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EDITED BY
Cem Işık,
Anadolu University, Turkey

REVIEWED BY
Gilda Massa,
Energy and Sustainable Economic Development (ENEA), Italy
Gul Jabeen,
Shenzhen University, China

*CORRESPONDENCE
Tang Xinfa,
xinfatang@sina.com

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Study of the mechanism of digitalization boosting urban low-carbon transformation

Tang Xinfa* and Li Jinglin

School of Economics and Management, Jiangxi Science and Technology Normal University, Nanchang, Jiangxi, China

The climate problem is severe and many urban climates are poor. To deal with a series of climate problems, low-carbon measures are indispensable. Digital development is becoming a new driving force for social development. Therefore, the development of urban low-carbon transformation should be based on digital construction. This paper explores the significance and theoretical mechanism of the research of the mechanism of digitalization boosting urban low-carbon transition. Theoretically, digitalization can reduce carbon emissions through mechanisms such as optimizing industrial structure, adjusting energy structure, improving government governance efficiency, and changing people's way of production and life. Finally, from the perspective of carbon neutrality, this paper puts forward relevant countermeasures, from the following six aspects: building a carbon emission measurement and monitoring system, promoting the digital transformation of enterprises, increasing the research and development of new energy technologies, improving the carbon emission market trading system, optimizing the carbon emission administrative management system, and practicing the low-carbon concept.

KEYWORDS

digitization, city, low-carbon transformation, boosting, study

1 Introduction

Cities play a pivotal role in economic and social development, and are centers of human life and production. More than half of the world's population lives in cities. However, the uncontrolled expansion of urbanization has also led to high energy consumption and the exponential growth of greenhouse gas emissions, which poses huge environmental and climate risks to society (Ding and Li, 2017; Sun et al., 2020). The greenhouse effect is caused by CO_2 emissions (Alvarado et al., 2021; Ahmad et al., 2021b). The main reasons for the increase in greenhouse gases are economic growth and the burning of fossil fuels, such as coal, gasoline, and natural gas (Işık et al., 2021a). In the twenty-first century, with the continuous advancement of industrialization and urbanization in China, rapid economic growth, continuous improvement of social productivity, and energy consumption emit a large amount of carbon dioxide (Wang et al., 2019; Wang et al., 2020). The resulting ecological problems have caused immeasurable economic losses (Deng et al., 2019; Li Z et al., 2021; Jia et al., 2022).

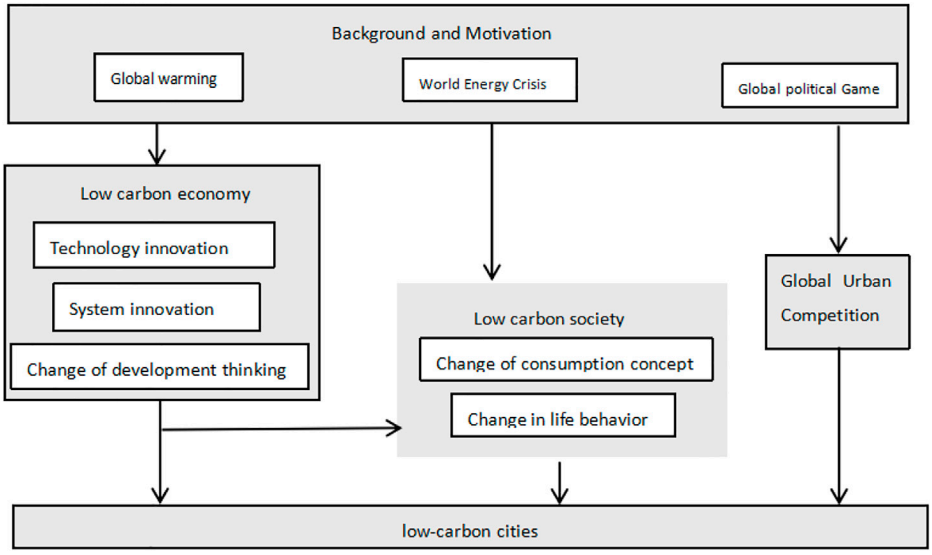

FIGURE 1
The formation and connotation of a low-carbon city. Source: According to the literature of Cheng et al. (2012).

