

**DIGITAL ECONOMY AND CARBON EMISSIONS
IN CHINA: THE MEDIATING ROLE OF
INDUSTRIAL STRUCTURE UPGRADING**

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2025

DIGITAL ECONOMY AND CARBON EMISSIONS IN CHINA: THE MEDIATING ROLE OF INDUSTRIAL STRUCTURE UPGRADING

by

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**Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy**

July 2025

ACKNOWLEDGEMENT

This thesis could not have been finished without the assistance and support of numerous individuals. I would like to begin by expressing my profound gratitude and sincere appreciation to my supervisor, Dr. Haslindar Ibrahim, for her unwavering support, guidance, and insightful feedback during my PhD. Dr. Haslindar has been extraordinarily patient and cooperative in offering me insightful feedback to facilitate ongoing enhancements at each stage of development. I want to express my gratitude to Associate Professor Dr. Abdul Hadi Bin Zulkafli, Associate Professor Dr. Anwar Bin Allah Pitchay, and Associate Professor Dr. Aza Azlina Md Kassim for their constructive feedback and valuable insights, which have contributed significantly to the improvement of the quality of my thesis.

I am deeply thankful to the Institute of Postgraduate Studies (IPS) staff and the School of Management at Universiti Sains Malaysia for their continuous support throughout my learning journey. I want to thank the School of Management for providing a suitable environment for my research by organising several academic conferences and events to better interact with academics and enhance my academic skills. I want to express my heartfelt gratitude to my parents and family for their unwavering spiritual and financial support throughout my study. I am incredibly grateful to my parents for their constant encouragement. Without their understanding and patience, this thesis would not have been possible. I dedicate this thesis to my parents and my younger brother. I sincerely thank my hometown friends and classmates for their encouragement and support during my doctoral studies. Their help in my most difficult times lit the way forward and gave me the strength to complete my thesis.

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LIST OF ABBREVIATIONS

ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
Inf	Digital Infrastructure Level
Dig	Digital Industrialization Level
Ind	Industry Digitization Level
Tec	Digital Technology Innovation Level
Fin	Digital Financial Development Level
Eco	Economic Development Level
Hum	Human Capital Level
Agg	Economic Agglomeration
Inv	Foreign Direct Investment
Pop	Population Density
Str	Industrial Structure Upgrading
Car	Carbon Emissions
GDP	Gross Domestic Product
DE	Digital Economy
CO ₂	Carbon Dioxide
NGOs	Non-governmental Organizations
R&D	Research and Development
UK	United Kingdom
AI	Artificial Intelligence
FEM	Fixed Effects Model
REM	Random Effects Model
IoT	Internet of Things
IDC	International Data Corporation

LIST OF APPENDICES

APPENDIX A TABLE OF CHINESE PROVINCES (SAMPLES)

EKONOMI DIGITAL DAN PELEPASAN KARBON DI CHINA: PERANAN PENGANTARA MENAIKTARAF STRUKTUR INDUSTRI

ABSTRAK

Ekonomi digital ialah paradigma baru adalah berlandaskan ciri, struktur dan mekanisme yang berbeza. Penggunaannya telah menghasilkan transformasi yang ketara merentasi pelbagai sektor, dengan itu memudahkan pemodenan dan peningkatan industri konvensional. Hubungan antara kemajuan ekologi komuniti global dan pelepasan karbon yang dijana oleh pelbagai syarikat sering dilihat. Meningkatkan kecekapan tenaga operasi perindustrian sepanjang fasa pembuatan diakui secara meluas sebagai pemangkin untuk mengurangkan pelepasan karbon dan meningkatkan keuntungan ekonomi. Dalam konteks ekonomi digital, data mempunyai potensi untuk mengurangkan pelepasan karbon dengan ketara dalam konteks serantau dan perindustrian sambil pada masa yang sama memupuk pembangunan ekonomi. Oleh itu, kajian ini bertujuan untuk mengkaji hubungan antara ekonomi digital dan pelepasan karbon dengan mensintesis penyelidikan domestik dan antarabangsa sedia ada. Selain itu, sampel set data yang terdiri daripada 30 wilayah di China (tidak termasuk Tibet, Hong Kong, Macao dan Taiwan) dari 2012 hingga 2021 digunakan. Pada mulanya, analisis statistik deskriptif awal dijalankan untuk mendapatkan pandangan tentang pengedaran keseluruhan pembolehubah data yang dikumpul. Selain itu, pembolehubah yang dipilih menjalani ujian korelasi untuk memastikan sebarang potensi korelasi antara mereka dan arah pengaruh. Selepas itu, ujian Hausman digunakan untuk menentukan kesesuaian model kesan tetap. Berikutan ini, kaedah regresi berperingkat digunakan untuk mengkaji kesan individu ekonomi digital, peningkatan struktur perindustrian dan pelepasan karbon. Dengan menggunakan

model kesan pengantaraan, kajian ini mengkaji peranan pengantara yang penting dalam menaik taraf struktur perindustrian dalam laluan di mana kesan ekonomi digital terhadap pelepasan karbon direalisasikan. Ekonomi digital secara tidak langsung boleh mencapai sasaran pengurangan pelepasan karbon dengan menggalakkan peningkatan struktur perindustrian. Tambahan pula, *Spatial Durbin Model* digunakan sebagai asas untuk mengkaji pengaruh ekonomi digital terhadap pelepasan karbon. Kajian ini menyiasat kesan ekonomi digital ke atas pelepasan karbon dengan menganalisis kesan limpahan spatial melalui *Spatial Durbin Model*. Akhir sekali, kajian ini juga menjalankan pelbagai ujian kekukuhan (termasuk menggantikan model kesan tetap dengan model *Generalized Method of Moments (GMM)*, menggantikan kaedah pengukuran pembolehubah teras dan menggunakan matriks pemberat spatial alternatif), yang kesemuanya mengesahkan keteguhan dan kebolehpercayaan kesimpulan teras. Penyelidikan telah menemui korelasi songsang yang ketara antara ekonomi digital dan pelepasan karbon, menunjukkan bahawa kemajuan ekonomi digital secara cekap mengurangkan pelepasan karbon. Selain itu, ekonomi digital mempunyai kesan ketara terhadap pelepasan karbon merentasi banyak kawasan geografi. Peningkatan struktur industri secara serentak mempengaruhi kesan ekonomi digital ke atas pelepasan karbon. Untuk mempercepatkan penurunan pelepasan karbon, adalah perlu untuk mempercepatkan pelaksanaan pembinaan infrastruktur digital baharu. Meningkatkan kemajuan teknologi digital melalui penyelidikan dan pembangunan serta memudahkan penyepaduan pendigitalan dalam usaha kelestarian alam sekitar. Pada masa yang sama, terdapat potensi untuk meningkatkan keberkesanan penunjuk penilaian prestasi untuk memupuk persaingan yang membina dalam kalangan kerajaan tempatan. Selain itu, adalah penting untuk merangka strategi pembangunan ekonomi digital yang sejajar dengan jurang serantau, dengan itu

memastikan bahawa kesan pengurangan pelepasan karbon ekonomi digital meluas ke semua kawasan geografi melalui analisa *spatial spillover effect model*.

