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Impact of Energy Transition on China's Economic Growth under Carbon Neutrality Climate Policies

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Abstract
President Xi has proposed climate action, and China will be carbon neutral by 2060. This paper investigates the changes in the energy consumption market during the energy crisis and finds out how different economic agents responded. In order to simulate the development of a high-quality economy, a vector auto-regression model (VAR) is constructed by using updated energy factors. First, it identifies the relationship between the factors that will influence carbon emissions development and the digital economy. To determine how carbon emissions, energy consumption, and the digital economy respond to shocks generated between carbon emissions, energy consumption, and the digital economy, this paper performs impulse response analysis on three indicators. Digital economy development requires a lot of energy to fuel its economic activities. Furthermore, technological improvements will reduce the unnecessary consumption of energy and thus contribute to carbon neutrality. In this paper, the greatest contribution is the use of VAR models to investigate the impulse effects of carbon neutrality. This is a challenging energy environment. Using impulse response analysis, the model takes into account effects on energy consumption and income, which makes it more realistic when simulating carbon neutrality.

Keywords: Vector Auto Regression (VAR) model, The Pulse Effect, Time Series Data, Carbon Neutrality, The Russian-Ukrainian War

Introduction
China's President Xi suggested taking climate action to become carbon neutral by 2060. China has consistently led the world in CO2 emissions over the past ten years. In 2020, China produced nearly 9.9 billion tons of CO2, which accounted for 30.66% of all emissions worldwide. By 2030, Chinese CO2 emissions are expected to peak between 10.4 and 11 billion tons.

Climate and energy have always been intertwined. During the First and Second industrial revolutions, steam and internal combustion engines greatly enhanced industry productivity. However, cotton and steam engines required a greater supply of iron, steel, and coal. Internal combustion engines permitted fuel to be burned within a machine, converting the heat it produced directly into a heat engine. With the arrival of the third industrial revolution, the information age, network demand has increased. This has resulted in the need for a large number of data centers, which in turn increases electricity demand. Consequently, energy consumption and carbon dioxide emissions from machines are becoming an increasing environmental concern.

Scholars have long been concerned about climate and energy policies. There has been a great deal of discussion about the relationship between economic growth and carbon emissions, so several models have been developed to study this relationship. According to the environmental Kuznets curve theory, economic growth and carbon emissions exhibit a U-shaped relationship, and when economic growth gradually saturates, the increase in carbon emissions will negatively affect the economy. To observe the impact of energy and carbon emissions on economic growth in the era of knowledge-intensive and digital transformation, this paper develops a new model of the relationship between energy and carbon intensity, economic growth, and the digital economy. As well, this paper constructs external shocks through standard deviations to observe the changes in both the variables themselves and other factors in response to external shocks. The paper's innovation and contribution are here.

To develop corresponding rational energy and climate policies, the purpose of this paper is to investigate the relationship between energy mix, carbon emissions, and the digital economy. Hopefully, the following questions will be answered at the end of the paper:

1. What are the Climate Policies of China? Is there any relationship between Energy policies and Climate Policies?
2. What is the relationship between Carbon emissions and the digital economy?
3. How the energy crisis is used as an external shock to impact China's output and carbon emissions response?

This paper is structured as follows: Chapter 1 introduces the hot topics discussed in academia and the shortcomings of the research sought in these studies. Chapter 2, details the vector autoregressive model, constructs new indicators, and then applies the vector autoregressive model to find the relationship between the new variables. Chapter 3 analyzes the current state of the energy mix and finds the relationships of factors through the results of the model. In Chapter 4, the reasons behind the factor relationships are analyzed, and corresponding policy recommendations are given. Chapter 5 summarizes the innovative findings of this paper through the results and analysis and gives directions for future research to address the shortcomings of this paper.

Academic Background and literature review

Climate change has resulted in global warming, glacial melting, and more extreme weather events. To mitigate the current climate situation, various government departments have adopted corresponding policies. Carbon neutrality, for example, refers to the consumption of excess carbon dioxide emissions using afforestation, energy conservation, and emission reduction, thereby achieving a dynamic balance of carbon emissions. An objective of carbon neutrality is not to achieve "absolute zero emissions", and this level of emission reduction is difficult to achieve. Rather, it is a means of reducing the impact of anthropogenic emissions on nature to an almost negligible level through technological innovation, achieving a new balance between anthropogenic emissions sources and nature, and achieving a harmonious coexistence between humans and nature as a whole.

