

Exploration of Digital Transformation Empowering Carbon Emission Reduction in Industrial Enterprises Under the “Dual Carbon” Goal

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Abstract: As key supervised entities for carbon emissions, the effective carbon reduction of industrial enterprises is crucial to the achievement of the “Dual Carbon” goal. With the arrival of the digital era, digital transformation has become an inevitable path for the high-quality development of all industries, providing new ideas for carbon emission reduction in industrial enterprises. This paper aims to explore the necessity of carbon emission reduction in China's industrial sector and the importance of digital transformation for achieving carbon emission reduction, analyze the impact of digital transformation of industrial enterprises on carbon emission reduction, and explore effective paths for digital transformation to reduce carbon emissions. It is of great significance for the coordinated development of low-carbon transformation and digital transformation of industrial enterprises.

Keywords: Industrial enterprises; Digital transformation; Carbon emission reduction

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1. Necessity of carbon emission reduction in China's industrial sector

In recent years, the issue of carbon emissions has attracted attention from all sectors of society. In 2021, global energy-related carbon dioxide emissions increased by 5.6% year-on-year to 33.9 billion tons, of which China's carbon dioxide emissions were 11.9 billion tons, accounting for 35% of the global total^[1]. Therefore, China should assume the responsibility for carbon emission reduction. In addition, against the background of the proposal of the “Dual Carbon” goal, China should actively, steadily and in-depth promote carbon peaking and carbon neutrality based on the characteristics of energy and resource endowments, and implement carbon peaking and carbon neutrality actions in an orderly manner^[2]. As of February 2024, industrial carbon emissions accounted for more than 70% of the national total. Meanwhile, China's carbon emission intensity in 2019 decreased by 48.1% compared with 2005, while the industrial carbon emission intensity decreased by 57.8%. It can be seen that the industry is a key monitored industry for national carbon emissions and a key field for

achieving the carbon peaking and carbon neutrality goals. As key economic entities in the industrial sector, industrial enterprises are the main actors in practicing the “Dual Carbon” strategy^[3]. Their energy consumption and pollutant emissions are higher than those of other enterprises, making it imperative to implement carbon emission reduction actions.

2. Ideas of digital transformation empowering carbon emission reduction in industrial enterprises

Currently, the development of the digital economy is in the ascendant, and digital transformation has become a forerunner for the high-quality development of all industries. With the large-scale application of digital technologies, accelerating the digital transformation of traditional industries has become an important task and core link for in-depth optimization of the supply-demand structure, promotion of industrial manufacturing upgrading, and continuous expansion of the digital economy^[4]. As a traditional energy-consuming industry, the industrial sector should prioritize digital transformation. Under the constraints of the “Dual Carbon” goal, the emerging low-carbon economy and the accelerating digital economy advance side by side and collide with each other, providing new development directions for industrial enterprises. On the one hand, integrating the “Dual Carbon” goal into the overall social development has led enterprises to take the path of low-carbon development. Carbon emission reduction has become the primary task for enterprises to achieve low-carbon development and an inevitable direction to gain market competitive advantages. Enterprises obtain competitive advantages by reducing carbon emissions, and can also achieve good returns in the market after gaining competitive advantages. On the other hand, compared with developed countries, China faces a tight schedule, arduous tasks and greater difficulties in achieving the “Dual Carbon” goal, requiring low-carbon and green reforms in social, economic, energy and technological systems. Digital transformation brings new momentum for enterprises’ carbon emission reduction, and digital technology is an important means for enterprises to achieve the “Dual Carbon” goal.

Digital transformation provides solutions to the carbon emission problems faced by industrial enterprises. First, in terms of the manufacturing link, due to the requirements of digital transformation, industrial enterprises must adjust their production models, adopt new digital technologies, optimize production processes, enhance equipment operation efficiency, and refine the management of production processes. Companies can more effectively manage data on their energy use, carbon emission levels, and environmental protection and energy-saving measures^[5], which can not only increase the production capacity and efficiency of industrial enterprises but also effectively reduce carbon emissions. Second, from the perspective of energy use, if industrial enterprises over-rely on fossil fuels, carbon emissions will increase, so it is necessary to control carbon emissions by reducing energy consumption. Through information integration, visual monitoring and other methods, digital transformation reduces energy consumption in the production process, improves the utilization efficiency of traditional fossil energy, and accelerates changes in the energy structure. Finally, from the perspective of industrial development, digital transformation accelerates enterprises’ transformation from resource-driven operation methods to innovation-driven operation strategies, thereby significantly improving productivity and reducing information asymmetry among upstream, midstream and downstream of the industrial chain. This is more conducive to controlling carbon emissions related to the manufacturing link^[6]. At the same time, all stakeholders can benefit from it and promote the reduction of carbon emissions in the process of

enhancing their own interests, ultimately achieving a Pareto optimal state of the whole society ^[7]. In summary, relying on digital technologies, industrial enterprises transform from high energy consumption, low efficiency and high emissions to greenization, high efficiency and low emissions, realizing the “parallel development” of digital transformation and green transformation.