Therefore, there is an urgent need for urban low-carbon transformation. The concept of the low-carbon economy comes into being in the context of climate concern.

The formation and connotation of low-carbon cities are shown in Figure 1. The development of a low-carbon economy is also a global initiative (Tang and Tian, 2022). The Low Carbon Competitiveness Report of G20 Countries (2009) defines a low-carbon economy as an economic form with a certain level of carbon productivity and sustainable development, which is characterized by low energy consumption, low pollution, low emissions and environmental friendliness, as well as a global common vision of controlling greenhouse gas emissions and developing social economy (Lu and Zhu, 2013). As early as 2005, China started to study low-carbon economy (Zhuang, 2005; Zhuang, 2007; Fu and Liu,2010).They have taken the lead from the form of development, development mode, development process and other aspects of low-carbon economy. Pan et al. (2010) believe that the low-carbon economy has three core characteristics, namely: low-carbon emission, high carbon productivity, and stage.

The essence of low-carbon economy is the efficient use of energy and the development of clean energy. Its core is technological and institutional innovation, with the goal of controlling greenhouse gas emissions and promoting sustainable human development (e.g., Yang, 2012; Xie et al., 2017; Zhong, 2018). In recent years, more and more scholars have joined the research of low-carbon and sustainable development. Işık et al. (2021b) investigate the validity of the environmental Kuznets curve (henceforth, EKC) hypothesis for eight OECD countries. Fatima et al. (2022) believe that the use of energy can be reduced by adopting environmentally friendly technologies. Ahmad et al. (2021a) studied the long-term and short-term heterogeneous links among urban concentration, non-renewable energy use intensity, economic development, and environmental emission index at the regional development level of 31 provinces in China. Işik et al. (2020) discusses the relationships among tourism income, renewable energy consumption, and CO_2 emissions. Işık et al. (2022) studied the environmental Kuznets curve (EKC), and found that policy makers in the US states can determine and adjust their gold spending levels to prevent environmental degradation and GDP decline.

Governments around the world have been racing to translate the development of low-carbon economy from idea into practice. The European Union has taken the lead in developing a number of low-carbon policies to change the traditional lifestyle of their residents (Government, 2009; Dagoumas and Barker, 2010; Hughes and Strachan, 2010). The United States pays more attention to technological innovation to solve environmental problems. Meanwhile, Japan is rapidly developing high technology and applying it to clean energy (Strachan et al., 2008; "2050 Japan Low-Carbon Society project team, 2008).

As for the reasons for the development of low-carbon economy, first, Huang (2009) believed that China is currently in the process of rapid industrialization and urbanization, and the consumption of energy and resources will increase significantly with industrial growth. Second, from the perspective of international politics, with the rise of China, the international community is also asking China to commit

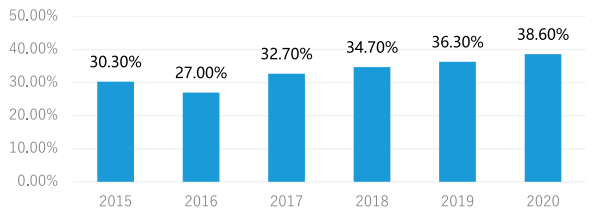

FIGURE 2
Share of digital economy in GDP. Data source: China Academy of Information and Communication Technology.

to more greenhouse gas emission reduction obligations. Third, the low-carbon industry represented by new energy and renewable energy is a sunrise industry with infinite potential. Fu et al. (2008) pointed out that China is faced with great pressure to reduce greenhouse gas emissions, China's energy security is facing serious threats, and China's resources are overused and ecological environment deteriorates. Feng (2009) believes that the development of a low-carbon economy not only needs China to change the development mode but also adjust the industrial structure, improve the efficiency of resources and energy use, and protect the ecological environment.

