Simulation and Prediction of Regional Economic Growth Effects under the Background of Dual Carbon Policy - A Case Study of Shandong Province

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Abstract: The dual-carbon goal reflects China's determination to build a resource-saving and environmentally friendly society, and the realization of the dual-carbon goal ultimately requires implementation at the regional level. Shandong Province, a strong economic province in China, is dominated by traditional energy and thus bears a significant task of green transformation. Using the multi-regional CGE model (The Enormous Regional Model, TERM), this paper focuses on the macroeconomic and sectoral effects of the dual-carbon goal on the regional economy and discusses the implementation effects of different policy scenarios. The simulation results show that, compared with the baseline scenario, the dual-carbon goal scenario in 2030 will help reduce the proportion of high-energy-consuming and high-polluting industries, while the service and high-tech industries will face greater growth opportunities. Shandong Province's economic structure will tend to become greener and more advanced. However, in the short term, this may lead to a slowdown in economic growth, an increase in the unemployment rate, a decline in government expenditure, and a decrease in household income. On the whole, achieving the carbon peak in 2030 is the optimal choice for Shandong Province. Therefore, Shandong Province should exercise prudence in policy-making during the implementation of the dual-carbon goal.

1. Introduction

The "dual carbon" goal refers to the short-term objective of reaching peak carbon emissions by 2030 and achieving carbon neutrality by 2060. The 14th Five-Year Plan also clearly lists the "dual carbon" goal as an important task, seen as a crucial path to accelerate the transition from old to new kinetic energy. The realization of the "dual carbon" goal must ultimately be implemented at the regional level. Shandong Province has long been an economic powerhouse in China, consistently ranking among the top three in the country in terms of GDP and industrial added value. The "Overall Plan for the Construction of the New and Old Kinetic Energy Conversion Comprehensive Pilot Zone in Shandong Province," issued by the National Development and Reform Commission, highlights Shandong Province's solid economic foundation, diverse range of industries, extensive market space, and geographical advantages near Japan and South Korea, along with coordinated land and sea management. However, it also faces challenges such as a predominantly heavy industrial structure and the continued dominance of traditional kinetic energy. According to the CEAD database, Shandong Province's carbon dioxide emissions in 2019 reached 937 million tons, the highest in the country. In the future, Shandong Province should align with national policies and assume a leading role in achieving the "dual carbon" goal. Therefore, this paper intends to use the multi-regional CGE model (The Enormous Regional Model, TERM) to focus on two aspects: (1) the macroeconomic and industrial effects of the "dual carbon" goal on the regional economy, and (2) the implementation effects of different policy scenarios.

The structure of this paper is as follows: Section 2 presents a literature review, Section 3 describes the analysis mechanism and theoretical basis, Section 4 details model construction and scenario setting, Section 5 discusses result analysis, and the final part offers research conclusions and policy

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suggestions.

2. Literature Review

This paper is mainly related to two types of literature, the first type of literature is the influencing factors and economic effects of the dual-carbon goal for each province. In terms of influencing factors, most literature believes that the time for each province to achieve the dual-carbon goal is not completely synchronized[1], and the progress depends on the industrial structure[2-3], but some scholars hold the opposite view[4]. The level of economic development, population density, ecological environment are also worth considering[5], the synergistic effect and governance pressure between regions will also affect the carbon neutrality performance[6], from the perspective of economic effects, Wang et al.[7] The research results show that the return on investment of the power sector transformation in the Guangdong-Hong Kong-Macao Greater Bay Area will increase, Shi and Li[8] also pointed out that the carbon emissions within the region will also show a significant differentiation trend, some areas of GDP loss is serious[9-11], and the degree of loss is proportional to the speed of carbon peaking[12], but the economic structure has been adjusted, reflected in the high-energy-consuming industries development is suppressed, low-carbon industries face new development opportunities. In summary, the implementation of the dual-carbon goal will promote the regional economy to reshape the development pattern in the depth adjustment[13], is a green industrial revolution, is an important fulcrum for achieving high-quality development[14].