Currently, China has established specific targets for achieving carbon neutrality at different times:

Figure 1.: The specific targets of different periods

	2025	2030	2060
Target	The country's carbon dioxide emissions per unit of GDP will be lowered by 18 percent from the 2020 level, and by 2030 will have dropped by more than 65 percent compared with the 2005 level. China's energy consumption per unit of GDP will be lowered by 13.5 percent from the 2020 level, the forest coverage rate will have reached 24.1 percent, and the forest stock volume will have risen to 18 billion cubic meters.	China's total installed capacity of wind power and solar power will reach over 1,200 gigawatts, the forest coverage rate will have reached about 25 percent, and the forest stock volume will have reached 19 billion cubic meters.	China will have fully established a clean, low-carbon, safe and efficient energy system, with energy efficiency reaching the advanced international level, according to the guideline.

Source: http://www.news.cn/english/2021-10/25/c_1310266060.htm

Scholars studying carbon emissions can be divided into two main areas: the drivers of carbon emissions and the issue of the efficiency of carbon emissions.
From the drivers of carbon emissions, we aim to identify the sources of pollution and eliminate them from the source. The efficiency of carbon emissions leads to the efficiency of energy conversion, resulting in the reduction of energy consumption and waste by improving the efficiency of energy use. By linking regional and global datasets, Bin Su analyzes the spatial aggregation problem of determining region-specific emissions and intensities of countries, providing MRIO and SDA formulas for implied emissions and intensities, and finding that spatial aggregation affects regional results more than sectoral results. (Su et al., 2021) In addition to demonstrating the impact of changes in industrial structure on carbon intensity, Zhenguo Wang also demonstrates the effect of structural decomposition on carbon intensity. (Wang et al., 2020) A structural decomposition analysis (SDA) model was used by Fan and Sanmang Wu to analyze the trend of total carbon emissions in Beijing in 2002, 2007, and 2012. It was proposed that carbon emission reductions be proposed at the urban and rural levels based on the relationship between urban and rural carbon consumption and emissions. (Fan et al., 2019) It is argued by Hao Cai that China's export carbon footprint is characterized by a reverse "U" shaped pattern and that the secondary sector is responsible for the majority of China's export carbon footprint. (Cai et al., 2020) Moreover, Zhang examined six possible key factors associated with changes in regional energy consumption. During the period 1987–2007, changes in final demand outweighed efficiency gains,

driving energy use in all regions, and improving energy efficiency in key industries would lead to a significant reduction in energy intensity. (Zhang & Lahr, 2014) Accordingly, scholars have examined industrial structure, urban-rural differences, and regional differences to determine the cause of the increase in carbon dioxide emissions.
The efficiency of carbon emissions is used to examine the problems that arise during the energy transformation process. Xianyong Lin assessed and optimized the energy structures of 29 countries and regions, concluding that developed countries have a higher energy conversion efficiency than laggards. (Lin et al., 2020) From 1997 to 2004, Zhou examined the emission performance of the world's 18 largest carbon dioxide emitters using this index. He concluded that technological progress has contributed to the reduction of total factor carbon emissions. (Zhou et al., 2010) Using the perspective of households and businesses, Donald Huisingh examines the efficiency of emissions in different sectors, technological innovation, and policy development. In his view, fossil-free production should be enhanced, and efficient use of resources achieved. (Huisingh et al., 2015) As part of a comparison of the impact of carbon trading policies on industrial enterprises' carbon emissions from 2008 to 2016, Wei Zhang analyzed industrial carbon emission data from 30 Chinese provinces. In addition, he considers the operational efficiency of seven carbon emission trading markets (ETMs), concluding that carbon trading policies increase the total value of industrial production. (Zhang et al., 2020)

Several scholars have examined the relationship between carbon emissions and economic growth using models. William D. Nordhaus argues that long-term macroeconomic models can incorporate insights from natural and climate science and market failures resulting from CO2 emissions. Various warming pathways are derived based on the relationship between GDP growth and CO2 levels and the impact of CO2 on global average temperatures. (Nordhaus, 1991) Paresh Kumar Narayan tested the Environmental Kuznets Curve (EKC) hypothesis in 43 developing countries, from which he concluded that long-term income elasticity is smaller than short-term income elasticity, and as income increases, CO2 emissions decrease. The model revealed that this phenomenon occurs only in the Middle East and South Asia. (Narayan & Narayan, 2010) Based on empirical results, Lin Boqiang calculates a general equilibrium model that predicts future oil demand and simulates the impact of electric vehicles on conventional energy sources, macroeconomics, and carbon dioxide emissions. Electric vehicles will have a positive impact on carbon emissions as they become more popular. (Lin & Wu, 2021) Under three different scenarios, Levent Andin analyzes the impact of oil price shocks using TurGEM-D, a dynamic multisectoral general equilibrium model for the Turkish economy. (Aydın & Acar, 2011) Vijay P. Ojha demonstrates that there is a perceived imbalance between carbon emissions and economic growth, resulting in a lack of incentive for governments to implement carbon reduction policies. The possibility of shifting carbon tax revenues to households for use in construction or the clean energy sector may also improve income distribution. (Ojha et al., 2020)