3. Impact of digital transformation of industrial enterprises on carbon emission reduction

Digital transformation includes three parts: digital infrastructure construction, digital technology application and digital development. Digital infrastructure construction is the foundation of digital transformation, providing strong support for it; digital technology application is the basic manifestation of digital transformation, emphasizing the popularization and application of digital technologies; digital development is an extension of digital technology application, consisting of digital industrialization and industrial digitalization.

3.1. Impact of digital infrastructure construction on carbon emission reduction

As an infrastructure system driven by data innovation and composed of data processing capacity facilities based on communication networks, digital infrastructure construction constitutes a key support for promoting enterprises’ digital transformation ^[8]. This concept includes not only elements such as sensor endpoints, 5G networks, big data centers and industrial internet but also the upgrading or updating of traditional physical infrastructure through the use of emerging information technologies such as the Internet of Things, edge computing and AI. Under the “Dual Carbon” goal, promoting the construction of digital low-carbon infrastructure helps improve management and operational efficiency and reduce the consumption of personnel and resources ^[9]. Based on this, digital infrastructure should be combined with traditional high-carbon emission fields, eliminate outdated high-energy-consuming equipment, and give full play to the enabling role of digital infrastructure.

At the enterprise level, digital infrastructure has gradually integrated into enterprise development with the tide of the times and technological innovation. From the enterprise’s perspective, with the changes of the times and technological progress, enterprises have begun to integrate these advanced information tools into their businesses. For example, a large number of machine learning algorithms are used to automatically control various operating systems in factories to better monitor the entire product life cycle and make accurate data statistics on various key indicators such as power consumption and manufacturing costs ^[10]. This method can not only greatly increase our sense of responsibility for environmental protection but also significantly reduce the generation of greenhouse gas pollutants, promote the improvement of energy use efficiency, and reduce enterprise carbon emissions to a certain extent. Digital infrastructure exerts positive externalities and brings obvious economies of scale to enterprises.

3.2. Impact of digital technology application on carbon emission reduction

When the construction of digital infrastructure is gradually improved, the application of digital technologies follows. In the digital economy era, digital technology endows means of production with digital attributes, realizing in-depth integration in all links of production. For the industrial sector, the progress of digital technology means the gradual improvement of the efficiency of fossil energy use in the production process, leading to a reduction in carbon emissions ^[11]. Since 2010, the Ministry of Industry and Information Technology

has actively promoted methods to implement conservation measures in the industrial sector: achieving this goal by using digital technology to establish real-time monitoring and management systems.

Industrial enterprises introduce digital technologies. When the application of digital technologies reaches a certain scale, they can reduce carbon emissions by reducing enterprises' fossil energy consumption, providing motivation for the achievement of the "Dual Carbon" goal. First, digital technology has transformed the current energy management system, improved processing and conversion speed, optimized the effect of energy transmission, distribution and storage, and significantly reduced management costs in the traditional manufacturing stage. Second, the application of digital technology can promote the transparency of carbon emission data, which further accelerates the company's technological innovation to reduce energy consumption. Because digital technology makes the production process more refined and mechanical equipment realizes automatic control, the output rate of the company's products and the energy use effect in the process flow are enhanced. In this way, the company can more effectively grasp digital technology to share information and accurately predict market demand. It can be seen that the application of digital technology improves the efficiency of enterprise resource utilization and reduces enterprises' fossil energy consumption.

3.3. Impact of digital development on carbon emission reduction

As the main form of digital economic development, one of the important characteristics of digital development is industrial digitalization, which means upgrading traditional industries and transforming them into new forms through the use of advanced digital technologies^[12]. This process includes using the latest digital technologies, focusing on the core points of value creation, and focusing on data-driven to comprehensively, in-depth and continuously reform the entire industrial chain. The essence of digital industrialization lies in the progress of digital technology, which can bring us various products and services based on digital technology, such as digital technology and equipment. As traditional energy-consuming enterprises, industrial enterprises should deeply integrate the digital economy with the real economy and help the industry achieve transformation and upgrading through their own efforts.

