction of carbon emission right markets. Nevertheless, China's carbon emission rights management system still needs to be improved, and due to its own characteristics, carbon emission rights may also generate certain risks of volatility. Therefore, the establishment of a sound carbon emissions trading market is crucial for promoting energy saving and emission reduction by enterprises and the healthy development of the clean energy industry. For the success of projects such as carbon sinks, carbon capture and sequestration, the data element plays a crucial role, which provides strong support for carbon data calculation and carbon market construction, thus further improving the economic level and socio-economic benefits of carbon sinks in China. At present, although pilot work has been carried out in some regions, there is still much room for improvement in terms of theoretical foundation.

4.4 Lack of Autonomous Innovation Capacity

China's traditional industries suffer from a lack of creativity and productivity, and core production technology is heavily dependent on external introduction. In industrial development, some industries lack the ability to innovate, and the overall level of technology and equipment is not high. Many traditional industries invest less in product and technology research, the quality of their products is generally poor, and their production methods lag behind

market demand. Although China is the world's largest industrialized country, the level of development of industrial industries still lags behind that of other countries. Compared with many economically developed countries, the level of production equipment in China's industrial industry is relatively lagging behind, and there is a certain gap. This lack of independent innovation capability makes China face some challenges in digital transformation, and it needs to pay more attention to technological innovation and independent research and development, and improve the core technology level in the upstream of the industrial chain.

4.5 Insufficient Pool of Composite Talent

At present, China's exploration and investment in the areas of technical support for digital transformation and the cultivation of "double-carbon" talents are still insufficient. In the face of the demand for talents brought about by digitalization and the scarcity of talents in traditional industries, China is in urgent need of cultivating a number of shortage-type professionals and cross-border compound talents. In addition, because some traditional industries have long been constrained by their mode of operation and level of development, they are unable to provide competitive salary conditions and welfare benefits for core technical talents, and have yet to form a comprehensive set of policy mechanisms to guarantee the introduction of digitized talents.

4.6 The Level of Greening of the Industry Needs to be Improved

Compared with developed countries, China's industrial structure is heavily weighted, with relatively low value-added products, and the "high-carbon dependence" of traditional industries is still significant. Although China has been implementing energy-saving and emission reduction actions in recent years, it still focuses on "high-tech energy-saving and carbon reduction, and light structural adjustment and carbon reduction", and high-pollution and low-efficiency industries account for a large proportion in the national economy. Realizing the goal of "double carbon" forces traditional industries to increase energy saving and consumption reduction, however, this inevitably brings a series of problems such as additional costs, decline in added value of products and waste of resources. At present, although there are technical means such as carbon capture, utilization and sequestration to cope with the problem of carbon dioxide stock, due to the high cost, it may be difficult for small-scale enterprises with low economic efficiency to bear. For enterprises with larger assets, the effectiveness of these technical means is limited, and the greening of the industry needs to be urgently improved.

5. Optimizing the Path to Achieving the "Double Carbon" Goal Enabled by the Digital Economy

5.1 Driving Scientific and Technological Innovation: Contributing to the Advancement of Low-Carbon Digitalization

The way to address carbon emissions from the digital economy lies in the innovation of low-carbon digital technologies. However, technological innovation cannot be driven alone, subject to limited rationality and marginal emission costs, and stronger government measures and resources are needed to ensure that the digital economy is compatible with "double-carbon" goals. First, infrastructure needs to be optimized. Around the "double-carbon" goal, it is necessary to promote the construction of new digital infrastructure and enhance the green energy supply while improving the utilization rate of digital elements, so as to significantly reduce the energy consumption of equipment. For example, for green computing infrastructure, clean energy sources such as wind, light and nuclear can be fully utilized to reduce carbon emissions from data centers. In addition, it is necessary to accelerate the construction of urban arithmetic networks, integrate resources such as core arithmetic, terminal arithmetic and edge arithmetic by means of policy guidance and special incentives, activate idle arithmetic resources, reduce ineffective energy consumption and promote the synergy between the power network and arithmetic network in order to rationally dispatch power supply and realize efficient allocation of resources. Second, key technologies should be mastered. In the face of the key technical difficulties of low-carbon digital technology innovation, it is necessary to quickly master the key technologies in the relevant fields and compete for the leadership of the new round of industrial change. To this end, the advantages of the new state system should be fully utilized to focus on the basic frontier technologies and key core technologies required for low-carbon digital technology innovation. This can be done by providing fiscal and tax incentives to reduce costs and utilizing green financial products such as green credit, green bonds and green insurance to bring in social resources. We should follow the law of scientific development and motivate professional experts to conduct in-depth research on low-carbon digital infrastructure and long-term exploration of core areas, so as to ensure that we can maintain an independent position in the digital economy under the "double-carbon" policy. Second, we need to build a complete standardization system. In order to promote the development of low-carbon digital technological innovation, it is necessary to optimize the existing standards and regulations, accurately measure the proportion of carbon emissions of digital technologies, and formulate basic guidelines for low-carbon digital technological innovation. For example, for the example of green computing power, the relevant standard system should cover

all aspects of computing power exchange, computing power provision, computing power access, computing power deployment and computing power guarantee, and be standardized through legal certification, quality assessment and technology connection, aiming to reach consistent definitions, standard facilities construction and quality control of the content of , so as to prevent the technological modes from various parties from conflicting, and thus save computing power resources. The aim is to achieve consistent definitions, standardized facilities, and quality control of content to prevent conflicts between technical models from various parties and to conserve computing power.

5.2 Strengthen Environmental Monitoring and Further Improve the Institutional System

In the face of the challenge of "double-carbon" targets, it is not enough to rely solely on scientific and technological development to solve the problem; we need to review and assess the system in all its aspects.