There has been a great deal of research done on the causes, effects, and projections of energy efficiency and economic growth. The effects of carbon emissions have been extensively studied in relation to the energy industry and mapped to economic growth. Yet, little attention has been paid to the relationship between the digital economy and carbon emissions. On the basis of Chinese provincial data from 2003-2018, Xie constructs a total factor non-radial directional distance function (TNDDF), and argues that the digital economy will reduce carbon emissions and accelerate the move towards carbon neutrality. (Xie & Zhang, 2022) As Kangni Lyu argues, the digital economy has a nonlinear effect on spatial carbon emissions, as well as an inverted U-shaped structure in terms of carbon emission efficiency. The effect of the digital economy on carbon emissions is significant regional heterogeneity and city-scale variation, which leads to an initial increase in carbon emissions followed by a subsequent decrease in carbon emissions. (Lyu et al., 2023)

Based on the current research status, this paper will use a vector autoregressive model in order to analyze and predict the relationship between carbon emissions and the digital economy. It is important to note that the digital economy is still a new and hot topic, and most scholars tend to focus on the industrial sector for the most part, since it is directly related to carbon dioxide emissions, as opposed to emerging industries, which have an indirect relationship with carbon dioxide emissions. However, the research direction of this paper is in line with the 14th Five-Year Plan strategy, which can provide a better understanding of the green development and digital development of China's economy.

2. Methodology

2.1 Indicator construction

On the basis of existing data, this paper constructs three data indicators: carbon dioxide emissions, total energy production, and income level in the digital economy. In the first place, as the units of data are not the same, it is necessary to quantify their data. Our paper uses log function transformation, which reduces the variability of the data and makes the meaning of the data clearer by transforming it by a certain base.

$$New\ Value = Ln(\ Value)$$

2.2 Model design

It is common for explanatory and explanatory variables to be set up when studying the relationship between variables. As a result, causality will be used to identify the explanatory and explained variables involved in the relationship between their factors. It is important to understand that reality is complex, and some factors that are independent variables may also be dependent variables at the same time. As a result, the use of the joint cubic equation structure will allow a clearer understanding of the relationship between the interactions of variables.

$$\begin{aligned} Y_{1,t} &= \alpha_1 + \beta_{11,1} Y_{1,t-1} + \beta_{12,1} Y_{2,t-1} + \beta_{13,1} Y_{3,t-1} + \varepsilon_{1,t} \\ Y_{2,t} &= \alpha_1 + \beta_{21,1} Y_{1,t-1} + \beta_{22,1} Y_{2,t-1} + \beta_{23,1} Y_{3,t-1} + \varepsilon_{1,t} \\ Y_{3,t} &= \alpha_1 + \beta_{31,1} Y_{1,t-1} + \beta_{32,1} Y_{3,t-1} + \beta_{33,1} Y_{3,t-1} + \varepsilon_{1,t} \end{aligned} \begin{bmatrix} y_{1,t} \\ y_{2,t} \\ y_{3,t} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} + \begin{bmatrix} \varphi_{11} & \varphi_{12} & \varphi_{13} \\ \varphi_{21} & \varphi_{22} & \varphi_{23} \\ \varphi_{31} & \varphi_{32} & \varphi_{33} \end{bmatrix} + \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \\ y_{3,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \end{bmatrix}$$

$Y_{1,t}$: *Total CO2 Emissions values at t time period*;

$Y_{2,t}$: *Total Energy Consumption at t time period*;

$Y_{3,t}$: *Revenue from Software Business at t time period*.

2.3 Data collection

To analyze the relationship between factors, this paper collected data from 2005 through 2021. This is primarily due to the fact that the 11th Five-Year Plan (2006-2010) started to encourage the upgrade of industrial structures and China gradually moved toward the era of the Internet. Therefore, the purpose of this study is to measure the relationship between these three indicators from the CSMAR database.[1]

3. Results

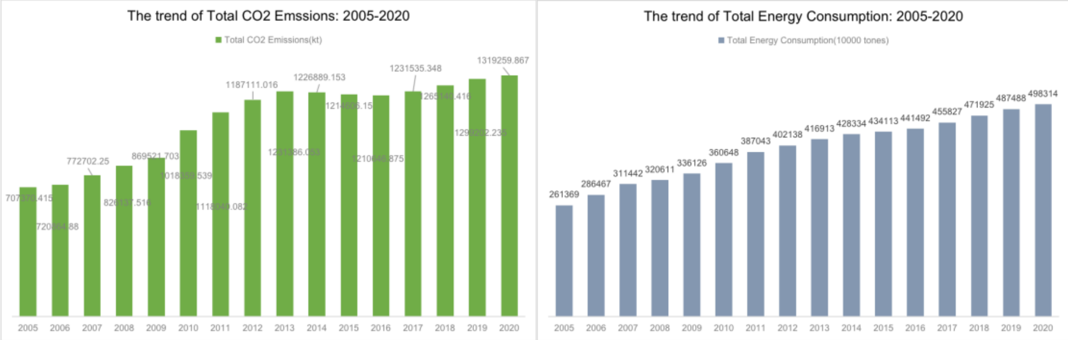
3.1The current situation

Carbon emissions have generally changed in two phases: from 2005 to 2013 and after 2014. Between 2005 and 2013, there was a significant increase of 67% in the number of people. Nevertheless, after 2013, the growth rate remained relatively low, at approximately 3%. As compared to 2014, there was negative growth in 2016, with a 1.3% decrease in carbon emissions. There was a very slow growth in 2020, mainly due to the effects of the epidemic, with an increase of 1.5%.