The rapid development of digital technology provides an important way toward the low-carbon transformation of Chinese cities. Digital technologies and the digital economy permeate many areas of energy systems and economic development, reshaping business and operating models, and disrupting almost every industry (Gómez-Barroso and Marbán-Flores, 2020; Li D et al., 2021). With the advent of the digital era, the world has experienced an unprecedented digitalization process, and the digital economy and digital transformation have steadily been growing (Pan et al., 2022). As an intangible asset, the digital economy has positive externalities, which can reduce information frictions, optimize the matching of supply and demand, generate significant value, and are almost cost-free (Spence, 2021). The current situation of China's digital economy is shown in Figures 2, 3. It can be seen in these figures that digital technology is deeply integrated with key areas of carbon emissions (e.g., energy and power, industry, transportation, and buildings) to effectively improve the efficiency of energy and resource use, reduce carbon dioxide emissions, and realize the low-carbon transformation of cities.

The digital economy itself is low-carbon, and its impact on the low-carbon transformation and development of cities is obvious (Xu et al., 2019). For the role of digitalization on urban low-carbon transformation, the literature mainly focuses on the impact and path research of digital technology on urban low-carbon industry development, urban spatial layout, and enterprise green development, while few studies focus on the internal mechanism of digitalization on urban low-carbon transformation and development. Therefore, this paper will discuss the significance and theoretical mechanism of digital technology in an urban low-carbon environment, and finally puts forward relevant countermeasures of digital technology in urban low-carbon transformation.

2 Theoretical mechanism

2.1 Urban low-carbon transformation is the only way toward urban sustainable development

China has transferred from the high-speed development stage to a high-quality development stage. In the new development stage, economic indicators are no longer solely pursued but sustainability, innovation, equilibrium and competitiveness of economic development are given more emphasis (Li et al., 2019). The development of a

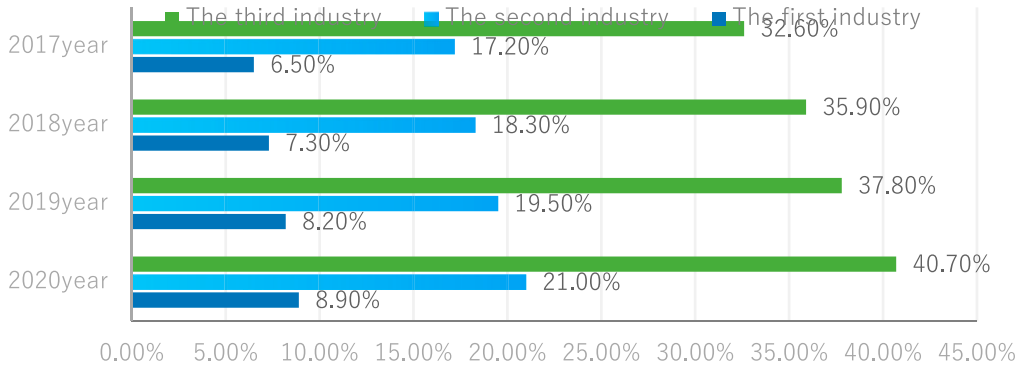

FIGURE 3
Penetration rate of China's digital economy. Data source: China Academy of Information and Communication Technology.

