A Long-term Economic Analysis on the Carbon Peaking, Carbon Neutrality and the Dual Circulation Policy in Shandong Province

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Abstract: Dual Circulation, peak carbon dioxide emissions before 2030 and carbon neutrality in 2060 are important strategies for China to foster economic growth and achieve its climate ambition. As a province of China with a high proportion of high-carbon industries, the industrial structure transformation of Shandong province is under greater pressure. In this paper, we employ computable general equilibrium model to predict the industrial structure of Shandong during the period of 2020-2060. According to the simulation results, the output of the steel, nonferrous metals, and coal industries in Shandong Province would shrink by 2% on an annual basis between 2020 and 2060, while the output value of the service industry will decrease year by year. This research will help to illuminate the future industrial structure transition of Shandong Province.

1. Introduction

In 2020, Chinese national leaders proposed the establishment of a "dual circulation" pattern, with a primary focus on domestic circulation and the mutual promotion of international and domestic circulations. This indicates that future economic growth in China must prioritize increasing domestic demand, promoting consumption and investment, and facilitating internal circulation. Every country faces the challenge of achieving sustainable economic operations without causing harm to the environment. However, accomplishing this goal remains a difficult task.

To address climate change and shoulder carbon reduction responsibilities, the Chinese government set targets to "peak carbon emissions before 2030" and achieve "carbon neutrality (net-zero emissions) by 2060." China, as the world's largest emitter of carbon, faces significant challenges and practical difficulties in meeting its emission reduction goals. To unleash domestic demand potential, upgrade the supply chain, and align with the "dual circulation" strategy, China's "dual carbon" approach should integrate with an emphasis on green and low-carbon development, outlining directions and pathways for implementation.

Shandong Province boasts a large and rapidly developing economy, consistently ranking among the top three in GDP among China's 30 provinces for many years. Over the past decade, while the economic momentum in Shandong has remained strong, the growth rate has slowed down. Both the total GDP and per capita GDP in Shandong have increased annually, leading to significant improvements in people's lives.

The "dual-carbon" strategy will expedite "capacity reduction" and restructuring in high-energy-consuming industries. Under the "carbon neutrality" goal, traditional industries will encounter stricter carbon emission limits, accelerating capacity reduction and compression. On one hand, traditional industries with relatively high carbon emission costs will witness a decline in cost advantages, diminishing their competitiveness. The likelihood of relying on scale expansion will decrease, with increased risks of capacity clearance and industrial migration, gradually giving way to low-carbon products.

As the "carbon neutrality" initiative progresses, leading enterprises with more advanced technologies and facilities within industries are expected to gain a competitive advantage, intensifying

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trends of mergers, acquisitions, and restructuring. The implementation of this initiative will lead to a significant transformation and upgrade of the industrial sector, ultimately resulting in improved quality of economic growth. While industrialization plays a significant role in promoting economic growth, regions in the industrialization phase face challenges in reducing carbon emissions.

Currently, Shandong Province is still in the industrialization phase, with industrial value-added accounting for approximately 32% of GDP. Given the emphasis on industrial structure adjustment, industry energy efficiency, and the development of non-fossil energy as primary emission reduction measures, the relatively high carbon reduction targets may have some negative impact on the overall economy of Shandong Province. Therefore, forecasting and estimating the future economic and industrial structure of Shandong Province become crucial.

In the field of forecasting, two primary methods are used: the synthetic index method and the model-based forecasting method. The synthetic index method involves creating business cycle indices based on leading indicators and predicting economic trends based on the characteristics of the indices.

Research focuses on advancements in model-based forecasting. Early studies on economic growth rate prediction, such as those by Tinbergen (1939, 1974) and Klein (1970), were primarily based on national income accounting theory[1-2], estimating linear equations for each sector to forecast economic growth rates. However, these methods overly relied on national income accounting theory and lacked effective integration with other time series models[3], possibly resulting in less effective predictions compared to simple time series models like autoregressive models[4].