Unlike the situation regarding carbon emissions, the overall energy consumption is showing a linear growth trend, and the total energy consumption in 2020 is estimated to be approximately 4.97 billion tons of standard coal, meeting the "13th Five-Year Plan" target of "controlling the total energy consumption within 5 billion tons of standard coal". According to the 13th Five-Year Plan, the target of controlling total energy consumption within 5 billion tons of standard coal has been achieved. Despite this, it is important to note that there has been an increase of 90% between 2005 and 2020. The massive energy consumption is a reflection of the fact that energy consumption is still on the rise. In comparison with 2019, 2020 shows a 2.2% increase. An increasing trend is also evident in production corresponding to energy consumption.

[1] CSMAR, short for China Stock Market & Accounting Research Database, is a comprehensive research-oriented database focusing on China's Finance and Economy.

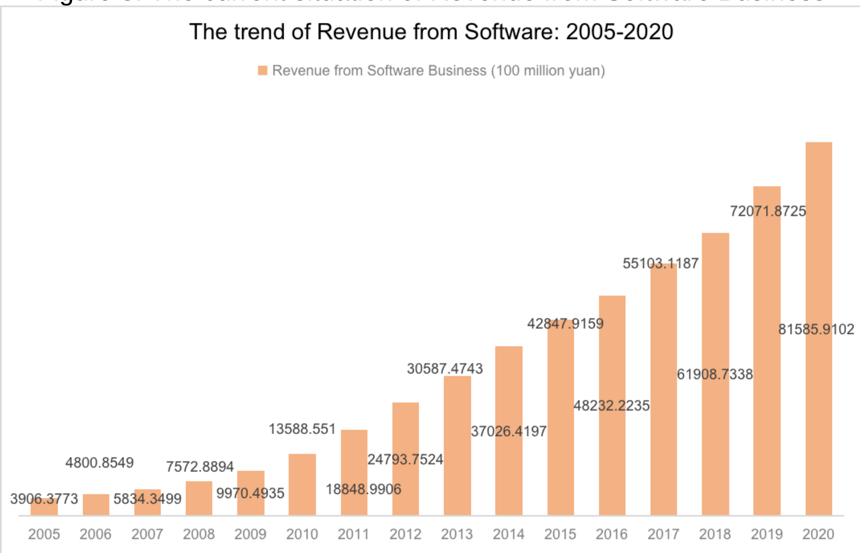
Figure 2: The current situation of CO2 and Energy Consumptions



Source: CSMAR Database

It is important to note that software revenue increased at a low rate from 2005 to 2008, with no significant growth. In 2009, the company began to grow at a fast rate, resulting in an increase of sevenfold. There were fluctuations in the number of businesses above the scale of the software industry in 2020, but the overall number was over 32,000 and has shown an upward trend over the past few years. Despite the epidemic, software revenue did not decrease; rather, it increased by 13% compared to the same period last year. As of now, the digital economy is still experiencing rapid growth and will continue to do so for some time to come.

Figure 3: The current situation of Revenue from Software Business

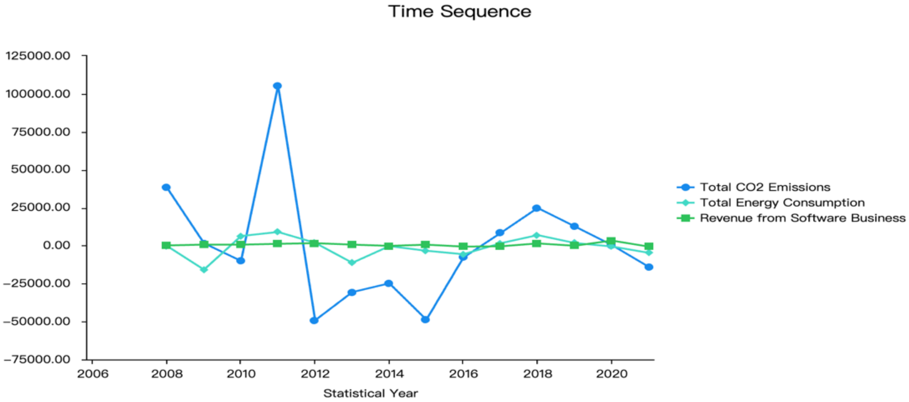


Source: CSMAR Database

3.2 Examination of smooth series

Time series charts can be used to illustrate a variable's evolution over time and are often used to assess the data's stability over time. It is possible to judge the degree of smoothness of the time series data before conducting a VAR model, for example, by examining the consistency of the trend of the time series data.