low-carbon economy can help China's high-quality development from many aspects. First, it helps to optimize the industrial structure. For high energy consumption, high pollution enterprises were an important force to support the rapid economic growth in the preliminary period. However, China has entered the period of high-quality development and the high enterprise green and low-carbon transition has become key to China's economic development and transformation. The development of the low-carbon economy can promote the upgrading of consumption to green products and the greening of the supply chain, and then promote the transformation of enterprises to green and low-carbon, eliminate industries with backward production capacity and serious pollution, and realize the optimization of China's industrial structure. Second, it helps to optimize the energy structure (Liu, 2018). At present, the energy structure of China is still mainly based on fossil energy. However, CO_2 and other greenhouse gases produced in the use of fossil energy can seriously damage the climate and environment, which threatens human survival, is not conducive to sustainable development, and goes against the concept of high-quality development. The development of the low-carbon economy is conducive to improving the proportion of clean energy and energy utilization, optimizing the energy structure, and promoting high-quality development. Third, it will help to enhance China's international influence and competitiveness. At present, the climate and environment are deteriorating, and fossil energy is increasingly scarce. Consequently, sustainable development has become a global concern. The development of a low-carbon economy is helpful to protect the climate and solve the energy crisis. From the perspective of a common community of human destiny, developing a low-carbon economy reflects the responsibility that is borne by China and shows how it can win a better international reputation, and also promote its international influence and competitiveness.

2.2 Theoretical mechanism of digital development for urban low-carbon transformation and development

In this part, we will study the digital urban low-carbon transformation and development mechanism in four categories: industrial structure upgrading and optimization, energy structure, government governance, and production and lifestyle.

2.2.1 Upgrading and optimizing the industrial structure

Digital technology can promote technological innovation (Qi and Xu, 2020), promote industrial upgrading and new energy development, and then reduce carbon emissions. The proportion of the tertiary industry is an important indicator of a city's low-carbon transformation. The development of digital technology can give rise to new industry that provides more opportunities and information services. In addition, the development of the digital city is beneficial to digital data information collection, it can also accelerate industry and improve of the promotion of information technology, information equipment, and all kinds of information service industrialization. From the perspective of long-term development, digitalization reduces transaction costs. Enterprises use digital technology throughout the entire production process, which helps to improve the efficiency of resource allocation and labor productivity of enterprises; drives the transformation of business, organization, and business model with data; and promotes a more detailed division of labor. Digitalization has promoted scientific and technological innovation, deepened the integration of information technology and industrialization, spawned new production factors, enabled productivity, production relations, transformation and upgrading of organizational models, and helped to upgrade the industrial structure. From the perspective of production factors, in the digital era, data (as digital knowledge and information) has become a new production factor, and many new digital industries have been formed with the help of digital technology. From the perspective of productivity, the productive forces of social development are gradually shifting from steam, electricity, and information, to computing power in the digital era. This plays an important role in promoting the digital transformation and upgrading of industries. From the perspective of the production relations, "big data + traditional industry" can provide an opportunity to transform and upgrade business; foster digital technology innovation and traditional industry depth fusion; foster intelligent transformation to promote the traditional mode of production; setup big data analysis based on cloud computing and the Internet of Things cloud platform; can let each system and each business link with all kinds of digital equipment through information data connectivity; and through the production process, it can improve the overall production efficiency and product pass rate. In the process of industrial structure transformation and upgrading, enterprises continue to optimize the allocation of resources in various industries through scientific and technological innovation. Enterprises can upgrade their industrial structure, mainly by optimizing production and consumption. For production, digital technology has disrupted and innovated traditional industries, and accelerated the integration of resources in the upstream and downstream of the industrial chain. For consumption, digitalization promotes the change of social consumption structure and consumption quality. Industrial structure is increasingly advanced through the

emergence of new scenes of digital consumption to stimulate consumption potential to meet consumer demand.