DIGITAL ECONOMY AND CARBON EMISSIONS IN CHINA: THE MEDIATING ROLE OF INDUSTRIAL STRUCTURE UPGRADING

ABSTRACT

The digital economy is a novel paradigm characterized by distinct features, structures, and mechanisms. Its adoption has engendered significant transformations across diverse sectors, thereby facilitating the modernization and enhancement of conventional industries. The correlation between the ecological progress of the global community and the carbon emissions generated by diverse companies is frequently seen. Enhancing the energy efficiency of industrial operations throughout the manufacturing phase is widely acknowledged as a catalyst for mitigating carbon emissions and enhancing economic gains. In the context of the digital economy, data has the potential to significantly mitigate carbon emissions in both regional and industrial contexts while concurrently fostering economic development. Hence, this study aims to examine the relationship between the digital economy and carbon emissions by synthesizing existing domestic and international research. Additionally, a sample dataset consisting of 30 provinces in China (excluding Tibet, Hong Kong, Macao, and Taiwan) from 2012 to 2021 is utilized. Initially, a preliminary descriptive statistical analysis is conducted to gain insights into the overall distribution of the collected data variables. Additionally, the selected variables undergo a correlation test to ascertain any potential correlation between them and the direction of influence. Subsequently, the Hausman test is employed to determine the suitability of the fixed effects model. Following this, the stepwise regression method is utilized to examine the individual effects of the digital economy, industrial structure upgrading, and carbon emissions. Using mediation effect models, this study examines the significant

mediating role of industrial structure upgrading in the path through which the digital economy's impact on carbon emissions is realised. The digital economy can indirectly achieve carbon emission reduction targets by promoting industrial structure upgrading. Furthermore, the spatial Durbin model is used as the basis for studying the influence of the digital economy on carbon emissions. This study investigates the impact of the digital economy on carbon emissions by analysing the spatial spillover effect through the spatial Durbin model. Finally, this study also conducted a variety of robustness tests (including replacing the fixed-effects model with a GMM model, replacing the core variables' measurement methods, and using an alternative spatial weighting matrix), all of which validated the robustness and reliability of the core conclusions. Research has uncovered a significant inverse correlation between the digital economy and carbon emissions, indicating that the progress of the digital economy efficiently reduces carbon emissions. Moreover, the digital economy has a noticeable impact on carbon emissions across many geographical areas. Industrial structure upgrading simultaneously influences the impact of the digital economy on carbon emissions. To accelerate the decrease of carbon emissions, it is necessary to speed up the implementation of new digital infrastructure construction. Enhance the advancement of digital technology through research and development and facilitate the integration of digitalization in environmental sustainability efforts. Simultaneously, there is potential for enhancing the efficacy of performance assessment indicators to foster constructive competition among local governments. Additionally, it is imperative to devise digital economy development strategies that align with regional disparities, thereby ensuring that the carbon emission reduction impact of the digital economy extends to all geographical areas by utilizing the spatial spillover effect model.

CHAPTER 1

INTRODUCTION

1.1 Introduction

China has become one of the world's greatest carbon emitters due to the extensive use of diverse energy sources from industrialization. At the same time, accelerating urbanization is also putting pressure on carbon emissions. According to Li and Wang (2022), China's rapidly expanding digital economy not only offers many prospects for economic expansion and innovation to society but also exerts a substantial influence on carbon emissions.

First, thoroughly examining China's digital economy will evaluate its immediate implications on carbon emissions. To mitigate carbon emissions, the digital economy must be advanced and cultivated. Measuring these effects and deriving conclusions from data and models. Digitization, data, networking, and intelligence underpin the digital economy, which evolved from rapid information technology growth. The Internet, big data, and AI facilitate the advancement of the digital economy by enabling digital, networked, and intelligent economic and social development. Economic structure optimization and production efficiency are achieved (Bukht & Heeks, 2017).

Second, the growth of China's digital economy is inextricably related to industrial structure upgrading. Digital technologies and digital industries are making traditional industries more knowledge-intensive and innovative. This industrial structure upgrading may significantly reduce carbon emissions. Some emerging digital industries are characterized by energy efficiency and reduced carbon emissions. Cheng et al. (2023) note that traditional industries may have reduced output, but their energy-

intensive nature may increase carbon emissions. Through industrial structure upgrading, the digital economy has the potential to moderate the complicated influence on carbon emissions.

Third, China's digital economy is reflected in the province and may affect surrounding provinces. Zhu et al. (2022) note that the development of the digital economy has regional spillover effects, and its impact on carbon emissions is not only reflected locally but also extends to surrounding areas through interregional technology diffusion and industrial linkages. Therefore, this study uses a spatial Dobson model (SDM) to analyse the spatial spillover effects of the digital economy on carbon emissions. This model can identify the direct impact of the digital economy on local carbon emissions, as well as its indirect impact on carbon emissions in neighbouring regions. By introducing a spatial weight matrix, it is possible to reveal the interregional linkage effects more comprehensively, providing a basis for cross-regional cooperation in promoting low-carbon development.

This study aims to elucidate the concepts of the digital economy, industrial structure upgrading, and carbon emissions. This research aims to contribute to the sustainable development of the digital economy, upgrading industrial structure, and reducing carbon emissions. It provides targeted proposals to legislators, businesses, and all community sectors in China to address the increasing environmental issues by lowering carbon emissions. Apart from the problem statement, research objectives, research questions, research relevance, research gap, definitions of important terms and organisation of the thesis. Chapter 1 introduces the research background of the digital economy, industrial structure upgrading, carbon emissions, and their impact. This study has a thorough background supplied.

1.2 Background of the Study

1.2.1 Background of China's Provinces

China has advanced in the financial and digital sectors, according to Li et al. (2020), the digital economy is dependent on the Internet and technology. AI, cloud computing, data analytics, and e-commerce serve as illustrations. China's digital economy is expanding rapidly, and it is a major player in the Internet industry. The growth of internet-based financial services, E-commerce, and online payment systems can be attributed to the contributions of Alibaba and Tencent. Chinese technology enterprises have made substantial advancements in artificial intelligence (AI) and big data (Zhang & Chen, 2019). Nevertheless, the swift growth of the digital economy has sparked worries over carbon emissions. Data centres, servers, and communication equipment are essential for the functioning of the digital economy. However, they consume a significant amount of energy and release carbon emissions (Barefoot et al., 2018). In addition, Wang et al. (2024) point out that the production and disposal of electronic equipment generates large amounts of e-waste, which is harmful to the environment.