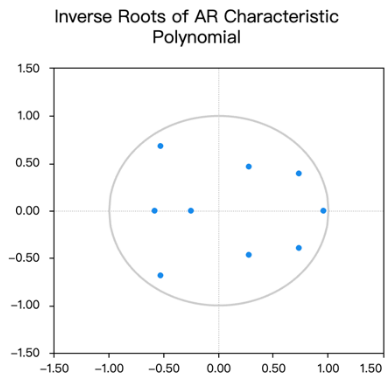
Figure 4: Time Sequence



Source: Own work

It is important to determine the stability of the VAR model after it has been constructed by examining the AR root diagram; from the diagram, we can see that all characteristic values are within the unit circle, i.e. all the points are within the circle, indicating that the model is stable at present.

Figure 5: Characteristic Polynomial



Source: own work

3.3 Impulse corresponding analysis

A model can be constructed in which each variable is used separately as the dependent variable in order to study the effects of random perturbations from other variables, including the dependent variable's own lagged value by one standard deviation, as well as the changes in the path of their effects. By using the impulse response function, one can describe the trajectory of these effects by showing how perturbations of one variable affect all other variables in the model and eventually feed back into the model itself. There are three lags of data in the model, i.e., the three indicators are influenced by their own data from the previous three periods, as well as by each other's data. It is confirmed that the three indicators satisfy the previous assumptions. Orthogonalized impulse response plots illustrate the dynamic impact of a shock on a variable or other variables. In general, if the absolute value is greater than 0, it represents a positive shock, and if it is less than 0, it represents a negative shock, with greater absolute values representing larger shocks and smaller absolute values representing smaller shocks.

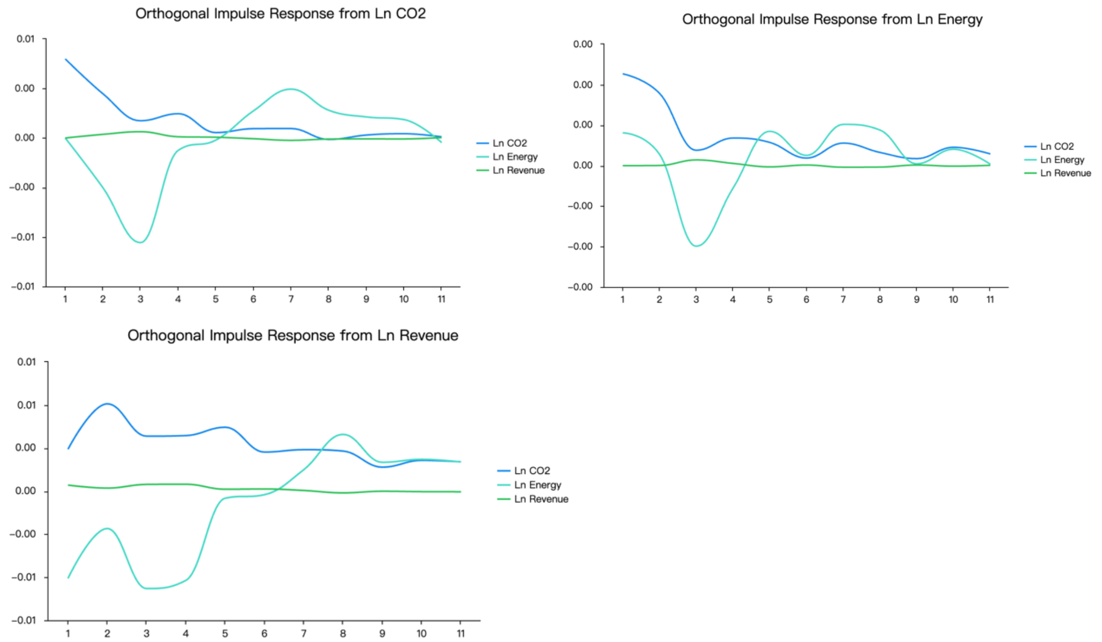
$$
\begin{aligned}
Ln\ CO2 = {} & 7.755 + 0.162 * L1.Ln\ CO2 + 0.144 * L1.Ln\ Energy + 0.518 * L1.Ln\ Revenue - 0.235 * L2.Ln\ CO2 \\
& - 1.228 * L2.Ln\ Energy + 0.553 * L2.Ln\ Revenue - 0.144 * L3.Ln\ CO2 + 0.746 * L3.Ln\ Energy - 0.750 * L3.Ln\ Revenue \\
Ln\ Energy = {} & 2.935 + 0.201 * L1.Ln\ CO2 + 0.422 * L1.Ln\ Energy + 0.012 * L1.Ln\ Revenue - 0.306 * L2.Ln\ CO2 \\
& - 0.158 * L2.Ln\ Energy + 0.287 * L2.Ln\ Revenue - 0.170 * L3.Ln\ CO2 + 0.425 * L3.Ln\ Energy - 0.191 * L3.Ln\ Revenue \\
Ln\ Revenue = {} & -4.238 + 0.680 * L1.Ln\ CO2 + 0.495 * L1.Ln\ Energy + 0.507 * L1.Ln\ Revenue - 0.438 * L2.Ln\ CO2 \\
& - 0.553 * L2.Ln\ Energy + 0.501 * L2.Ln\ Revenue - 0.556 * L3.Ln\ CO2 + 1.366 * L3.Ln\ Energy - 0.257 * L3.Ln\ Revenue
\end{aligned}
$$