The first priority is to define the scope of responsibility of public institutions. When faced with real challenges, they need to be empowered to control the development of the digital economy under the "two-handed" policy. In order to promote this trend, the administrative units should define a precise framework for the development of information technology and actively participate in the draft law on the implementation of the Environmental Protection and Adaptation Measures (EPAM) to ensure a consistent approach to the implementation of the law. At the same time, it is necessary to refine the content of the work of each functional body and the criteria for evaluating its performance. In addition, in order to improve efficiency and quality of service, the relevant departments should build an efficient and practical information system tool - the so-called "green smart brain" - to keep track of energy consumption and analyze and warn of possible problems in the future.

Next, we should create an effective data feedback system. Although digitization can dramatically increase the speed of decision-making, it also faces problems such as the lack of initial data or the expansion of misleading information. Therefore, in order to solve these problems, we need to build a comprehensive data feedback system. From the perspective of data collection, we need to develop rigorous data acquisition steps, design efficient information processing algorithms, and introduce manual job review processes to facilitate checking whether the data obtained by digital technology is correct. In case of possible errors or mistakes, we need to adopt various channels and platforms to verify their authenticity, identify the source and correct any errors or omissions that have already been publicized, so as to minimize the impact on society. In addition, government agencies, industry organizations and other relevant units should also introduce relevant technical guidelines to limit the behavior of scientific and technological researchers, as well as implement environmental information storage strategies to minimize the risk of environmental misinformation. The last point is to enhance supervision and management. All participants have environmental responsibilities, so they all need to be subject to stricter management and rapid accountability. For example, we can use blockchain technology as an example to illustrate this issue: first, we advocate relevant companies within the blockchain industry to create their own standards for carbon emission control, as a way to dissipate the carbon footprint effect generated by blockchain technology and achieve zero energy consumption. Then, the carbon emission detection methods of blockchain technology should be further optimized, for example, by providing policy incentives to promote blockchain companies to join the market of buying and selling carbon emission rights and enjoy relevant preferential policies. Then, it is necessary to increase the monitoring of third-party recycling companies and implement effective control of blockchain waste electronic equipment by setting qualifications and refining commodity categories.

5.3 Promote Multifaceted Cooperation for Inclusive Transformation

Government agencies are inherently misunderstood, and therefore, the advancement of the digital economy cannot rely solely on government agencies to drive it.

The first priority in promoting the parallel development of digitalization and environmental protection is to promote cooperation among all parties. In order for the development of the digital economy to meet the legitimate demands of various stakeholders in a more comprehensive manner, we must involve more entities in the simultaneous process of environmental protection and technological development. To do this, we need to optimize the participation pathways of society and create a service-oriented government. This means improving the transparency of environmental information, increasing the public's influence on environmental policy, increasing the rate of reporting of environmental violations, and supporting legal proceedings for environmental protection, among other measures to ensure citizens' right to participate. In addition, government agencies need to fulfill their service responsibilities, for example, by setting up a digital platform for environmental complaints and other service facilities. Similarly, we should stimulate the market by guiding companies to develop new products independently, creating a digital industry consortium to form a low-carbon digital industry ecosystem, and inspiring leading companies to achieve zero emissions as soon as possible. In addition, we need to safeguard the

rights and interests of vulnerable groups in the transition process in order to build the widest possible win-win social system.

Once again, it is emphasized that we should actively promote regional cooperation. From a domestic perspective, it is necessary to create a way of joint action across regions with regard to climate change and related challenges brought about by digitization. For example, in environmental tribunals, because digitization has transcended geographical boundaries, the environmental damage involved may occur in other places far from the defendant's location, which requires us to form an effective regional coordination mechanism to deal with the collection of evidence, the transmission of information and the synchronization of work during the trial process. In addition, given the significant differences in infrastructure and resource requirements between cities, we need to develop a comprehensive plan to deal with these situations. For example, in terms of computing power, we should set up a system for the deployment and transfer of computing power between cities, create a multi-layered and multi-location computing network architecture to better meet the demand for computing power, and reduce the cost of energy consumption arising from digitization through rational distribution, load balancing and effective scheduling.

We must strike a balance between self-sufficiency and high-level transnational collaboration, both at home and abroad. It is only through high-quality external interactions that we will be able to drive science and technology innovation and promote the development of a green digital industry. When faced with constraints such as "necking", we need to simultaneously implement effective strategies to break down barriers to ensure secure control of core technologies, and proactively participate in the development of the information industry worldwide. Strengthening communication with governments and non-governmental organizations will enhance our influence in the global informatization process, thus achieving a win-win situation under our "double-carbon" strategy.

6. Conclusion

This paper focuses on the challenges and dilemmas faced by the digital economy in promoting green development. With the vigorous development of the digital economy, especially the soaring demand for computing power in areas such as artificial intelligence, energy consumption and carbon emissions have become increasingly severe. Meanwhile, due to the imperfections in the carbon data management system, accurate assessment of carbon emissions has become difficult. Furthermore, the inadequacy of the carbon trading system has hindered enterprises' efforts in energy conservation, emission reduction, and the development of clean energy. Additionally, issues such as insufficient independent innovation capability, a shortage of interdisciplinary talents, and a need to improve the level of industrial greening have also affected the sustainable development of the digital economy. To address these challenges, the article proposes specific paths and suggestions for technological innovation, institutional framework improvement, and diversified collaboration, aiming to achieve an organic integration of the digital economy with the "dual carbon" (carbon peaking and carbon neutrality) goals and promote the green and sustainable development of the digital economy.

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