2.2.2 Energy structure

From the perspective of energy structure, digital development can drive the transformation of energy structure to a low-carbon environment from the following three aspects. First, it can promote the change of energy production structure. The digital empowered energy production process is conducive to the upgrading of the production management system of energy enterprises and the intelligent transformation to realize the recycling of energy and improve the utilization efficiency of energy. Second, it can promote the optimization of the energy consumption structure. Digital enterprises can help other industries to reduce their energy consumption through digital technologies. Digital development is also changing the way in which we produce and live, driving the "virtualization" and "dematerialization" of economic activities, and minimizing urban greenhouse gas emissions (Pradhan et al., 2020). Third, it can accelerate the development of new energy sources. Research of the key emission reduction technologies has been continuously deepened, including cleaner energy structure and high energy use. Through digital technology, more new energy will replace traditional fossil energy, the consumption structure of energy will be further optimized, and carbon emissions and environmental pollution will be alleviated. For traditional energy sources, digital technology can improve the efficiency of energy supply, while for clean energy sources digital technology is helpful to solve the problem of the stability and absorption of clean energy. Therefore, digital technology is needed to help build an efficient, safe, clean, and low-carbon energy system; promote the deep integration of modern information, new materials, and advanced manufacturing technology with energy technology; and accelerate the low-carbon transformation of production and lifestyle. Digital technology can also monitor and optimize energy consumption and equipment operation. Carbon footprint analysis and tracking technology for various products, and supply and demand are built on the basis of the full life cycle analysis model, which can improve the efficiency of resource and energy use throughout the process. At the same time, the enterprise industrial Internet platform can realize multi-place collaborative management and control; improve the utilization efficiency of energy resources from the inside of the industry; build a safe, efficient, clean, and low-carbon energy system; and accelerate the realization of low-carbon changes in production and lifestyle.

2.2.3 Government and governance

The government utilizes the ever-evolving digital technology to give full play to the value of data for society, the market, and itself. Compared with the previous government operation form, the most direct feature of the digital government lies in the extensive application of digital technology, the opening of various system connection channels, and continuous data fusion to replace the previous manual operation, and thus improve the ability of the public sector to take advantage of data and information. Any organization that uses digital technology can make data serve us better. The ability of public organizations to exert the value of data and information is manifested in decision-making, management, evaluation, service, supervision, mobilization, certification, and many other aspects, which are not only for public institutions themselves but also for the market and society as a whole. For example, for public institutions, the ability to use big data can promote scientific decision-making and evaluation, through the examination and approval, registration or direct docking enterprise platform system to the market main body and the regulation of the market activity ability, to establish public data resources assigned to open platform for the market, through the health code and data sharing to provide certification standards, through the network transmission core values to realize the mobilization capacity of social governance.

Digital technology also empowers government governance, which can be summarized in four aspects. The first aspect is the digital "collaboration" of the subject, which means that the mutually dependent subject and object cooperate and govern each other based on the shared information channel, "let the data run more" and "open up" the internal and external relations of the organization with technology. The second aspect is the digital "reconstruction" of the organization, which is reflected in the optimization and reorganization of information architecture, business process and responsibility system to realize the transformation from organization digitalization to digital organization. The third aspect is the digital "connection" of tools (i.e., the construction of communication infrastructure) to realize the mutual connection between the subject and object of government governance, and build a huge information channel covering the whole country, which is the foundation of realizing digital government. The fourth aspect is to digitally "empower" business; that is, the public sector can use information technology to improve its ability to deal with business problems and achieve policy goals, mainly reflected in the information system supporting public services and administrative management for various industries. The digitization of subject, organization, tool, and business covers different aspects of the construction of digital government. However, it is not a mutual substitution relationship. It is the stage of gradual progress from the macro point of view, and the framework guide of its construction from the micro point of view.