Three graphs illustrate the extent to which the shock has been transmitted from one indicator to another and to other indicators. A shock is experienced by CO2 when it is shocked on its own. It has a hugely positive reaction, followed by a return to normal in the third period. As a result of this shock, energy consumption does not respond significantly and remains at approximately 0. In contrast, the digital economy's software revenue has a large negative shock in the second period and peaks at -0.01 in the third period. It turns from negative to positive in the sixth period and reaches 0.02 in the seventh period.

If energy consumption is hit by its own standard deviation, it is also positively impacted in the first period, but its response is negative in the third period, after which it slowly returns to normal. The relationship between CO_2 emissions and total energy consumption is similar, but the response tends to be moderate. In the first and second periods, CO_2 emissions are strongly positive, and then they return to normal in the third period.

A positive response to the standard deviation of the shock for digital economy income results in CO_2 emissions. As a result, the development of the digital economy contributes negatively to CO_2 emissions, while it hurts energy consumption, reaching its maximum negative value during the third and fourth periods.

Figure 6: The Orthogonal Impulse Response



Source: Own work (the data is in the appendix)

3.4 Differential term analysis

The fluctuations in CO_2 emissions are primarily the result of its own shocks, which explain 100% and 75% of the fluctuations in the first and second periods, respectively, before dropping rapidly to about 38% in the third period. As a whole, other energy consumption and digital economy income account for approximately 25% of the CO_2 fluctuations, with energy consumption accounting for the majority of both. In the first two periods, shocks in CO_2 emissions mainly explain 88% and 90% of fluctuations in energy consumption, while digital economy income explains a negligible number of fluctuations. Most of the fluctuations in digital economy income are attributed to changes in total energy consumption, accounting for 80% in the first period and remaining around 50% for the next nine periods.

Variance Decomposition-Ln CO2

Period	Variance Decomposition of S.E.	Ln CO2(%)	Ln Energy(%)	Ln Revenue(%)
1	0.004	100.000	0.000	0.000
2	0.005	76.824	23.052	0.124
3	0.007	38.748	61.010	0.242
4	0.008	40.076	59.683	0.241
5	0.008	40.144	59.613	0.243
6	0.008	39.112	60.652	0.237
7	0.008	35.726	64.039	0.235
8	0.008	34.705	65.062	0.233
9	0.008	34.160	65.608	0.232
10	0.008	33.783	65.985	0.232

Impulse Response Table-Ln Energy			
Period	Ln CO2	Ln Energy	Ln Revenue
1	0.002	0.001	0.000
2	0.002	0.000	0.000
3	0.000	-0.002	0.000
4	0.001	-0.001	0.000
5	0.001	0.001	-0.000
6	0.000	0.000	0.000
7	0.001	0.001	-0.000
8	0.000	0.001	-0.000
9	0.000	0.000	0.000
10	0.000	0.000	-0.000
11	0.000	0.000	0.000