When digital development reaches a certain scale, the scale of the digital industry increases significantly. According to the information asymmetry theory, industrial enterprises break enterprise boundaries, promote the exchange of various information among industrial subjects, and realize industrial transformation and upgrading^[13]. With the progress of digitalization, the economies of scale it generates can effectively reduce environmental pollution and emission reduction costs, and increase investment in environmental protection technologies, thereby promoting enterprises to improve carbon emission reduction effects^[14]; endowing industrial development with new momentum through digital means can enhance resource utilization efficiency and optimize resource allocation, thereby reducing carbon emissions caused by the "extensive" development mode^[15]. It can be seen that at this time, digital transformation can bring positive carbon emission reduction effects.

4. Implementation paths of digital transformation empowering carbon emission reduction in industrial enterprises

4.1. Give play to the leading role of the government

To accelerate the development of the digital economy, administrative departments at all levels can provide policy and financial support for industrial enterprises' digital transformation according to specific conditions,

invest in the construction of digital public services to realize the digital reform of public service popularization, attract enterprises to introduce digital infrastructure, ensure the practical application of digital technologies, and thus help enterprises carry out digital transformation. In addition, environmental supervision should be fully used to stimulate enterprises' low-carbon orientation. Due to the possible increase in enterprise costs caused by low-carbon transformation, such as insufficient financial resources, technical capabilities, and talent accumulation, this is a huge pressure for small and medium-sized industrial enterprises. Therefore, precise assistance must be provided, the intensity of environmental supervision should be enhanced, legal systems should be implemented into enterprise action plans, and enterprises should be encouraged to participate in carbon emission reduction activities, thereby helping to achieve the "Dual Carbon" goal in detail.

4.2. Accelerate the development of digital transformation

Industrial enterprises should clarify their transformation ideas according to their own conditions, explore digital transformation paths in line with their development direction, and increase the intensity of digital transformation, including the research and development and application of digital technologies. When carrying out digital transformation, enterprises must inevitably change their production methods, introduce digital technologies, optimize production processes, improve equipment operation efficiency, and strengthen the accuracy of production process management. At the same time, they need to make full use of data resources, release the potential of data, and realize intelligent enterprise decision-making, thereby improving productivity and work efficiency.

4.3. Drive carbon emission reduction through digital transformation

The application of digital technologies can penetrate into the industrial field and major carbon emission industries, thereby reducing the use of energy and resources, and improving the energy efficiency, cost-effectiveness, risk prediction, and management decision-making capabilities of traditional industries.

Overall, it improves energy-saving effects, reduces production costs, and enhances product quality and economic benefits. To achieve the "Dual Carbon" goal, we need to base ourselves on energy conservation and emission reduction across the entire industrial chain. At present, consumption at the end of the industrial chain has become one of the important sources of carbon emissions. Therefore, it is not only necessary to actively implement energy conservation and emission reduction measures on the supply side, but also to reduce carbon emissions by restricting consumption, thereby promoting green consumption behavior and stimulating the supply side to take more energy-saving measures. At the same time, focus on green development, advocate the green orientation of digital technology research and development, and digital transformation empowers green technological innovation of industrial enterprises, thereby giving play to the leading role of green technological innovation. Digital transformation has a key impact on reducing energy consumption and enhancing resource utilization efficiency. Promoting the transformation of the industrial sector towards intelligence and environmental protection through digital technology is an important current trend. By applying digital technology to improve links such as energy management and decision-making regulation, traditional manufacturing can move towards a more efficient and greener path. When digital transformation comprehensively promotes the overall improvement of industrial enterprises, it also makes the integration of green technology possible, which helps to further improve resource use efficiency and ultimately achieve the goal of sustainable development.

4.4. Coordinated development of enterprises' internal and external environments

At present, there are still many challenges in promoting carbon emission reduction through the digital transformation of the industrial sector. Among them, how to better promote the digital transformation of the industrial sector is a problem that needs to be considered and solved by all social parties such as the government, enterprises and individuals. To give full play to the carbon emission reduction effect of the digital transformation of industrial enterprises, internally, enterprises should base themselves on their own conditions, enhance environmental awareness and accelerate digital transformation, lead enterprises in technological upgrading through digital transformation to reduce energy consumption. Externally, enterprises should attach importance to the supporting role of the external environment, effectively promote healthy competition among enterprises, and establish digital sharing platforms with external parties to achieve data sharing and reduce the cost of digital transformation. Enterprises' internal and external efforts should be combined to promote the coordinated development of digital transformation and carbon emission reduction of industrial enterprises.

Disclosure statement

The author declares no conflict of interest.

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