Study on the Economic Effects of Dual-Carbon Economy from the Perspective of General Equilibrium Theory

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Abstract. This paper takes the general equilibrium theory as the research perspective, takes the three new economic growth modes of green technological progress, green consumption, and green finance as the basis, constructs a dual-carbon economic growth model including carbon emissions trading, analyses the economic effect of dual-carbon economic growth theoretically, and conducts numerical simulation using Chinese data, and the results show that the dual-carbon economy can effectively promote the progress of China's green technology and green consumption, and achieve high-quality economic development.

Keywords: General Equilibrium theory, Dual-carbon, Economic Growth model

1 Introduction[1]

The dual-carbon economy is a new economic growth model proposed in the context of "carbon peaking" and "carbon neutrality", which aims to achieve high-quality economic development by promoting three new economic growth models: technological progress, green consumption and green finance. At present, academic research on dual-carbon economy mainly focuses on the theory and policy research of dual-carbon economy, while there are relatively few related studies from the perspective of general equilibrium theory. This paper constructs a dual-carbon economic growth model including carbon emissions trading under the framework of general equilibrium theory, theoretically analyses the role of the dual-carbon economic growth model on green technological progress, green consumption and green finance, and conducts numerical simulation using Chinese data, and the results of the study show that the dual-carbon economic growth model can effectively promote the high-quality development of China's economy.

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2 Literature Review

This paper takes the general equilibrium theory as the research perspective and adopts the general equilibrium model (hereinafter referred to as the general equilibrium model) that includes carbon emissions trading to analyse the impact of dual-carbon economic growth on China's economic growth.

The general equilibrium model is an abstract modelling of the real world from the real world, through the introduction of micro subjects such as the enterprise sector and the household sector, abstracting the economic variables and economic subjects in the real economy, and portraying the operating laws of the real world through the analysis of the model. The research in this paper contains three main parts: general equilibrium model, carbon emission right trading model and energy pricing model.

The article "Towards a general equilibrium theory of allocation of time for the digital revolution era." by Sanchis Raúl G contributes to the existing literature on time allocation theoretical models by suggesting a general equilibrium framework likely to respond to some existing challenges in modern economies.[1].

Bai Xue;Chatterjee Arpita;Krishna Kala;Ma Hong develops a new model with heterogeneous firms under perfect competition in a Heckscher-Ohlin setting. [2].

Beenstock Michael The study explores some implications of SGE theory for the aggregate supply of GDP in terms of spatial differences in total factor productivity (TFP) and amenities. [3].

Michael Beenstock explore how spatial factors, such as transportation costs, trade barriers, and regional policies, impact the overall productive capacity and allocation of resources within a spatial economy. [4].

Douglas Gale;Piero Gottardi develop a general equilibrium theory of the capital structures of banks and firms. [5].

Yasuhiro Sakai is concerned with the question of why and how my research interest has been changed from general equilibrium theory to the economics of uncertainty. [6].

Simone Landini;Mauro Gallegati;J. Barkley Rosser estimated behavioral assumptions for agents that may allow for a better way to model non-equilibrium evolutionary economic dynamics. [7].

3 Theoretical Model

3.1 General Equilibrium Theory

General Equilibrium Theory (GET) is a branch of theoretical microeconomics that seeks to explain production, consumption and prices within the framework of the overall economy.

3.2 Economic Growth Models

Economic growth models are models used to describe long-term growth and development in an economic system. These models attempt to explain the causes, drivers, and effects of economic growth on economic variables (e.g., output, employment, investment, etc.). Below are two common models of economic growth.

3.3 CEG Model

CEG is a computational approach based on the general equilibrium theory of Vallas and the basic idea is to transform the framework of general equilibrium theory into a computable model for empirical analysis and policy evaluation. It solves for the equilibrium state in an economic system through mathematical modelling and computational methods, thereby revealing the interdependence between markets and the efficiency of resource allocation.

4 Research Methods

(1) Literature survey method Literature review method is a method of collecting, identifying and organising literature to develop a scientific understanding of facts through the study of literature. Existing literature is collected to gain an overview and understanding of the research topic and related studies and current status both at home and abroad. Conducting targeted analytical studies to formulate hypotheses, which are then tested using the scientific method to form new conclusions and hypotheses.

(2) Theoretical Modeling (Theoretical Modeling): Based on the existing theoretical framework or constructing a new theoretical model, derive mathematical formulas for economic relationships, conduct qualitative or quantitative analysis, and infer economic phenomena and predict results through model analysis.