The oil crisis of the 1970s and the Rational Expectations Revolution raised questions and criticisms about the predictive ability of models based on national income accounting theory. Subsequently, unconstrained Vector Auto Regressions (VAR) and Dynamic Stochastic General Equilibrium (DSGE) models gradually became the predominant methods for predicting economic growth rates.

Sims (1980) argued that large macro-econometric models lacked support from economic theory and empirical facts, leading to the proposal of unconstrained VAR models. Since then, VAR models have become powerful tools for macroeconomic analysis and forecasting, serving as benchmark models for comparing the predictive performance of other models[5].

DSGE models trace back to Kydland and Prescott (1982)[6], who introduced the Real Business Cycle (RBC) model. They assumed rational expectations and dynamic consistency in economic agents' decision-making within the framework of the new neoclassical growth model. They used dynamic programming to derive optimal behavioral equations for economic agents under uncertain conditions, attributing economic fluctuations mainly to productivity shocks[7].

In the realm of macroeconomic forecasting, the literature review reveals a continuous absorption and adaptation of the latest foreign econometric techniques, analytical methods, and large-scale economic models. Scholars have updated and improved macroeconomic monitoring systems and forecasting models in conjunction with practical considerations, yielding rich research outcomes. However, existing quantitative studies on macroeconomic forecasting mostly focus on overall economic analysis, with fewer methods and models applicable to specific sectors. This is a primary concern addressed in this research[8-9].

2. Methodology

The Computable General Equilibrium (CGE) model, grounded in general equilibrium theory and utilizing input-output tables and national accounts as data foundations, enables policy simulations by adjusting relationships among endogenous variables. In conditions of limited resources, producers determine optimal supply quantities based on the principles of income maximization or cost minimization, while consumers determine demand quantities based on the principle of utility maximization. Achieving equilibrium prices in the balance of product supply and demand optimally utilizes resources, maximizes consumer utility, and allows producers to achieve maximum income or minimum cost, resulting in overall economic equilibrium.

Once the CGE model reaches a balanced state, policy shocks can be applied to it. The model's various economic accounts and their interrelated relationships allow for simulations, helping assess

the impacts of policy changes on different aspects of the economy. This analytical approach enables effective analysis and prediction of the effects of policy changes on production, consumption, employment, and other relevant areas, providing a powerful tool for policy formulation.

Based on the simulation results as a benchmark, adjustments to the initial equilibrium of the CGE model are made, focusing on three aspects: macroeconomics (GDP), population and resource endowments (factors), and industrial development. The CGE model is then used to detail the long-term economic projections and analysis for the future. Specifically, in terms of the economy, it is anticipated that Shandong Province will continue to lead the nation in high-quality development, pioneering the construction of a socialist modernized strong province. By 2060, the achievements of building a socialist modernized strong province will be further consolidated, with the provincial GDP reaching 31.984 trillion yuan, and the urbanization rate reaching 85%, with an average annual growth of 2.5% during this period.

For the economic system, industrial structure is an endogenous variable, that mainly depends on the trend of demand and the correlation between input and output of various industries. The input-output model can be used to establish a method to calculate the industry output and industry-added value from the demand.

According to the classical input-output model identity: $AX + Y = X$, when the final demand y is known, we can get:

$$X = (I - A)^{-1}$$

Where a is the intermediate input coefficient matrix in the input-output table; X is the column matrix of the total output of each industry; Y is the column matrix of the final demand of products in various industries; I is a unit matrix with diagonal elements of 1 and others of 0.

From this, the calculation formulas of added value of various industries are as follows:

$$VAD = Va * (I - A)^{-1} * Y$$

Among them, VAD is the added value of various industries; Va is the added value rate of various industries. According to the above formula, we can calculate the weight of the industrial structure.

3. Results

In the future, Shandong Province is expected to expedite the process of eliminating outdated and excess production capacity, with a faster development pace for emerging industries such as high-technology manufacturing and services. Traditional manufacturing industries are projected to accelerate their transformation towards intelligent and green industries.