The second type of literature is the tools or paths to achieve the dual-carbon goal. The tools to achieve the dual-carbon goal can be summarized as technical tools and market-based tools. Technical tools mainly include forest carbon sinks[15], industrial transformation and upgrading[16], the former uses the photosynthesis of forest systems to absorb carbon dioxide, therefore, it is very necessary to establish a cross-regional ecological compensation mechanism[17]; the latter mainly through reducing energy consumption[18], promoting energy transformation[19], popularizing new energy technologies[20-21], improving transportation[22] and other ways to achieve; market-based tools mainly include carbon tax and carbon emission trading. Because carbon tax is considered to be the most effective way to reduce carbon emissions without harming the economy[23], and is also more suitable for the national conditions, but Wu et al. emphasize that the carbon trading mechanism is more effective, the advantages and disadvantages of the two are that carbon tax is conducive to stabilizing carbon prices, lack of flexibility, while the carbon trading mechanism is flexible, but the regulatory costs are high, and some scholars have proposed a provincial carbon emission quota scheme[24-25]. Different from the "bottom-up" system in the United States, China is more "top-down" driven, so it needs more government guidance, such as playing the role of fiscal automatic stabilizer, paying attention to regional coordination, levying resource tax, forming a stable and unified national market[26], and tailoring low-carbon development level improvement strategies according to local conditions is the key. In summary, the implementation of the dual-carbon goal is an evolutionary process involving various subjects, industries, and regions, and a series of policy combinations are needed in practice to achieve more effective results[27].

The above literature analyzes the dual-carbon goal problem from different perspectives, because of the differences in model selection, analysis angle, scenario setting and other aspects, the research conclusions of the same problem are very different. In summary, there are mainly the following problems: first, most of the literature's scenario setting is relatively simple, only considering the impact of a single policy tool such as carbon tax, carbon emission trading or technology upgrading, rarely considering the cross-effect of multiple policy tools, the "Industrial Energy Efficiency Improvement Action Plan" jointly issued by the six national ministries and commissions in 2022 clearly requires, both to promote new energy, but also to improve energy efficiency, indicating that the realization of the dual-carbon goal is a diversified policy combination to achieve the effect, therefore, only considering one policy tool and reality out of touch; third, the research method is mainly econometric method, single-region CGE model and global CGE model. China's implementation of the dual-carbon goal, in addition to the need for macro-policy guidance, but also need local governments to introduce specific policies, existing research has proved that the

implementation of specific measures significantly better than the macro-guidance program, econometric model prediction effect is not as good as CGE model, and single-region CGE model ignores the heterogeneity of different regions, global CGE model, that is, GTAP model mainly research scale is global, not very suitable for provincial economic analysis; third, the outbreak of the new crown epidemic at the end of 2019 also profoundly affects China's dual-carbon goal realization process, but few literature discuss this issue.

This paper takes Shandong Province as an example, using the multi-regional CGE model to simulate the economic effects of the dual-carbon goal, may have the following two contributions: first, the scenario setting as far as possible to consider a variety of possible policy combinations, both market-based tools scenarios, but also technical improvement scenarios, using counterfactual analysis method, looking for the optimal policy tools; second, using the multi-regional CGE model, fully considering the input-output relationship between different regions, taking into account the heterogeneity and non-synchronization of different regions to achieve the dual-carbon goal."

3. Model and Method

This paper mainly uses the TERM model for analysis. The policy simulation system of the TERM model is based on the optimization assumption of economic entity behavior (minimization of producer costs, maximization of consumer utility), reflecting the endogenous mechanism of prices, determining the prices of goods and factors through supply and demand decisions, i.e., adopting the market equilibrium assumption; simulating the changes in policies and behaviors of various economic entities such as governments, enterprises, consumers, and imports and exports. The core structure of this model includes three major value systems: the base value, the delivery value, and the consumer value. These three major value systems constitute a complete cross-regional general equilibrium model. Its main features are (1) the optimization behavior of economic entities is regional, which can analyze policy impacts on the supply side and demand side of 31 provinces and cities; (2) the model depicts economic connections between regions, including inter-regional trade, inter-regional investment flows and labor flows, and transfer payments between governments, residents, and enterprises. Therefore, the multi-regional general equilibrium model system treats each region as a separate economic entity and depicts modules of inter-regional economic connections and interactions. It can be used to analyze regional differences as well as inter-regional influences and feedback. The TERM model compares and ranks the overall economic condition, industrial structure, fixed asset investment structure, consumption structure, trade status, etc., of each region at the total and industry level. At the same time, it calculates the contribution to the economic development of each region through inter-regional industrial connections (including regional influence coefficient, inter-regional influence coefficient, regional sensitivity coefficient, inter-regional sensitivity coefficient), inter-regional product flow (including regional product flow coefficient and inter-regional product flow coefficient), and the contribution of final demand.