2.2.4 Way of life

To put it simply, digitalization changes people's way of life, including eating, shopping, consumption, leisure and

entertainment, interests and hobbies, attitudes and concepts, personality characteristics and other aspects. Digitization makes our life more convenient and intelligent. A mobile phone, and the Internet, can solve the problems of finding food, clothing, shelter, and transportation. Such as daily use of takeout food, scanning code cycling, scanning code payment, online shopping platform, online classes, online office, video conferences, and so on. Offline resources are uploaded to the cloud to realize resource communication and information sharing. A large number of resources have been stored in the cloud. Books that used to be purchased in bookstores can now be viewed online. Information can also be conveniently found on the Internet. The new generation of information technology and the sharing of educational resources have also changed teaching methods. During the COVID-19 pandemic, students were able to continue their studies online, and could also interact with teachers and other students through videos even in isolation, which not only achieves the goal of epidemic prevention but also improves learning efficiency. Digitization improves efficiency and reduces manpower in many areas, such as navigation, transportation, medical services, education, agriculture, tourism, online registration, scanning codes to pick a meal, save customers' time waiting in line and also save the work of the service personnel. In addition, face recognition, fingerprint matching, DNA matching and so on can effectively improve the work efficiency of all walks of life. The deep integration of the digital economy and traditional economy has resulted in a series of new businesses, such as online car hailing, bike-sharing, food delivery and online education. With the emergence of a large number of new forms of business and new models, the integration of online and offline is deepening. Digital development plays an important role in promoting employment and also helps cities in their low-carbon transformation.

3 Countermeasures for digitalization to boost urban low-carbon transformation

In this part, through reading a large number of literature and data analysis, we will put forward the countermeasures of digitalization on urban low-carbon transformation and development.

3.1 Build a carbon emission measurement and monitoring system

An efficient and accurate carbon emission measurement and monitoring system is an important guarantee for realizing low-carbon cities. For China, it is necessary to timely and accurately grasp the carbon emission level of economic activities in various sectors and also measure the carbon absorption capacity of the natural environment. For micro enterprises, only by fully understanding the carbon emissions of each link can they adjust and optimize the production process in time and carry out carbon emission reduction. Using big data technology to obtain massive and multiple types of data through multiple channels can help us to comprehensively analyze carbon emissions, effectively overcome the defects of traditional measurement methods, and accurately measure carbon emissions and carbon absorption level. First, it can establish carbon measurement and monitoring, shorten the period of econometric analysis in real-time, improve the efficiency of econometric analysis and form a dynamic feedback, trace the energy-intensive link in the process of production and track energy-intensive sectors of the economy, help the enterprise production management change in a timely manner, and help government departments to produce a planning guide in a timely manner. Second, the investment of deep learning algorithm should be increased to explore the common characteristics of carbon emissions, and the characteristics of departments and regions to help government departments grasp the characteristics of carbon emissions from a global perspective, which is conducive to the government's macro-control and the formulation of a carbon emission reduction strategy that not only integrates the overall situation but also takes into account the differences between departments and regions. Third, the carbon emission trend simulation and prediction system can be constructed to effectively simulate the carbon emissions of various regions and economic sectors under different technological conditions and different policy environments, and realize the effective prediction of the carbon emission trend.

3.2 Promote the digital transformation of enterprises

Reducing energy consumption and practicing the concept of green development are the core approaches to realize urban low-carbon transformation. For the production sector, enterprises should reduce consumption and improve efficiency, actively carry out green transformation, and realize low-carbon production; As far as consumer departments are concerned, residents should strengthen their awareness of environmental protection and practice the concept of living a green life. Digital technology can promote the green transformation of enterprises and lead to a green life in many aspects.

First, with the help of digital technology to promote the green and lean production mode of enterprises. In product research and development, virtual simulation and big data technology are used to reduce energy and material loss, and improve research and development efficiency. In the supply of raw materials, the Internet of Things, big data, artificial intelligence, and other technologies can help to realize the digitalization of the supply

chain, shorten the supply cycle of raw materials, reduce the procurement and storage costs of enterprises, and effectively reduce unnecessary energy consumption. In the process of manufacturing, digital technology can monitor the energy consumption of the production process in real time and optimize the production process. In product sales, technologies such as big data and artificial intelligence can reduce the cost of customer search and matching, and reduce energy consumption. Digital technology can promote the precise coordination of the whole process of research and development, procurement, production, and sales; strengthen the sharing and utilization of production factors; optimize the allocation of production resources; and improve the efficiency of green manufacturing.