Chen et al. (2023) identify the relationship between the digital economy and the fluctuation of carbon emissions in Chinese provinces. With strong growth in e-commerce, technology, and internet-based financial services, Guangdong, Jiangsu, and Zhejiang are digital economy leaders. These regions must undertake policies to counteract the negative environmental implications of the digital economy due to carbon emission pressure. However, Guizhou, Yunnan, and Shaanxi in western and central China are slower to develop the digital economy (Luo et al., 2023). However, these regions possess substantial reserves of renewable energy sources, including hydropower and solar energy. These sites can reduce carbon emissions caused by the

digital economy by utilizing renewable energy sources. In addition, they can promote the integration of economic growth and environmental preservation by advocating for coordinated development (Zhao et al., 2023).

China's provinces exhibit variations in both the digital economy and carbon emissions. However, wealthy and developing nations need to acknowledge the ecological consequences of the digital economy. Chinese provinces may bolster the digital economy and diminish carbon emissions by advocating for energy efficiency, clean energy, and sustainable production and consumption. Implementing sustainable development would result in substantial advantages.

1.2.2 The Carbon Emissions in China

The 1750s Industrial Revolution advanced global economic and social advancement, but mineral energy usage damaged the environment. The 21st century has seen fast economic expansion at the expense of enormous energy usage loss as nations focus on industrial development. This causes global warming. According to the “White Paper^① on Low Carbon Transition in Chinese Energy Enterprises,” energy consumption accounted for 90 % of China's CO₂ emissions in 2020, amounting to 14.3 billion tonnes and 33.3 % of global emissions (Xing et al., 2023). In addition, Ning et al. (2021) state that human societies are increasingly aware of resource and environmental constraints.

In September 2019, President Xi Jinping committed to enhancing China's economy and society by achieving carbon neutrality by 2060 and reaching the carbon

^① **White Paper:** The name given to an important document or report officially issued by the government or parliament and bound in a white cover.

peak target by 2030. By committing this, China shows it is doing its part to promote energy autonomy and sustainable, low-carbon development. Enterprises have improved their development planning and high-level design in response to the implementation of the "double carbon" target, which seeks to reach "peak carbon" by 2030 and attain "carbon neutrality" by 2060. The state's involvement in this matter has been expanding (Wang et al., 2021).

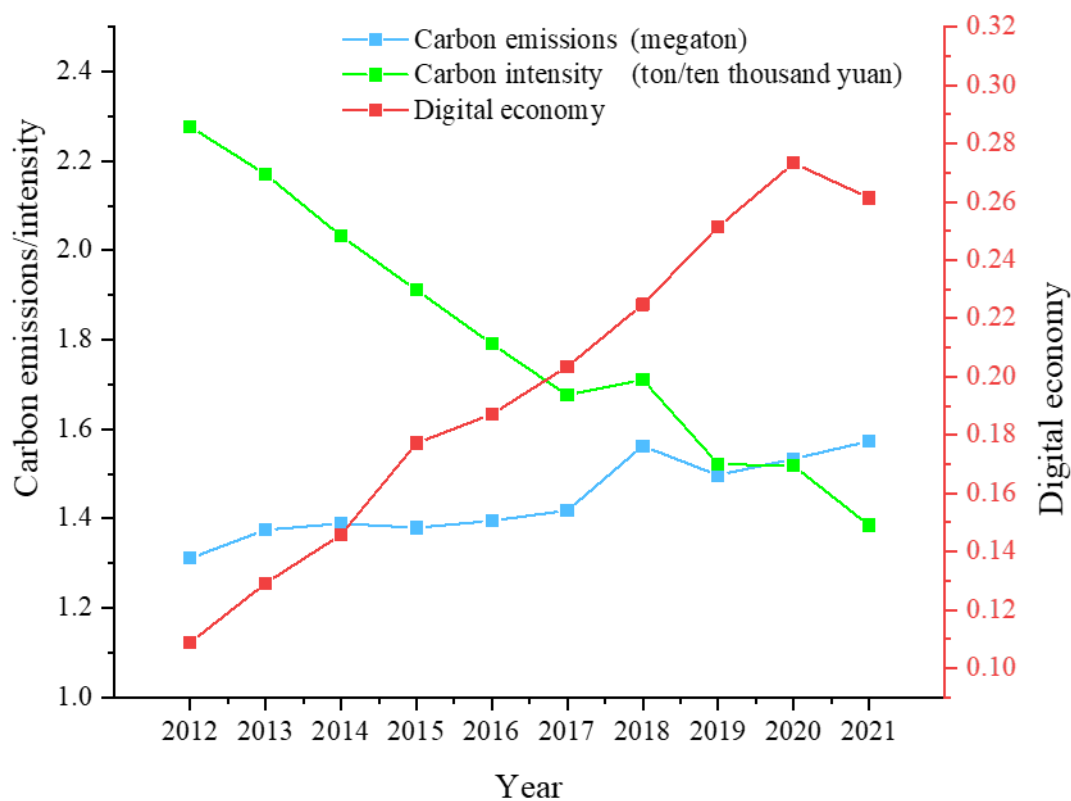


Figure 1.1 Trends in China's Digital Economy, Carbon Emissions, and Carbon Intensity (2012–2021)
Source: China Statistical Yearbook, China Energy Statistical Yearbook (2021)

Figure 1.1 shows the trends in China's digital economy, carbon emissions, and emission intensity from 2012 to 2021. The annual growth of the digital economy has been consistently increasing since 2012, but the "COVID-19 pandemic" led to a decline in 2021. Even though it has added to the increase in carbon emissions, China

intends to reach peak carbon in 2030. Due to this, the increase in carbon emissions has been gradual. Nevertheless, the magnitude of carbon emissions is diminishing. The digital economy has led to a substantial reduction in carbon emissions. China is now during a new technological era, characterised by the widespread use of digital technology and the subsequent conversion of some industries to digital formats.

The White Study on Digital Transformation of Energy (2022) explains how the creative application of new technologies like big data and cloud computing in China's energy system can do more than just cut down on energy waste and increase productivity; it can also spur the development of cutting-edge methods for conserving energy and cutting down on carbon emissions, speed up the process of energy digitization and integration in China, and encourage the country's regions to reduce their carbon footprints (Wen et al., 2021).

In 2020, China's digital economy reached 39.2 trillion-yuan, accounting for 38.6% of GDP. In 2021, it reached 45.5 trillion yuan, representing a year-on-year increase of 16.2%. In 2022, it is expected to reach 50.2 trillion yuan. China's digital economy is expected to continue growing and integrating deeply into various traditional industries, becoming a key force driving high-quality economic growth and green transformation (Chen et al., 2023). As a driver of efficient and high-quality social development, the digital economy has seeped into every facet of society (Wang & Zhong, 2023; Wu & Shao, 2022). Hence, I advocate for the complete utilization of digital technology, the thorough advancement of the digital economy, and the establishment of matching laws to mitigate carbon emissions. This would enable the economy and the environment to attain a state of harmonious and sustainable development.