5 Research Results

5.1 Research Object

The energy consumption of gas, natural gas, liquefied petroleum gas (LPG) and annual electricity consumption of 281 cities at prefecture level and above in China from 1990-2022 were obtained from China Urban Statistical Yearbook, China Urban Construction Statistical Yearbook and China Energy Statistical Yearbook, and the missing values of energy in individual cities were supplemented by interpolation method. Coal power generation, total power generation and carbon dioxide emission coefficients of each energy source for each year were obtained from China Electric Power Yearbook, China Electric Power Statistical Yearbook and China Contract Energy Management Network, respectively.

This paper examines the economic effects of dual-carbon economic growth through numerical simulation on Chinese data.

5.2 Research Method and Result Analysis

1. Carbon Emission Calculation: Based on the consumption of various energy sources and their corresponding CO2 emission coefficients, we first calculated the carbon emission of each city.

2. Economic growth model: Next, we constructed a model describing economic growth based on general equilibrium theory. This model reflects how factors of production (including labour, capital and energy) are transformed into output, and how carbon emissions change in this process.

3. Carbon Emission Trading: We further introduce carbon emission trading into the model, considering that market players can buy or sell carbon emission rights to cope with carbon emission constraints.

Math and Equations

$$Y(t) = A * [K(t)]^{\alpha} * [L(t)]^{(1-\alpha-\beta)} * [E(t)]^{\beta} \tag{1}$$

$$K'(t) = I(t) - \delta * K(t) \tag{2}$$

$$C(t) = \eta * E(t) \tag{3}$$

$$\pi(t) = Y(t) - w(t) * L(t) - r(t) * K(t) - \tau(t) * C(t) \tag{4}$$

t is time;Y(t) is output;K(t) is capital stock;L(t) is labour;E(t) is energy use;A, α, β is a parameter;K'(t) is the rate of change of capital;I(t) is the investment;δ is the depreciation rate;C(t) is the carbon emissions;η is the carbon emissions per unit of energy produced;w(t) is the wage;r(t) is the return to capital;τ(t) is the carbon tax.

Using GAMS to construct the model, we obtained:

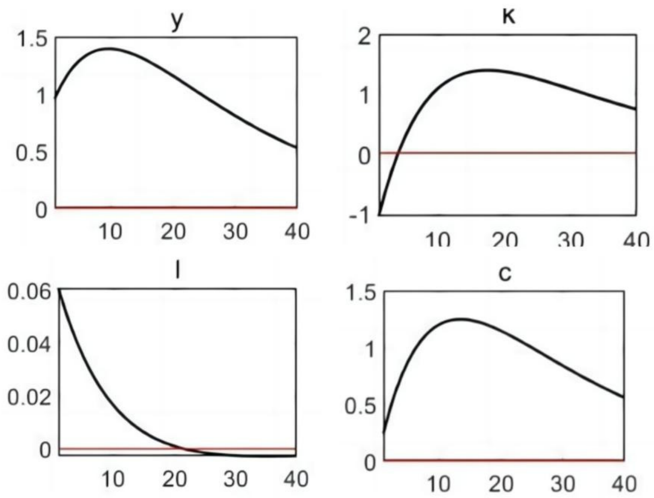

Figure 1. Impulse response diagram of the impact of technology shocks on China's economy

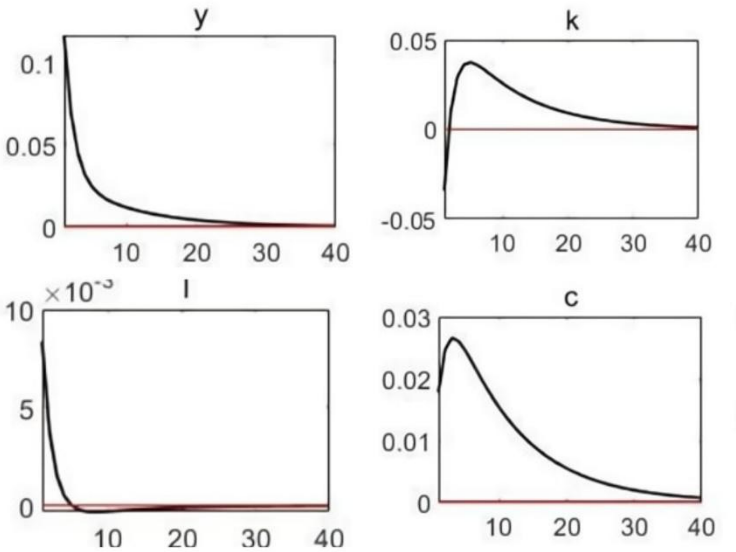

Figure 2. Measuring the effect of energy product efficiency shocks on China's economic growth