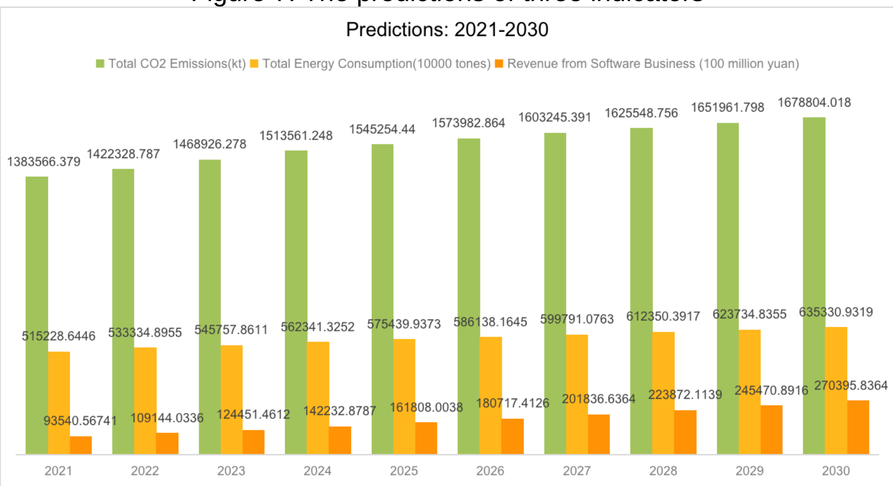
Impulse Response Table-Ln CO2			
Period	Ln CO2	Ln Energy	Ln Revenue
1	0.004	0.000	0.000
2	0.002	-0.003	0.000
3	0.001	-0.005	0.000
4	0.001	-0.001	0.000
5	0.000	-0.000	0.000
6	0.000	0.001	-0.000
7	0.000	0.002	-0.000
8	-0.000	0.001	-0.000
9	0.000	0.001	-0.000
10	0.000	0.001	-0.000
11	0.000	-0.000	0.000

3.5 Forecasting

Based on the impulse effect, the corresponding projections have been made for the three indicators in this paper. As can be seen from the graph, CO2 emissions are gradually increasing, however, energy consumption remains at approximately 55,000,000 tons. There will be a synchronized increase in both CO2 emissions and energy consumption by 2030, which will result in a 23% reduction in CO2 emissions and a 20% reduction in energy consumption.

Compared to the previous two, the digital economy's revenue will increase by 189% in 2030, which is a very fast growth rate and indicates a very strong momentum for its future growth.

Figure 7: The predictions of three indicators



Source: own work

4. Discussion

4.1 Current climate and energy policy

As a result of the rapid economic growth currently occurring, there has also been an increase in the consumption of energy as a result of the use of electricity. By increasing energy consumption, carbon dioxide emissions will increase, thereby increasing environmental pollution. The government has undertaken two initiatives to reduce carbon emissions: the construction of new energy base stations and the improvement of the efficiency of traditional energy sources. During the period 2022, renewable energy will continue to develop continuously and rapidly. Nationally, renewable energy installations exceed 1.2 billion kilowatts for the first time, surpassing coal power installations.

The government has increased investment in coal power conversion efficiency along with building traditional coal power plants. Global energy prices have spiked due to tensions in Russia and Ukraine, and domestic electricity consumption has been restricted. Therefore, China has approved 82 coal-fired power plant projects for construction in 2022, totaling 106 megawatts (gigawatts) of generation capacity. There have been six times as many coal-fired power plants built around the world since 2015, and there has been unprecedented speed in the process from approval to construction. The reasons for the construction of 82 new coal-fired power plants approved for 2022 have been disclosed by 57 of them in official documents, with the following new coal-fired projects appearing the most frequently: "to ensure a safe supply of electricity" (28 times), "to provide heat services" (21 times), "to provide power growth services" (16 times), etc. (GreenPeace, 2023). It is expected that new coal plants will be built to eliminate obsolete capacity and increase coal conversion rates, thereby reducing energy waste as well as CO2 emissions.

It is expected that coal will reach its peak by the years 2025–2030 in accordance with the "Action Plan for Achieving Carbon Neutrality by 2030" (Committee, 2021)and the "Opinions on Complete and Accurate Implementation of the New Development Concept for Carbon Neutrality"(Council, 2021). Approximately 2025–2030, coal consumption is expected to reach a peak coal demand ceiling according to the "Pre-2030 Carbon Peaking Action Plan," and peak coal consumption is expected to be approximately 2.94 billion tons of standard coal, with a compound annual growth rate of about 0.8% in comparison to 2020 (Council, 2021).

4.2 The relationship between the digital economy and carbon emissions

An economic system based on digital technologies and conducted through the Internet and other digital means is referred to as the digital economy. In most cases, carbon emissions are related to energy consumption in the digital economy. For the purpose of collecting, organizing, and computing network data, the digital economy relies on a large number of data computing centers. In order to accomplish this task, large amounts of energy, such as electricity, are required. Consequently, a considerable amount of carbon dioxide is generated during the production and consumption of energy.

Meanwhile, the digital economy relies on the development of new technologies. Through the constant advancement of information technology, it is possible to improve economic efficiency and minimize the consumption of resources and energy. It is possible to reduce CO2 emissions through the use of intelligent energy management systems that optimize energy use and reduce energy waste. In order to save energy consumption and reduce energy costs, energy management is the process of proactively monitoring, controlling and optimizing organizational energy consumption.

Furthermore, the digital economy has contributed to technological innovation, including the development of green technologies. An example, are renewable energy, intelligent transportation systems, smart city solutions, etc. It is believed that the application of these green technologies can contribute to the reduction of CO2 emissions and promote sustainable development.