Between the end of the 19th century and the beginning of the 21st century, worldwide average ocean and land temperatures climbed by 0.85°C, with an increasing trend, and were 0.78°C higher in 13 years (2000-2012) than in 50 years (1850-1900). The 2014 IPCC (Intergovernmental Panel on Climate Change) Fifth Climate Change Assessment found these. Rising sea levels, melting snow-capped mountains, and natural disasters endanger human culture. IPCC's Fifth Assessment Report (2014) confirms that people cause global warming. Due to Earth's evolutionary cycles, some scholars blame the sun for global warming.

Although there is insufficient evidence to establish a causal link between greenhouse gas emissions and global warming, empirical evidence suggests that the rise in carbon emissions as a result of human activities is a significant contributor to this phenomenon (Ramirez-Corredores et al., 2023). The 2005 "Kyoto Protocol," the 2007 "Bali Road Map," the 2009 "Copenhagen Accord," and the 2015 "Paris Agreement" are the latest instances of proactive measures and international agreements aimed at addressing climate change. These pacts are meant to encourage international collaboration in slowing the rate of climate change.

According to Yu and Zhu (2023), industrialization in China since New Carbon emissions rose in China. WWB: China's carbon emissions have climbed for 40 years since joining WTO. China joined the WTO, increasing carbon emissions. World's largest nation, it reached US economic production in 2005. Compared to 2005, China promised to reduce carbon emissions by 40% per unit of GDP by 2020 in the 2009 Copenhagen and 2015 Paris global conferences. On September 22, 2020, his UN General Assembly statement said, "China will make more aggressive efforts to cut carbon emissions and adopt more strict carbon reduction measures and policies and

will achieve peak carbon emissions between 2030 and 2060." China will reduce carbon emissions and tighten laws to peak and carbon-neutral by 2030 and 2060 (Yu & Zhu, 2023). To meet China's commitments, the 12th Five-Year Plan included carbon emissions as a key indicator in its medium and long-term strategic development plan, strengthened high-energy-consuming industry production capacity control, and closed some backward production capacity, reducing carbon emissions (Zhu, 2022).

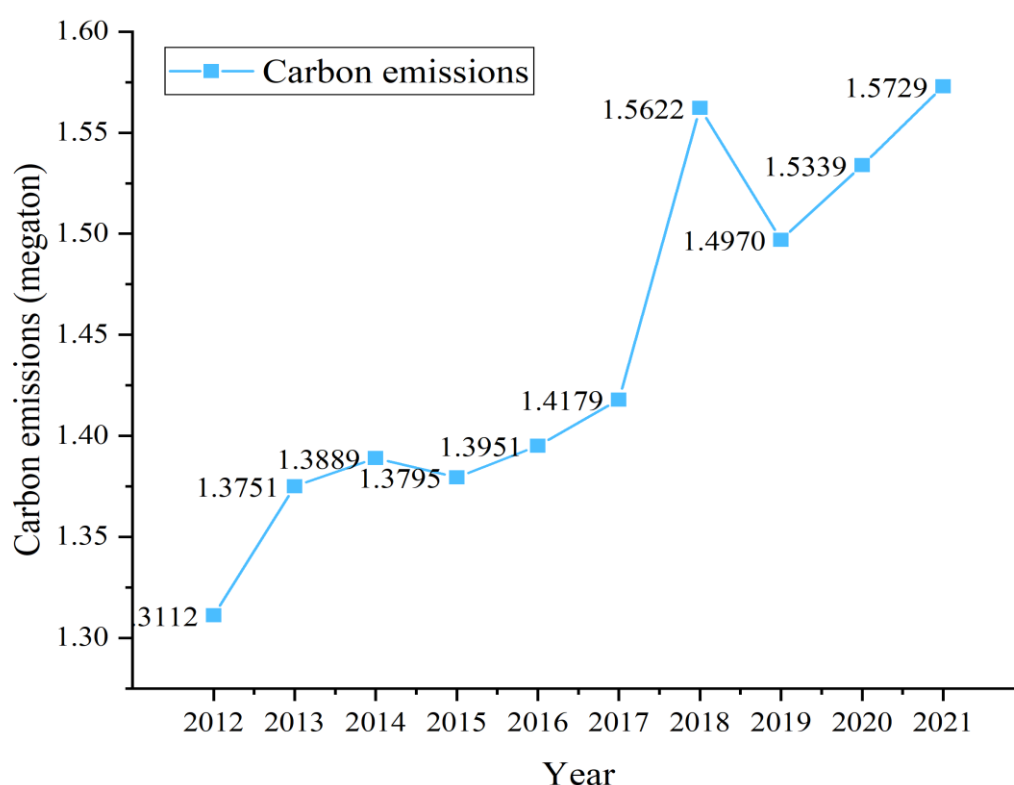


Figure 1.2 Change of China's Carbon Emissions from 2012 to 2021.
(Data source: CEADS carbon emission database, 2021)

As China built digital infrastructure after 2017, carbon emissions fluctuated, as seen in Figure 1.2. Digital infrastructure construction and operation use much fuel and produce carbon. The digital economy's growth from 2017 to 2021 also limited carbon emissions. Carbon emission density is falling. China wants to reach the carbon peak by 2030. Consequently, carbon emissions will gradually increase every year till that

time. China is experiencing the middle and late phases of industrialization, characterized by increasing urbanization, ambitious economic and social development objectives, and substantial pressure to reduce carbon emissions (Zhu et al., 2022). Although economically developed urban agglomerations like the Pearl River Delta and Yangtze River Delta have reached post-industrialization, China's urbanization task still needs to be completed due to uneven regional development and significant development gaps (Wang et al., 2022; Zhao et al., 2022). According to the above comments, energy-intensive businesses are still crucial to urbanization and industrialization, and the continuous increase in carbon emissions and environmental deterioration can largely be attributed to the vast amounts of energy-intensive fuels used.

Li et al. (2022) argue that according to the fundamental laws of urbanization, urbanization can be divided into primary urbanization, intermediate urbanization, late urbanization, and complete urbanization. The expansion of urbanization requires increased infrastructure, which will undoubtedly lead to increased energy consumption; therefore, China will face more significant pressure to reduce carbon emissions.