Figure 1 reflects the basic structure and characteristics of the TERM database. In this, ‘c' represents commodities, ‘s' indicates source, ‘m' signifies logistics, ‘r' denotes origin, ‘d' stands for destination, ‘p' implies the place where the logistics goods are supplied, ‘f' points to the final demander, ‘i' corresponds to industry, ‘u' represents users, which is the union of final demander and industry, ‘o' symbolizes skills, and ‘h' denotes households. Yellow indicates newly added components, white stands for file data. The MAKE matrix shows the conversion of industry output into goods. Figure 2 reflects the production nesting relationship of the TERM model, where various production factors and intermediate inputs generate final products through the Leontief production function, and generate themselves through the CES production function.

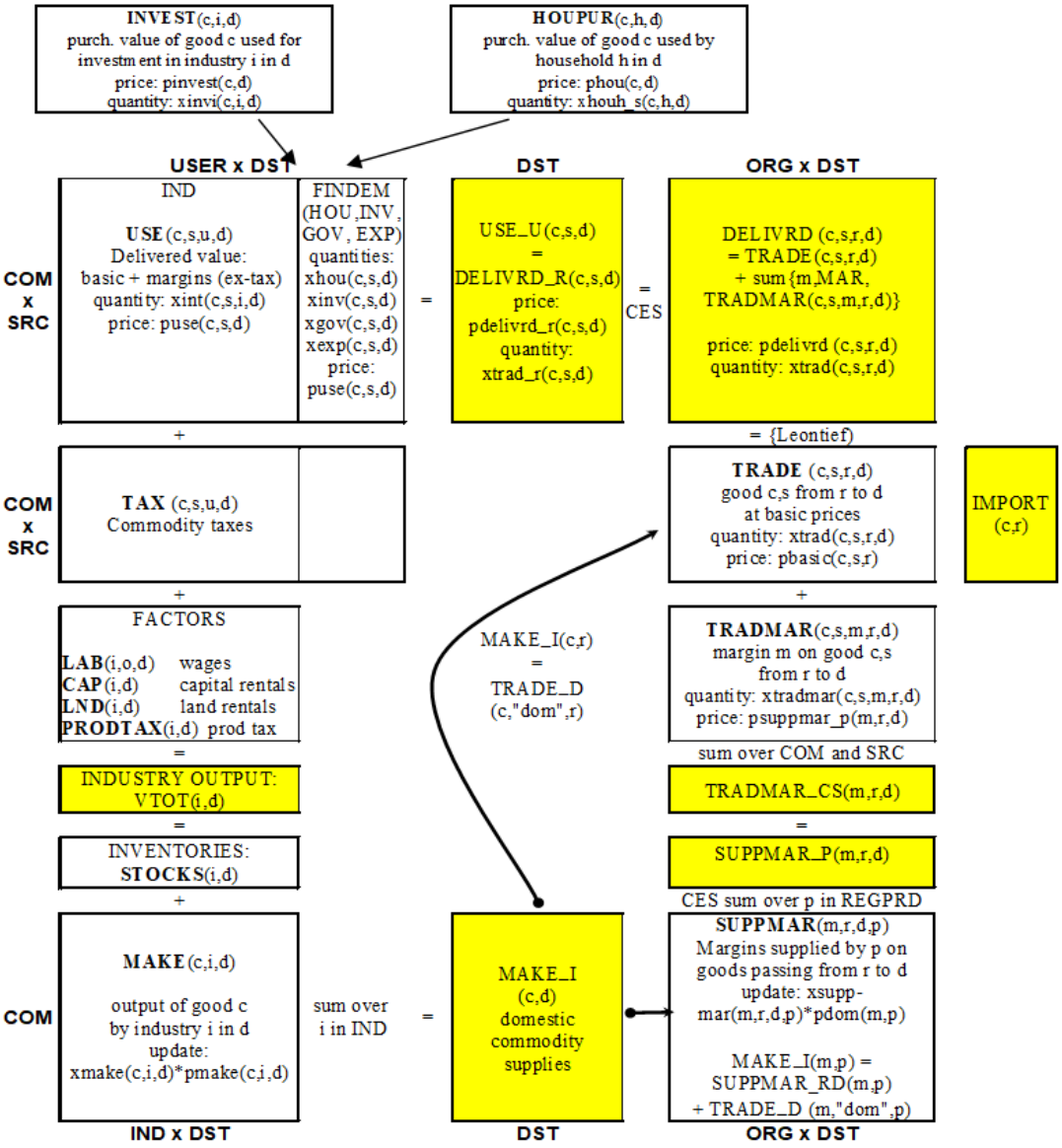

Figure 1 TERM Database structure

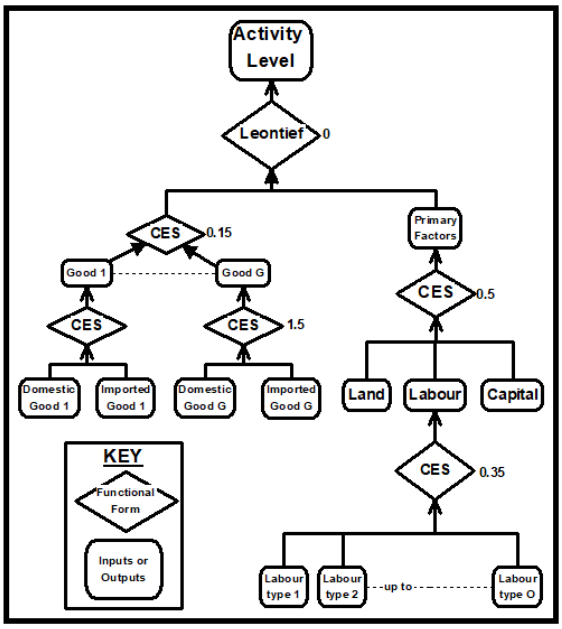

Figure 2 Inputs to production: Nests

4. Data sources and scenario settings

The main data source of this paper is the provincial and industry TERM database compiled by the Australian Policy Research Center, which is based on the input-output tables of each province in China in 2017 and covers the output, employment and tax information of 31 provinces and 24 industries in China. Because this paper uses a dynamic TERM model, the data after 2017 are simulated by a recursive method and further corrected according to the information of the known years.

In terms of scenario settings, this paper sets up the following two scenarios: baseline scenario, that is, no policy shocks; earliest possible scenario, that is, achieving carbon peak by 2030. China proposed the dual-carbon target in 2020, considering that there is a certain lag in the implementation of policies, so this paper takes 2021 as the first year of implementing the dual-carbon target. In terms of closure settings, the baseline scenario corresponds to the closure of exogenous regional labor income consumption propensity and endogenous aggregate household real consumption, which means that household real consumption and residents' labor income such as wages grow synchronously; the latest possible scenario and the earliest possible scenario correspond to the closure of exogenous production tax rate, which mainly means to adjust the industrial structure through tax tools, reduce the proportion of high-energy-consuming and heavy-polluting industries, and achieve the dual-carbon target. Table 1 and Table 2 are the regional and industry classifications of this paper.