Second, digital technology can help to promote the green and intelligent energy management of enterprises. Due to the uncertainty of the production environment, a large amount of energy will be wasted every year because of the imbalance of energy scheduling. Based on big data and artificial intelligence technology, green data centers can be built to monitor the energy consumption and utilization of enterprises in real time, form timely feedback, and dynamically optimize energy allocation. At the same time, cloud computing, industrial Internet and other technologies will be used to help enterprises achieve shared energy management and promote the construction of a regional energy consumption monitoring system.

Third, digital technology can help to promote the green recycling of enterprise resources. Technologies such as the Internet of Things and big data help to carry out information collection, flow monitoring and data analysis of industrial wastes, optimize the way of recycling and utilization of industrial resources, promote the formation of a new mode of "Internet +" recycling and utilization, and finally realize resource recycling and implement green environmental protection and energy saving.

3.3 Increase research and development of new energy technologies

Reducing energy intensity is conducive to the sustainable use of non-renewable fossil energy, and is also one of the main strategies to cope with climate change and environmental deterioration (Zhou, et al., 2013). The Fourth Plenary Session of the 19th Central Committee of the Communist Party of China explicitly called for "advancing the energy revolution and building a clean, low-carbon, safe and efficient energy system." In addition to adopting clean energy sources such as renewable energy and nuclear energy to reduce carbon emissions, new energy-saving technologies should be developed under our energy consumption system (which is currently dominated by coal). New energy technologies not only include the research and development and utilization of non-conventional energy sources (e.g., wind power, nuclear power, and solar energy, based on new materials and technologies) but also include the development and transformation of traditional conventional energy sources (e.g., coal, oil, and natural gas) by using new technologies and digital means.

3.4 Improve the carbon emission market trading system

The road to marketization is the only way to realize low-carbon cities. Carbon emission reduction and sustainable development are global tasks, and each country or region should bear the corresponding responsibilities. The marketization of carbon emission trading should not only guarantee green and low carbon but should also take into account the development needs of the global economy. Digital technology is expected to improve the existing market system.

Digital technologies such as the Internet of Things, blockchain, big data, artificial intelligence and satellite communication networks can promote the marketization of carbon emission rights. The basis of carbon emission trading is the certification of emission reduction. A data monitoring platform built with the help of the Internet of Things technology has high information transparency, high professional level, and can provide professional and accurate digital information, which greatly reduces the certification cost, transaction cost and violation cost in the process of carbon emission trading. On the one hand, the application of digital technology can encourage enterprises to actively participate in the market-based trading process of carbon emission rights. Real-time monitoring and early warning of AI technology can effectively avoid possible operational errors in the process of carbon emission rights trading. The use of technologies such as cloud storage protects law-abiding participants from the cost of violations. On the other hand, the application of digital technology can encourage countries that have not yet established carbon emission trading system to participate in global climate protection, constantly expand the scale of trading platform, realize the market-oriented operation of carbon finance with an excellent competition mechanism, and supply and demand mechanism, and promote the continuous improvement of carbon trading through market-oriented operation.

Digital technologies such as blockchain, satellite communication network, networked group control technology, and remote operation and maintenance service system can realize the interconnection between international carbon markets. The measurement unit of the international carbon market is tons of carbon dioxide equivalent (Zeng and Wan, 2009). Although the original unit is highly consistent, because of information asymmetry, carbon financial products are not standardized in carbon emissions and serious fracture

phenomenon exists. The application of digital technology makes the flow of information smoother and more convenient, so that the formation of international market is no longer out of reach. Meanwhile, digital technologies such as Internet of Things and blockchain can collect global carbon emission information. In addition, digital technologies such as Weiluoxy group control technology, and remote operation and maintenance service systems can realize the centralized control of carbon trading market, and realize the marketization of carbon emission rights in the international market.