1.2.3 The Digital Economy of China

As economic globalization progresses, the global population increases, and international trade becomes more interconnected. This has led to a larger scale of economic activities and a gradual deterioration and warming of the global atmosphere. These changes have had a significant impact on human production and life. Additionally, annual carbon emissions are rising, directly linked to human-induced climate change (Zhu et al., 2022). China's economy has experienced rapid growth since implementing its reform and openness policies. China has a massive domestic market, and its international trade is becoming increasingly crucial to its economy. This is

especially true in the last few decades, when both heavy and light industries expanded rapidly, using vast quantities of non-renewable resources like industrial fuels and fossil energy (Yi et al., 2022). Lv (2023) argues that as a classic emerging country, China must continue to move towards an industrialized world by advancing new manufacturing, intelligence, digitalization, and modern agriculture.

The digital economy is an economic model with digital technology and information and communication technologies at its central focus. It promotes the comprehensive upgrading and transformation of economic activities employing digitization, networking, and intelligence. The digital economy is not simply using digital technology to replace certain aspects of traditional economic activities but also the comprehensive application of digital technology throughout the entire economic system to promote economic growth, increase efficiency, and improve the quality of life (Zuo et al., 2024). In 2021, the wave of digitalization was evident, with the digital economy reaching a scale of RMB 45.5 trillion, accounting for approximately 40% of China's GDP. Infrastructure development was solid, and the e-commerce sector continued to thrive. By 2022, the scale of the digital economy had further expanded to RMB 50.2 trillion, accounting for 41.5% of the country's GDP. Infrastructure and data resources developed at an accelerated pace, and technological and application projects were implemented more deeply (Chen & Liu, 2025).

Without reducing carbon emissions, China's environmental development is in danger of being put in a difficult position, which Dong et al. (2022) suggest will have a chilling effect on the Chinese economy in the long term. Reducing carbon emissions in tandem with economic growth is the key to achieving the dual-carbon goal without disrupting average production and life, which is a worthwhile endeavour. Scholars

worldwide typically use digital infrastructure level, digital industrialization level, industrial digitization level, digital technology innovation level, and digital finance development level to comprehensively measure the digital economy (SHI, 2022; Van & Duy, 2020). Therefore, drawing on previous research, the digital economy is measured primarily in these five dimensions.

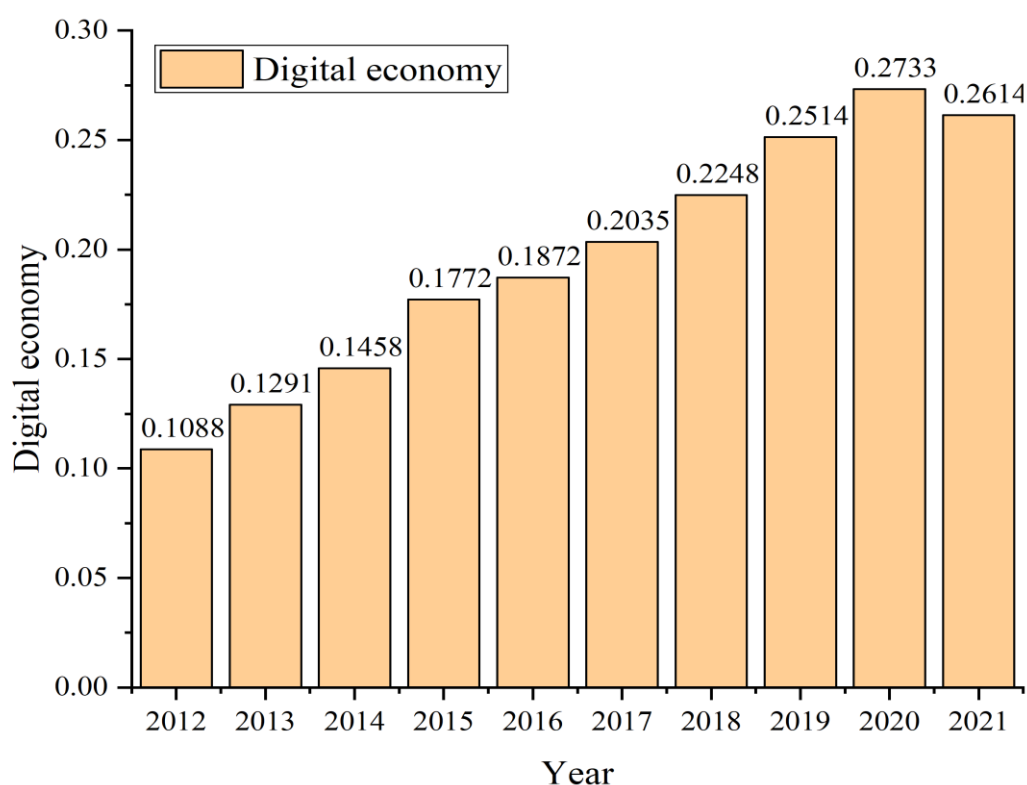


Figure 1.3 Trend of China's Digital Economy Development Level
Source: China Statistical Yearbook (2021)

Figure 1.3 depicts the trajectory of China's digital economic development level. China's digital economic development level is measured using the entropy approach (Yang & He, 2022). The COVID-19 epidemic will lower digital economic development in 2021, which was rising annually before 2020. China's digital economy and global economic progress have suffered. Although many studies have highlighted the rapid development of the digital economy in areas such as e-commerce and remote

work during the pandemic, this study found that its overall development level has been impacted to some extent. The reasons for this are as follows: supply chains were disrupted at the beginning of the pandemic, slowing down the construction of digital infrastructure; small and medium-sized enterprises lacked digital capabilities; and regional and industry development disparities increased. These factors have limited the comprehensive advancement of the digital economy, resulting in a less than obvious increase in its overall level or even a decline (Yu & Shao, 2025). With the trend of digital economic development to build digital infrastructure, the country should invest more in digital technology innovation, such as Big Data, AI, cloud computing, etc. According to Chen et al. (2023), using science and technology to aid economic development not only accelerates economic and social development while lowering carbon dioxide emissions, but the state must also prioritise the development of the digital economy to assist businesses in achieving healthy and sustainable development.

China's economy will benefit from a more data-driven approach to development that better supports economic activities, boosts national business output, and enhances GDP through a more granular and virtualized integration of data and information. In keeping with government policy, this embodies the idea of green economic development and advances the cause of a digitally and environmentally conscious economy. Deng et al. (2022) argue that promoting the digital economy is a practical method to combine economic and ecological benefits and is crucial for effectively reducing carbon emissions. The growing prominence of carbon peaking and carbon neutrality has made it imperative for the digital economy to expand to facilitate sustainable development. It is crucial to merge the digital economy with the existing economic progress to promote social progress, reduce carbon emissions, and

achieve sustainable economic growth and environmental conservation.

1.2.4 The Impact of the Digital Economy on Carbon Emissions

Tackling climate change is a formidable challenge that every country must confront in the twenty-first century. The digital economy plays a crucial role in driving economic and social growth. It is becoming increasingly vital in lowering carbon emissions and achieving sustainable development. Carbon emissions substantially drive global warming and climate change (Chang & Li, 2022; Yi et al., 2022). China's digital economy, the most populous and second largest globally, holds substantial research and practical significance in its impact on carbon emissions.