Table 1 Province division table

No.	Province	No.	Province
1	Beijing	17	Hubei
2	Tianjin	18	Hunan
3	Hebei	19	Guangdong
4	Shanxi	20	Guangxi
5	InnrMongolia	21	Hainan
6	Liaoning	22	Chongqing
7	Jilin	23	Sichuan
8	Heilongjiang	24	Guizhou
9	Shanghai	25	Yunnan
10	Jiangsu	26	Tibet
11	Zhejiang	27	Shaanxi
12	Anhui	28	Gansu
13	Fujian	29	Qinghai
14	Jiangxi	30	Ningxia
15	Shandong	31	Xinjiang
16	Henan		

Table 2 Industry division table

No.	Industry	No.	Industry
1	Agriculture	13	EleHeaProSup
2	CoalMine	14	GasProSup
3	OilGas	15	WaterProSup
4	Mine	16	Construction
5	FoodTob	17	WholRetail
6	Textile	18	TraStorPost
7	LightManu	19	Accommodat
8	CokeNucle	20	Finance
9	HeavyManu	21	Education
10	TransportEq	22	HealthSocial
11	EleMachEq	23	PubSocial
12	OthManProd	24	OthServe

5. Results Analysis

This paper mainly analyzes the impact of policy simulation from the perspectives of macroeconomics and industrial output. Table 3 and Table 4 reflect the macroeconomic situation of Shandong Province. Compared with the baseline scenario, the nominal income of various factors in Shandong Province, with the implementation of tax reduction and fee reduction policies, the production tax revenue in Shandong Province inevitably declined. However, the income of capital, labor, and land has increased, with the most noticeable increase in capital income. It shows that after implementing the dual carbon policy, capital-intensive industries will become the most obvious beneficiary sector. Moreover, this effect becomes more apparent over time.

Table 3 Nominal income of factors of production in Shandong Province

Year	Land	Labour	Capital	PRODTAX	ComTax
2024	6.78	48.57	738.61	-938.26	-0.39
2025	6.62	55.87	760.43	-954.28	0.04
2026	6.46	61.94	781.15	-971.71	0.33
2027	6.3	67.02	800.92	-990.53	0.52
2028	6.15	71.31	819.9	-1010.74	0.61
2029	6	74.97	838.21	-1032.41	0.64
2030	5.84	78.12	855.98	-1055.56	0.6

Table 4 reflects the cumulative effect of various final demands in Shandong Province calculated by the expenditure method. It can be seen that investment has almost no changes, government spending, and household consumption decrease significantly, exports remain positive, but the increment shows a declining trend. This paper believes that the implementation of the dual carbon policy will inevitably reduce the government's tax revenue in the medium and long term, which depresses government income. Government income is the basis for expanding government purchases, so government spending declines. The dual carbon policy will inevitably shut down and limit some enterprises, affecting residents' employment and reducing their wage income, and consumption levels will inevitably decrease. The tax reduction and fee reduction policies have reduced the production costs of some industries, and the price for foreign sales may also decrease, which may enhance the competitiveness of enterprises.

Table 4 Ordinary change in quantity expenditure GDP components in Shandong Province

	Household	Investment	Government	Exports	Imports
2024	-79.48	0	-16.62	439.16	-19.46
2025	-101.1	0	-21.01	434.39	-21.03
2026	-122.1	0	-25.23	429.79	-22.03
2027	-142.55	0	-29.31	425.49	-22.59
2028	-162.53	0	-33.27	421.6	-22.79
2029	-182.11	0	-37.11	418.16	-22.68
2030	-201.36	0	-40.85	415.2	-22.34

Table 5 reflects the output of different industries in Shandong Province. Generally, the overall output level of most industries has increased compared to the baseline scenario. The agricultural output value has shown a steady downward trend during this forecast period. This may reflect that with the progress of industrialization and urbanization, the proportion of agriculture in the overall economy is gradually declining. Meanwhile, the decrease in agricultural output may also be related to the agricultural structural adjustment and the process of agricultural modernization promoted by the government. The output value of the coal mining and oil and natural gas industries has also shown a declining trend. This may reflect that with the implementation of environmental protection policies and the development of clean energy, the status of traditional energy industries is gradually being weakened. For traditional energy producing areas like Shandong Province, this means that industrial transformation and upgrading must be carried out. The output value of traditional manufacturing industries such as textiles and light industry is also declining. This may reflect that in the context of

global industrial chain adjustment and domestic industrial upgrading, the competitive pressure of traditional manufacturing is increasing. The output changes in the construction industry and health and social work industry during this period have shown an upward trend. This may reflect that with the aging population and the deepening of the construction of the social security system, the demand for social services such as health and elderly care is increasing. The rise in the construction industry may be related to urbanization and the demand for infrastructure construction.