3.5 Optimize the carbon emission administrative management system

In addition to the "invisible hand" of the market, the "visible hand" of the government is also needed to promote the transformation of cities to a low-carbon environment. Because the carbon emission market is faced with negative externalities, incomplete information, and other problems, it may lead to market failure. However, digital technology can make the road of government administration smoother.

First, the administrative planning of carbon emission is facilitated by digital technology. Remote sensing technology, Internet of Things, blockchain and other digital technologies provide timely and accurate carbon emission data for the government to implement regulation. This helps the government to formulate detailed administrative plans, including emission reduction targets of governments at all levels, emission reduction support objects in key regions, emission reduction tasks of various enterprises, and so on. Finally, with the support of digital technology, carbon emission reduction will be realized by administrative means implemented layer by layer.

Second, digital technology can help the administration of carbon emissions. In the process of carbon emission management, big data technology can help the government to realize real-time monitoring and early warning, so as to avoid the active or passive excess emission of some subjects and aggravate the negative externality. The scheduling and management of carbon emission rights can also be implemented at the overall level according to the results of big data statistics and analysis, and it can be used as an effective supplement to market contracts to make up for the limitations of the road to marketization.

3.6 Practice the low-carbon concept

Green transportation is considered an effective way to reduce environmental degradation and improve human health (Yasir et al., 2022), with the help of digital technology to promote green consumption and build a low-carbon life system. Promoting green consumption is also crucial to urban low-carbon transition. Promoting the application of digital technologies and building a "digital plus" green consumption system will help to develop green consumption more accurately and efficiently.

First, we will promote the digital reform of the supply side of green consumption and expand the supply of green products, advocate and support enterprises to integrate digital technology into green product design, apply digital technology to green product certification, improve green product identification, and enrich the variety of green products.

Second, we should promote the concept of green consumption based on digital technology and create a green consumption atmosphere. Big data, cloud computing and other digital technologies are used to accurately match the consumer groups of green products, and short videos, WeChat media, and other platforms are used to strengthen the personalized and precise dissemination and promotion of green consumption.

Third, we should enrich green consumption scenarios based on green technology and optimize green consumption experience. Enterprises are encouraged to use digital technologies such as big data, the Internet of Things, and artificial intelligence to optimize the experience of green consumption scenarios based on personalized needs. For example, using artificial intelligence technology to improve shopping guidance, using facial recognition technology to optimize the transaction process, and enhancing the shopping experience through VR and Internet of Things technology.

4 Conclusion

With China's transition and development, a low-carbon economy has become an important part of achieving the goal of carbon peak by 2030 and carbon neutrality by 2060. This paper studies the necessity and theory of the role of digital means in urban low-carbon transformation to explain the boosting role of digital means in urban low-carbon transformation. It mainly expounds the following four aspects. First, the development of digitalization can force enterprises to transform and upgrade and optimize industrial structure. Especially in the face of sudden epidemics, digitalization has shown strong vitality. Second, digital technology can help to improve the energy structure and improve the efficiency of energy use. Third, collaboration between digital and governance can reduce carbon emission intensity. Finally, digital changes in production and life style can reduce unnecessary CO_2 emissions. In the last part of this paper, we put forward the relevant countermeasures. A city is influenced by the factors of low-carbon transformation. This paper studied the digital this factor only and did not discuss other factors, the digital booster effect is also illustrated. However, the extent of the digital development of each region is different, and the reduction effect of digital

economy is different. For regions with low technology level, it is difficult for the digital economy to give full play to its advantages in emission reduction.

In future research, it is suggested to further study the practical details of a manifestation of digital technology between different regions, technologies, and measures. We can also explore the factors affecting low-carbon development from many aspects. At the same time, China should continue to improve the construction of digital infrastructure, and promote the reform and innovation of enterprise digital technology to release the carbon emission reduction effect of the digital economy.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. Written informed consent was not obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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