4.3 The sustainable development of China

It is expected that the digital economy will develop rapidly with the premise of achieving carbon neutrality, as the study of this paper demonstrates. There are currently large numbers of energy supply plants being built in China, as well as infrastructure that will ensure the delivery of electricity. There will be a gradual shift in the mix of energy consumption, as well as a significant reduction in the use of fossil fuels. In addition, solar power and wind power have become the new mainstays of power generation. The Chinese government, however, continues to build coal plants in order to prevent power shortages and ensure electricity security, on the one hand, and to upgrade the equipment at traditional energy plants, on the other, in order to enhance energy generation efficiency and reduce greenhouse gas emissions.

With a sufficient supply of electricity, the digital economy will grow more rapidly. A development strategy for 'Eastern Digital and Western Computing' was promulgated by China in 2022 with the aim of increasing the speed of the digital economy and achieving carbon neutrality. (Commission, 2022) In part, the purpose is to alleviate the congestion of data in the computing centers in the eastern region, which is densely populated and where many economic and commercial activities take place. As for wind power generation, it is to make the most of existing wind resources in order to minimize CO2 emissions while using wind power more effectively in the western region. The new development plan will contribute to coordinated regional development, reduce environmental pollution from traditional energy generation, and promote the development of a digital economy. The goal of sustainable development will ultimately be achieved through this initiative.

Summary

As energy demand grows and greenhouse gas emissions increase, carbon emissions are still increasing. Carbon emissions are primarily caused by the development of energy production and use, as well as industrial production. Therefore, achieving carbon neutrality requires improvements in energy production. The purpose of this paper is to compare the different stages of carbon-neutral climate policies, in order to examine the goals that the government has set for each stage. An analysis of the causal relationship between carbon emissions, energy consumption, and the digital economy is presented in this paper using vector autoregression to observe the relationship between the indicators. A vector autoregression model requires a limited amount of data and can be used to predict the number of independent variables. The problem of data scarcity has been resolved in the digital economy, which has developed in recent years.

As a result of the findings, carbon emissions are influenced by their own data in the first three periods, but when it is subject to shocks, their own explanation is most likely to explain the fluctuations. Energy consumption is the mediator between carbon emissions and the digital economy, and the fluctuations of the digital economy are primarily influenced by energy consumption. Despite the growth of the digital economy in the future, CO_2 emissions and energy consumption will gradually decrease due to people's desire for sustainable development.

There are, however, some drawbacks to this study, since the vector self-consistency model is a purely theoretical model, and when significant sudden shocks and changes in variables occur, there will be data bias. To further investigate the impact of unexpected events, it needs to be combined with other models.

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Appendix

Table: The Impulse Response Table from Three Indicators

Impulse Response Table-Ln CO2			
Period	Ln CO2	Ln Energy	Ln Revenue
1	0.004	0.000	0.000
2	0.002	-0.003	0.000
3	0.001	-0.005	0.000
4	0.001	-0.001	0.000
5	0.000	-0.000	0.000
6	0.000	0.001	-0.000
7	0.000	0.002	-0.000
8	-0.000	0.001	-0.000
9	0.000	0.001	-0.000
10	0.000	0.001	-0.000
11	0.000	-0.000	0.000

Impulse Response Table-Ln Energy			
Period	Ln CO2	Ln Energy	Ln Revenue
1	0.002	0.001	0.000
2	0.002	0.000	0.000
3	0.000	-0.002	0.000
4	0.001	-0.001	0.000
5	0.001	0.001	-0.000
6	0.000	0.000	0.000
7	0.001	0.001	-0.000
8	0.000	0.001	-0.000
9	0.000	0.000	0.000
10	0.000	0.000	-0.000
11	0.000	0.000	0.000

Impulse Response Table-Ln Revenue			
Period	Ln CO2	Ln Energy	Ln Revenue
1	0.002	-0.005	0.000
2	0.005	-0.002	0.000
3	0.003	-0.006	0.000
4	0.003	-0.005	0.000
5	0.004	-0.000	0.000
6	0.002	-0.000	0.000
7	0.002	0.001	0.000
8	0.002	0.003	-0.000
9	0.001	0.002	-0.000
10	0.002	0.002	-0.000
11	0.002	0.002	-0.000

Source: Own work

Table: The predictions data

Predictions			
Time	Total CO2 Emissions(kt)	Total Energy Consumption(10000 tones)	Revenue from Software Business (100 million yuan)
2021	1383566.379	515228.6446	93540.56741
2022	1422328.787	533334.8955	109144.0336
2023	1468926.278	545757.8611	124451.4612
2024	1513561.248	562341.3252	142232.8787
2025	1545254.44	575439.9373	161808.0038
2026	1573982.864	586138.1645	180717.4126
2027	1603245.391	599791.0763	201836.6364
2028	1625548.756	612350.3917	223872.1139
2029	1651961.798	623734.8355	245470.8916
2030	1678804.018	635330.9319	270395.8364

Source: own work