Table 1. Calorific value calculation (partial)

Year	Total Energy Consumption	As Percentage of Total Energy Consumption（%）			
	(10 000 tons of SCE)	Coal	Petroleum	Natural Gas	Primary Electricity and Other Energy
1958	87.6	83.5	0.8	0.1	21.3
1970	190.5	77.1	1.2	0.1	15.6
1975	240.7	72.4	1.8	0.1	16.3
1978	280.2	78.3	2.4	0.1	19.7
1980	320.0	73.4	3.8	0.2	22.8
1985	420.4	65.7	7.6	0.3	26.4
1990	707.3	57.6	9.2	0.1	33.1
1995	775.2	75.0	10.2	0.2	14.6
1996	808.8	74.8	9.7	0.2	15.3
1997	814.0	73.9	10.5	0.1	15.5
1998	816.9	70.9	12.8	0.2	16.1
1999	823.1	69.6	13.0	0.2	17.2
2000	1518.6	89.0	6.7	3.4	0.9
2001	1578.8	89.1	6.7	3.4	0.8

The impulse responses of the impacts of technological shocks on the Chinese economy are simulated by the GAMS software as shown in Figure 1, which shows the deviation levels of each variable from the current steady state over 40 years when subjected to technological advances. The simulated impulse responses over 40 years are to a certain extent close to China's 2060 carbon-neutral vision after 40 years. When the modeled equilibrium system is subjected to a positive technology level shock, the ability to transform resource inputs into economic outputs is further enhanced with the increase in technology level, and outputs increase by about 1%, which peaks in the ninth period and then gradually decreases, but is always higher than the initial steady state level, and after 40 years of fluctuations, there is still an increase of 0.5%, which also indicates that China's economic growth cannot be achieved without technological progress. This also shows that China's economic growth cannot be separated from technological progress. The decrease in capital, by 0.9% compared to the steady state level, indicates that the technological progress at this time is capital-saving technological progress, the increase in labor productivity is greater than the increase in capital productivity, and part of the capital used for production is replaced by labor. Through the GAMS software, simulation calculation, when the economic system is subjected to the energy product use efficiency shock, its impulse response is shown in Figure 2, when the economic system is subjected to a positive energy use efficiency shock, the direction of the impact on the variables measuring economic indicators is the same as that of the positive technological progress shock, but with a smaller response amplitude. At present, coal still dominates the energy structure of China with a huge proportion. Total fossil energy consumption is directly proportional to total carbon dioxide emissions. Technological progress leads to effective improvements in energy efficiency and increased investment, which is greater than the increase in output. Improvements in the efficiency of energy use also increase the productivity of enterprises, leading to higher corporate profits, higher incomes for the population and higher consumption, which may cause energy prices to rise and fall, and short-term fluctuations in their prices can increase the capital stock, thus weakening the complementary relationship between capital and energy.

Table 1 presents selected energy consumption data to provide a source of data for the formula calculations and conclusions.

6 Conclusion

Starting from the general equilibrium theory, this paper constructs a dual-carbon economic growth model including carbon emissions trading, and theoretically analyses the economic effects of dual-carbon economy. Numerical simulations are conducted using Chinese data, and the results show that:

(1) The dual-carbon economy can effectively promote China's green technological progress and green consumption, and thus increase total factor productivity, per capita GDP and welfare level.

(2) The synergistic development of dual-carbon economy and traditional economy can be realised through the implementation of carbon emissions trading policy.

(3) Under environmental constraints, China will face tightening resource constraints and deterioration of the ecological environment, and the key to achieving ecological civilisation lies in the promotion of green technological progress and green consumption, which provides an important policy basis for achieving the dual-carbon goal and high-quality economic development.

(4) Under the "dual-carbon" goal, there will be a large number of investment opportunities in the field of new energy, which will bring opportunities for China's economic development, and the adjustment of the energy structure will have an average annual pulling effect of 0.8% on the GDP in the neutral scenario, and an average annual pulling effect of 0.9% in the positive scenario. In order to successfully promote carbon neutrality, China's quality economic growth requires that GDP growth be decoupled from energy and power demand growth as much as possible, so that a relatively low incremental increase in energy and power demand can guarantee a relatively high level of GDP growth, and it is necessary to increase the proportion of the tertiary industry in the GDP at the same time, and inhibit the scale of energy and power consumption in the secondary industry, especially in the energy-consuming industries.

The study in this paper has some limitations, such as a small sample size and a narrow research scope. Future research can further expand the sample size and research scope to draw more accurate conclusions. In addition, future research can also explore the impact of other influencing factors on dual-carbon economic growth.

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