Firstly, China is one of the world's largest emitters of greenhouse gases. With rapid economic growth and urbanization, China's carbon emissions are also increasing. However, Zhang et al. (2022) claim that China's rapid digital economy growth reduces carbon emissions. Digital technology adoption saves energy, reduces pollution, improves resource efficiency, and creates a greener economy. Thus, studying China's digital economy's greenhouse gas emissions can help develop and optimize strategies to reduce emissions and promote sustainable economic growth (Zhou et al., 2022).

Secondly, the development potential of China's digital economy is enormous. China has made great strides in Internet, e-commerce, and artificial intelligence (AI) in recent years. According to Zhao et al. (2022), digital technology has changed how people live and produce and affected the economy and supply chain. Carbon reduction opportunities abound in China's fast-growing digital economy. China can reduce carbon emissions and expand economically by prioritizing green IT innovation and digital low-carbon sectors. Understand how China's rising digital economy influences carbon emissions to promote green and sustainable economic development (Chang &

Li, 2022; Hu, 2023).

Concern over carbon emissions is growing internationally. Countries adopted carbon emission reduction targets and increased international cooperation to combat climate change. Numerous countries worldwide that have undergone digital transitions have exhibited the beneficial effects of the digital economy on reducing carbon emissions. For instance, Estonia has minimised resource waste through e-government initiatives, U.S. technology firms have propelled data centres to utilise renewable energy for carbon neutrality, Singapore has enhanced energy efficiency through smart city development, and South Korea has advocated for industrial emissions reduction through green ICT policies. These experiences demonstrate that digital technology can enhance efficiency and reduce pollution. Utilising international experiences can elucidate the influence of China's digital economy on carbon emissions, thereby augmenting the practical relevance and global perspective of the research (Yu et al., 2025; Zuo et al., 2024). China's emission reduction efforts are crucial to attaining global carbon emission objectives as a significant emitter. China's digital economy, a vital aspect of its economy, is essential for achieving its carbon emission reduction targets, according to Zhong et al. (2022). An analysis of the influence of China's digital economy on carbon emissions would enhance our comprehension of the prospects and obstacles in mitigating carbon emissions and establish a solid scientific basis for formulating a national policy to curtail carbon emissions. Governments and enterprises can benefit from thoroughly examining the digital economy's influence on carbon emissions if it identifies key areas and directions for technical innovation to reduce carbon emissions (Dong et al., 2022).

According to Liu et al. (2023), the digital economy faces significant energy

and carbon emission concerns, notwithstanding its potential to decrease carbon emissions. Data centres need much energy, and electronics creation and disposal harm the environment. Therefore, examining the influence of the digital economy on carbon emissions can provide insights into the complete ramifications of digitalization and facilitate the identification of strategies to support its continued expansion. Finally, analysing China's digital economy's carbon emissions can boost global growth. China's digital economy's rise affects the world as a prominent manufacturer and dealer. Economic carbon emissions and global supply chains are affected by this expansion. Liang et al. (2022) propose that China may inspire a green shift in the global economy by emphasizing carbon reduction and environmental friendliness in digitization. An in-depth examination of the carbon emissions from China's digital economy is necessary for effective global climate governance and sustainable development.

Ultimately, the digital economy is not antithetical to carbon emissions; instead, it serves as a crucial driver for attaining carbon reduction objectives. It offers China novel prospects for transformation in response to climate change issues while also acting as a strategic framework for advancing high-quality economic development. Regarding scholarly analysis and real-world application, the significance of China's digital economy's carbon emissions must be balanced. Analysing the emission-cutting potential of digital technologies from a scientific perspective can help China achieve its goals of lowering carbon emissions and promoting green growth. Studying the impact of the digital economy on carbon emissions will provide valuable insights into its environmental implications and its role in facilitating the global economy's transition towards sustainability.

1.2.5 The Industrial Structure Upgrading and Carbon Emission

Digitalization has transformed China's economy and society. All organizations

must undergo digital transformation as digital technology, and the Internet proliferate. Climate change concerns are growing, and all nations prioritize carbon emission reduction. China, the world's largest CO₂ emitter, promotes its low-carbon economy, and the digital sector's rapid growth offers new opportunities (Zhu et al., 2022). Electronic commerce, mobile payments, cloud computing, big data, and AI is all part of China's digital economy. China's digital economy has risen in importance to the economy. According to the National Bureau of Statistics (2022), the digital industry will contribute 41.5% of China's GDP, or RMB 50.2 trillion, in 2022, according to Xue et al. (2022). The rapid rise of the digital economy has boosted China's traditional sectors and GDP.

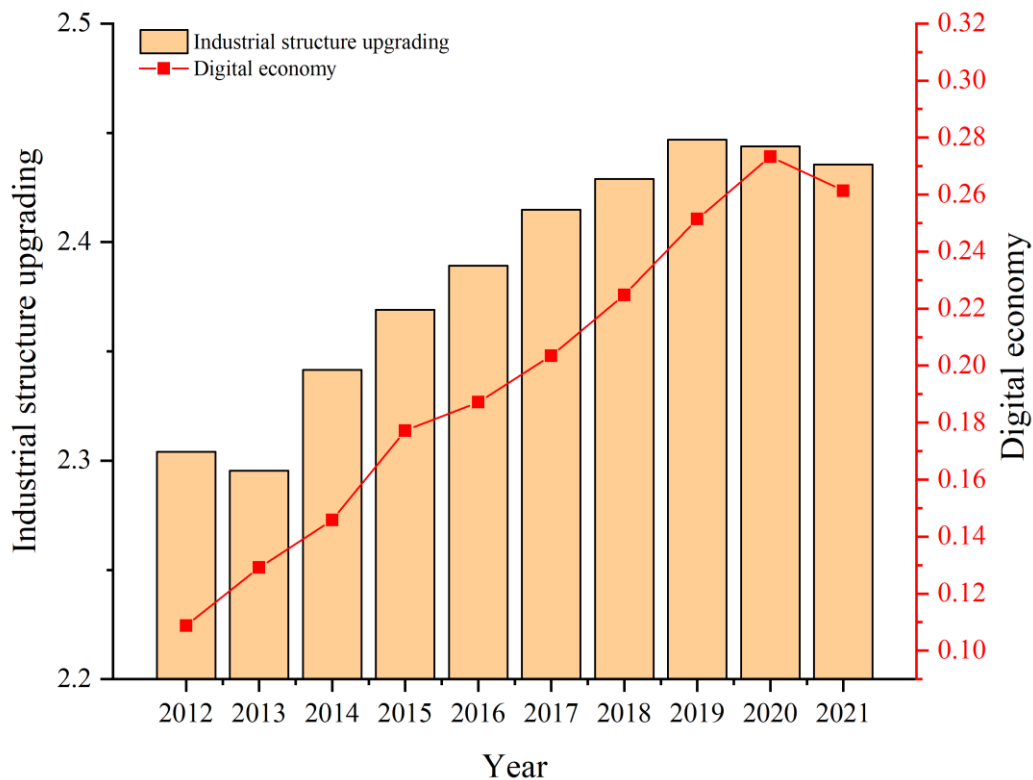


Figure 1.4 China's Digital Economy and Industrial Structural Upgrading Index, 2012-2021
(Source: China Energy Statistics Yearbook and China Statistics Yearbook, 2021)