Despite the acceleration of industrial restructuring, upgraded industries are anticipated to remain a major driving force for economic growth. Shandong Province's development positioning as a strong province in manufacturing is not expected to undergo substantial changes. The industrial structure adjustment is projected to be 6.5:36.0:57.5 by 2025, 5.5:34.0:60.5 by 2030, and 5.0:32.5:62.5 by 2035. Looking further ahead, the industrial structure adjustment is estimated to be 4.0:30.0:66.0 by 2050 and 3.5:29.0:67.5 by 2060 (See Table 1).

Table 1 The industrial output distribution in Shandong Province

	2025	2030	2035	2050	2060
Agricultural industry	6.50	5.50	5.00	4.00	3.50
Manufacturing industry	36.00	34.00	32.50	30.00	29.00
Service industry	57.50	60.50	62.50	66.00	67.50

Data Source: Model Simulation by the Authors.

It is projected that during the "14th Five-Year Plan" period, the agricultural, forestry, animal husbandry, and fishery industry in Shandong Province will achieve an industrial output value of 685 billion yuan. The industrial output value is expected to reach 31.4 trillion yuan, the construction industry to reach 608 billion yuan, the transportation industry to reach 465 billion yuan, the wholesale

and retail industry to reach 1.94 trillion yuan, and other service industries to reach 2.82 trillion yuan. Subsequently, all industries in Shandong Province will experience stable growth and continuously adjust their industrial structure.

By 2030, it is estimated that the industrial output value of the agricultural, forestry, animal husbandry, and fishery industries will reach 7.70 trillion yuan. The industrial output value is projected to reach 37 trillion yuan, the construction industry output value to reach 7.6 trillion yuan, the transportation industry output value to reach 5.8 trillion yuan, the wholesale and retail industry output value to reach 25.9 trillion yuan, and other service industries to reach 39.9 trillion yuan. During the period from 2030 to 2045, the industrial output value of the agricultural, forestry, animal husbandry, and fishery industries is projected to reach 9.8 trillion yuan, with the industrial output value reaching 52 trillion yuan, the construction industry output value reaching 12.5 trillion yuan, the transportation industry output value reaching 9.1 trillion yuan, the wholesale and retail industry output value reaching 50.3 trillion yuan, and other service industries reaching 90.7 trillion yuan. The average annual growth rates for each industry during 2030-2045 are expected to be 1.9%, 2.9%, 4.7%, 3.8%, 6.3%, and 8.5%, respectively.

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From 2045 to 2060, the growth rate of the manufacturing industry will slow down, while the service industry will experience a significant increase. The industrial output value of the agricultural, forestry, animal husbandry, and fishery industries is projected to reach 1.13 trillion yuan, the industrial output value will reach 58.6 trillion yuan, the construction industry output value will reach 16.3 trillion yuan, the transportation industry output value will reach 1.14 trillion yuan, the wholesale and retail industry output value will reach 78.4 trillion yuan, and other service industries will reach 161.9 trillion yuan. The average annual growth rates for each industry during 2045-2060 are expected to be 1.1%, 0.9%, 2.2%, 1.7%, 3.7%, and 5.2%, respectively (See Table 2).

Table 2 The average annual growth rates for the high-carbon industry in Shandong Province

	2020-2030	2030-2050	2050-2060
steel production	-2.70	-1.60	0.50
non-ferrous metal industry	-1.50	-2.70	-0.70
construction industry	-0.80	-2.10	-1.00

Data Source: Model Simulation by the Authors.

Specifically, with the gradual elimination of outdated production capacity, it is expected that during

the "14th Five-Year Plan" period, the proportion of steel production in Shandong Province will slightly decrease, dropping from 7.5% in 2020 to 7.2% in 2025. However, as the steel industry is traditionally advantageous in Shandong Province and plays a crucial role in building a province strong in manufacturing, the industry scale is not expected to continue declining. After the completion of the process of phasing out outdated production capacity, the proportion of Shandong Province's steel production to the national total will tend to stabilize, maintaining between 6.7% and 7.2%. The estimated crude steel production for Shandong Province is 0.61 billion tons, 0.45 billion tons, and 0.42 billion tons in 2030, 2050, and 2060, respectively. The average annual growth rates for the periods 2020-2030, 2030-2050, and 2050-2060 are expected to be -2.7%, -1.5%, and -0.8%, respectively.