Table 5 Output of all the industries in Shandong Province

	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.58	0.54	0.51	0.48	0.46	0.44	0.42
CoalMine	1.23	1.19	1.16	1.12	1.1	1.07	1.05
OilGas	0.46	0.43	0.39	0.37	0.34	0.32	0.3
Mine	0.85	0.82	0.79	0.77	0.75	0.74	0.72
FoodTob	0.42	0.38	0.34	0.3	0.27	0.24	0.22
Textile	1.17	1.07	0.98	0.9	0.83	0.77	0.72
LightManu	0.89	0.84	0.8	0.76	0.73	0.7	0.68
CokeNucle	0.99	0.96	0.93	0.91	0.89	0.87	0.86
HeavyManu	0.87	0.86	0.84	0.82	0.81	0.8	0.78
TransportEq	0.61	0.59	0.56	0.54	0.52	0.5	0.48
EleMachEq	0.82	0.77	0.73	0.69	0.65	0.62	0.6
OthManProd	0.87	0.81	0.75	0.69	0.65	0.61	0.57
EleHeaProSup	0.95	0.92	0.89	0.87	0.84	0.82	0.8
GasProSup	0.55	0.52	0.49	0.47	0.44	0.42	0.4
WaterProSup	0.25	0.23	0.21	0.19	0.17	0.15	0.14
Construction	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02
WholRetail	0.77	0.73	0.7	0.67	0.64	0.61	0.59
TraStorPost	0.79	0.75	0.72	0.69	0.66	0.64	0.62
Accommodat	0.48	0.46	0.43	0.41	0.39	0.37	0.35
Finance	0.9	0.87	0.84	0.82	0.79	0.77	0.75
Education	0.03	0.03	0.02	0.02	0.02	0.02	0.02
HealthSocial	-0.17	-0.16	-0.15	-0.14	-0.13	-0.12	-0.12
PubSocial	2.13	2.1	2.06	2.02	1.98	1.93	1.87
OthServe	1.04	1.03	1.01	0.99	0.98	0.96	0.94

6. Research conclusions and policy recommendations

This paper takes Shandong Province as an example and discusses the impact of achieving the dual-carbon target by 2030, and draws the following conclusions: First, achieving the dual-carbon target by 2030 will help increase the income of capital-intensive industries, and many high-tech industries have the characteristics of high-tech input and high capital input, which is of great significance for increasing the proportion of high-tech industries and adjusting the industrial structure; Second, the dual-carbon target will weaken the welfare of residents to a certain extent, reduce the government tax revenue, and stimulate the export of Shandong Province. This paper believes that this is an inevitable pain of achieving the dual-carbon target and adjusting the industrial structure, and it is still beneficial for the sustainable development of Shandong Province in the long run; Third, the dual-carbon target will help increase the output of most industries, and it is a major benefit for the construction industry, health and social work industry, and high-tech industry, which increase their income and objectively play a role in adjusting the industrial structure, making the industrial structure of the whole Shandong Province more regional and clean.

In view of the above research results, this paper puts forward the following policy recommendations: First, we should pay attention to the short-term adverse effects of the dual-carbon target, and adopt more flexible ways to ensure that the dual-carbon target is achieved while also

ensuring that the welfare level of residents does not decline; Second, we should improve the flexibility of policies, avoid "one-size-fits-all" policies, and achieve the dual-carbon target gradually according to the characteristics of different industries; Third, we should increase the publicity of the dual-carbon target, guide enterprises to consciously participate in the construction of the dual-carbon target, and use tools such as tax, finance, etc., to guide enterprises to produce greener and cleaner.

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