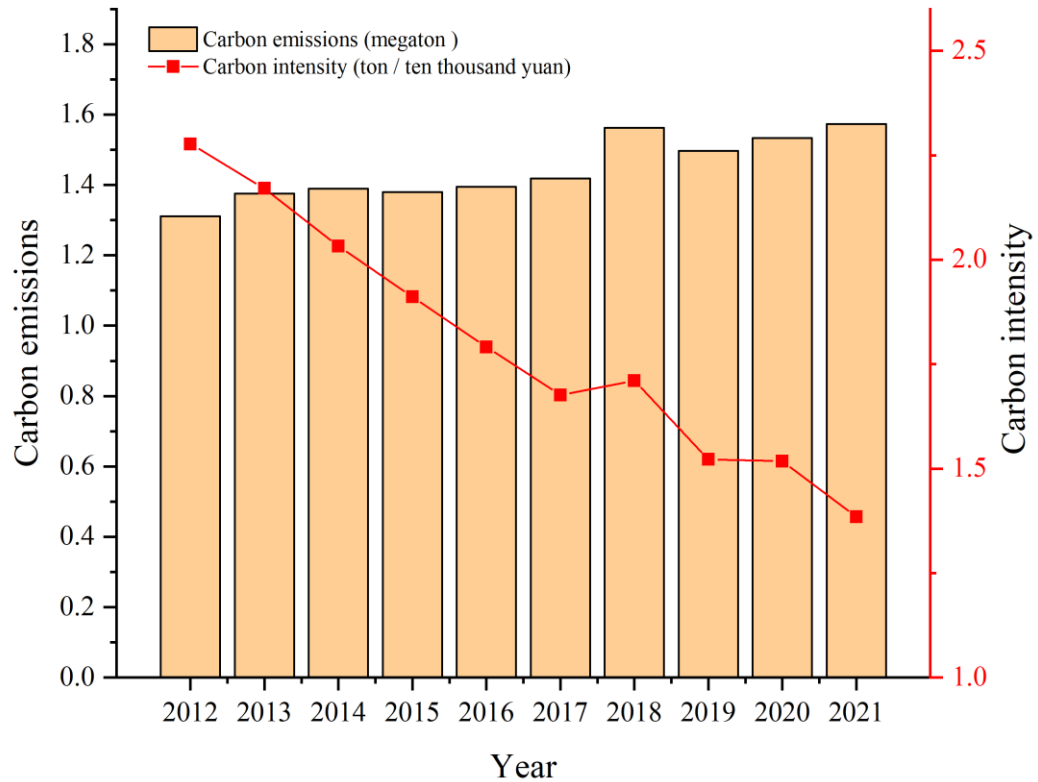


Figure 1.5 Changes in Carbon Emissions and Carbon Intensity in China, 2012-2021
(Source: China Energy Statistics Yearbook and China Statistics Yearbook, 2021)

In Figure 1.4, the index and development trend of the digital economy and industry structural upgrading from 2012 to 2021 demonstrates an increasing trend. Meanwhile, in Figure 1.5, China's carbon emissions and intensity from 2012 to 2021 show a decreasing trend. Although carbon emissions are rising annually, the digital economy supports industry structural upgrading, which reduces carbon emissions. The upgrading of China's industrial structure from a lower to a higher level has been dramatically impacted by digital economic development (Cheng et al., 2018).

Firstly, widespread digital technology has altered industrial and commercial models. Digital transformation has improved production efficiency, quality, resource usage, and energy emissions in conventional industrial industries. Electronic commerce, Internet finance, and the sharing economy are new enterprises produced by

digital technology. High-efficiency, low-carbon developing industries fuel economic growth (Xiao et al., 2023).

Secondly, the digital economy has fuelled the development of digital service businesses. Thanks to the Internet and technological advances, people increasingly use digital channels for shopping, education, and health care. Khattak et al. (2020) state that digital services improve efficiency, transportation, and carbon emissions. Modern logistics and transportation are more efficient and emit less carbon thanks to digital technologies. China's rapidly growing digital economy has reduced carbon emissions. Partially attributable to the digital economy, traditional industries have also become green. Digitalization and smart upgrades have improved resource use, energy consumption, and waste emissions, thereby reducing carbon emissions from traditional industries.

New low-carbon, high-efficiency, and low-carbon industries and digital service enterprises have emerged from the digital economy. The digital economy changed energy, too. Energy has gone digital and intelligent with the emergence of the Internet and IoT. Digital technology increases solar and wind energy and reduces fossil fuel use and carbon emissions (Sun & Chen, 2023).

The rapid development of China's digital economy has reduced carbon emissions by modernizing industrial structures. Digital transformation has increased resource usage efficiency and productivity in conventional industries, and low-carbon, high-efficiency new industries, and digital service sectors have driven economic growth. Zhu et al. (2022) find that the progress of the digital economy facilitates the transformation of energy composition and the production and use of renewable energy. China's digital economy and low-carbon economic transformation offer unique ways

to reduce carbon emissions. Industrial structure upgrading is critical for the connection between the digital economy and carbon emissions, and it reduces carbon emissions.

1.3 Problem Statement

China's industrialization and urbanization have driven economic growth in recent decades. This method has increased economic growth and living standards and caused severe environmental challenges. Large-scale industrial and urban construction has increased carbon emissions, aggravating global climate change (Dong et al., 2019). Some scholars have pointed out in their research that, according to the greenhouse gas report submitted by the Chinese government to the United Nations in 2021, national greenhouse gas emissions reached 13 billion tonnes of carbon dioxide equivalent, with the energy sector contributing as much as 77%, or approximately 11 billion tonnes, reflecting the dominant role of industrial production and urban expansion in carbon emissions (Xie & Zhang, 2022; Zhang et al., 2022). China initiated its industrialization in the 1980s, and through years of swift growth, it has emerged as the leading global manufacturer and exporter. The rapid growth of the industrial sector has led to significant energy consumption and emissions (Xu & Lin, 2015; Zhang & Chen, 2021). Sultana et al. (2023) state that the issue of carbon emissions is a global concern. China plays an essential role in the global carbon emission challenge, mainly due to its vast size, large population, and developed industry, which leads to its prominence in global carbon emissions. Long et al. (2015) point out through their research that the increase in carbon emissions seriously affects human health. The main issue addressed in this study is that China's rapid industrialization and urbanisation while driving economic growth, have also led to a surge in energy consumption and carbon emissions. This has resulted in environmental pollution, health threats and ecological crises, which may

jeopardise sustainable human development in the long term.