For the non-ferrous metal industry, it is anticipated that before 2030, the industry will maintain a growth rate of around 2.3%. However, after 2030, Shandong Province explicitly implements electrolytic aluminum reduction and replacement, leading to the relocation of some electrolytic aluminum enterprises. Simultaneously, with the increase in the accumulation of non-ferrous metals and the gradual replacement of ore smelting by recycled metals, the non-ferrous metal production in Shandong is expected to gradually decrease. The proportion of provincial non-ferrous metal production to the national total will significantly decline, accompanied by a substantial reduction in energy consumption. Production forecasts indicate that the electrolytic aluminum production in Shandong Province is estimated to be 7.3 million tons, 4.6 million tons, and 3.2 million tons in 2030, 2050, and 2060, respectively. The average annual growth rates for the periods 2020-2030, 2030-2050, and 2050-2060 are expected to be -1.6%, -2.7%, and -2.1%, respectively.

For the construction industry, Shandong will make full use of local resources, adopt low-energy and pollution-free production technologies, and develop low-energy materials. Therefore, it is expected that the building materials industry in Shandong Province will not be greatly affected by the pressure of emission reduction, and the proportion of output in the whole country is expected to decrease slightly based on maintaining stability. It is estimated that the cement output in 2025, 2035, and 2060 will be 1.5 million tons, 140 million tons, and 110 million tons respectively, and the average annual growth rate in the Thirteenth Five-Year Plan, 2020-2035 and 2035-2060 will be -0.5%, -0.7% and -1% respectively.

4. Conclusion

Considering the model's predictive results, Shandong Province's resource endowment, and the impact of dual carbon on economic development, it is expected that Shandong will continue to lead the nation in high-quality development, becoming a pioneer in building a socialist modernized province. By 2025, Shandong's comprehensive strength is anticipated to be at the forefront, with the province's GDP reaching new heights. The Shandong Peninsula Metropolitan Area is poised to become a new national economic growth pole. The provincial GDP is projected to reach 9.839 trillion yuan, with an average annual growth of 6.1% during the "14th Five-Year Plan." The urbanization rate is expected to reach 70%, and per capita GDP is forecasted to be 96,000 yuan.

From 2026 to 2035, Shandong's overall economic strength, technological capabilities, and comprehensive competitiveness are expected to significantly increase. By 2035, per capita GDP will reach the level of moderately developed economies (as outlined in Shandong Province's "14th Five-Year Plan"). The province is set to achieve new industrialization, becoming a strong province in advanced manufacturing, new energy and materials, and digital technologies. In 2030, the provincial GDP is projected to reach 12.438 trillion yuan, with an average annual growth of 4.8% during the "15th Five-Year Plan." The urbanization rate is expected to reach 75%, and per capita GDP is forecasted to be 122,000 yuan.

From 2036 to 2050, Shandong will enter the post-industrial development stage, with urbanization gradually stabilizing, economic growth slowing down, and the completion of building a socialist modernized strong province. By 2050, the provincial GDP is expected to reach 24.986 trillion yuan, with an average annual growth of 3.3% between 2036 and 2050. The urbanization rate is projected to reach 83%, and per capita GDP is forecasted to be 252,000 yuan.

From 2050 to 2060, the achievements of building a socialist modernized strong province will be further consolidated. The provincial GDP is estimated to reach 31.984 trillion yuan, with an average annual growth of 2.5% between 2050 and 2060. The urbanization rate is expected to reach 85%, and per capita GDP is forecasted to be 326,000 yuan (approximately 47,000 U.S. dollars), similar to the current levels in the United Kingdom and Germany. This corresponds to 70%, 108%, 112%, 97%, 112%, and 143% of the per capita GDP in the United States, the United Kingdom, France, Germany, Japan, and South Korea in 2019, respectively, and is comparable to Canada. Shandong's per capita GDP is positioned at an upper-middle level among developed countries.

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