Traditional economic systems use fossil fuels like coal, oil, and natural gas for energy. Unfortunately, fossil fuel combustion releases greenhouse gases like carbon dioxide into the atmosphere (Cutlip & Fath, 2012). Tan and Hong (2018) assert that the ongoing release of greenhouse gases is the primary driver of global climate change, attributing it to carbon emissions. Therefore, there is growing concern about heavy fossil fuel use's environmental and social impacts and the urgent need to switch to cleaner, more sustainable energy sources. The traditional economy itself does not pose a threat to China's economy. However, in the current context of digitalisation and green development, some high-energy-consuming and high-polluting traditional industries are indeed facing pressure to transform. If they fail to upgrade promptly, it may affect the high-quality development of China's economy.

The rise of the digital economy signals a trend towards a more environmentally friendly and sustainable development. The digital economy has a lower energy demand than the traditional economy due to its reliance on efficient information technology and data transmission rather than large-scale industrial output and high energy consumption (Li & Zhou, 2024; Xue et al., 2022). The digital economy significantly promotes carbon emission reduction. By driving technological innovation and industrial upgrading, improving energy efficiency, and optimising resource allocation, the digital economy has become a key force in achieving high-quality economic development and green, low-carbon transformation (Yu & Zhu, 2023). It not only helps reduce carbon emissions intensity but also enhances environmental governance capabilities through digital means, reshapes industrial structures, and supports China in achieving its 'dual carbon' goals (Huateng et al., 2021; Yang et al., 2022).

There is a close correlation between the digital economy development level and carbon emissions. The digital economy encompasses various levels: digital infrastructure, industrialization, industrial digitization, technology innovation, and finance development. Weaknesses in any of these areas can lead to problems with the continued growth of carbon emissions (Cheng & Qu, 2023; Li & Pang, 2022; Yang & Wang, 2023).

First, the digital infrastructure level is an important support for the digital economy, including the Internet, data centres, and communication networks. If the digital infrastructure is sufficiently robust and efficient, digital economic activities will be expanded, leading to more carbon emissions. Inadequate digital infrastructure may lead to wasted energy for data transmission and storage, increasing the carbon footprint (Chang & Li, 2022; Zha et al., 2022).

Second, the digital industrialization level and industrial digitization level are also closely related to carbon emissions (Arogundade & Hassan, 2025; Hu, 2023). When firms and industrial sectors need to digitize sufficiently, they may rely on traditional, energy-intensive production methods, often accompanied by high carbon emissions (Zhu, 2022). Lack of sufficient digital industrialization may hinder enterprises' capacity to embrace energy-efficient and environmentally sustainable technologies, impeding efforts to decrease carbon emissions. Li and Wang (2022) believe that digital technology innovation level plays a crucial role in reducing carbon emissions. Zhao et al. (2022) have shown that digital technological innovation at a high level can contribute to reducing carbon emissions by driving energy efficiency, developing carbon capture and storage technologies, and so on. However, if digital technology is not adequately applied, related innovation opportunities may be missed,

leading to increased carbon emissions.

Thirdly, the digital finance development level also impacts carbon emissions (Li & Wang, 2022). Digital finance can support the development of renewable energy projects and carbon markets, thereby reducing carbon emissions. However, Tang et al. (2022) argue that if the digital finance development level is low, financial flows may need to be able to adequately support carbon abatement initiatives, making it challenging to address carbon emissions.

Therefore, another problem statement is that currently, China's digital economy is still in its infancy and faces challenges such as high energy consumption, inadequate infrastructure, and incomplete policy support (Shang et al., 2023). While there is great potential in the digital economy sector, its fast-growing nature means increased demand, including in data centres, cloud computing, electronic devices, and communication networks, which inevitably leads to greater electricity consumption (Zhang & Liu, 2022). In China, in particular, electricity is supplied mainly by fossil fuels, increasing carbon emissions.

The digital economy was supposed to enable industry restructuring and growth through technology and information technology (Tang et al., 2022). Unfortunately, the digital economy has not contributed to industrial structural upgrading or carbon reduction. Xue et al. (2022) argue that there are many reasons for this situation. Small and medium-sized enterprises (SMEs) and traditional manufacturers are reluctant to embrace digital technologies, even though they are rapidly evolving. Some businesses and localities may need more digital infrastructure and technical staff, thus limiting the development of the digital economy. Furthermore, government policies may fail to guide digital economy development for industrial restructuring (Chen et al., 2022; Lyu,

2022). Inconsistent, short-term policies and insufficient support for digital transformation can make businesses nervous about new projects. To realize the potential of the digital economy, governments should be more proactive in promoting digital innovation and sustainable growth (Dong et al., 2022).

The key issue that needs to be addressed urgently is how to leverage the digital economy to reduce carbon emissions. This can be achieved through the following measures: increasing the application of digital technologies, enhancing digital infrastructure, promoting industrial digital transformation, supporting research and development of new technologies, and improving policy and market supervision systems. These measures are crucial to achieving green, low-carbon, and sustainable development.

1.4 Research Objectives

The "dual carbon" development model—achieving "peak carbon" by 2030 and "carbon neutrality" by 2060—is driven by the digital economy. Panel, mediation, and spatial effect models are used to examine the digital economy's impact on carbon emissions in 30 Chinese provinces and cities from 2012 to 2021. Therefore, this study will introduce the following research objectives:

1. To evaluate the relationship between the digital economy and carbon emissions.
2. To examine the relationship between the digital economy and the industrial structure upgrading.
3. To investigate the relationship between industrial structure upgrading and carbon emissions.

4. To investigate the mediating effect of industrial structure upgrading between the digital economy and carbon emissions.
5. To evaluate the impact of spatial spillover effects of the digital economy on carbon emissions.

1.5 Research Questions

Based on the research objectives, the following research questions were formulated.

1. Is there a relationship between the digital economy and carbon emissions?
2. Is there a relationship between the digital economy and industrial structure upgrading?
3. Is there a relationship between industrial structure upgrading and carbon emissions?
4. Does industrial structure upgrading mediate the relationship between the digital economy and carbon emissions?
5. Is there a spatial spillover effect between digital economy and carbon emissions?

1.6 Significance of the Study

1.6.1 Practical Significance

To achieve "carbon neutrality" by 2060 and "peak carbon" by 2030, the "double carbon" objective entails examining the impact of the digital economy's expansion on carbon emissions. First, the digital economy flourishes. China's robust infrastructure and abundant people resources facilitate the growth of a digital economy (Liang et al.,