A Linear Programming-Based Analysis of Dual-Carbon Implementation in East China's Major Industries

Yongshi Fang[1,*][a], Xiwen Liu[2][b] and Donghao Tu[3][c]
[1]RCF Experimental School, Beijing, 100012, China
[2]Chengdu No. 7 High School, Chengdu, Sichuan, 610041, China
[3]Shanghai United International School Hefei Campus, Hefei, Anhui, 230071, China
1,* 2 3

Keywords: Dual-Carbon, Challenge, Government, Enterprise.

Abstract: In today's social environment, dual carbon has become a hot topic. The definition of dual-carbon is the abbreviation of carbon peak and carbon neutral. The study is based on how the three major industries in East China implement the dual-carbon goal by two methods to maximize the economic harvesting basin. The study incorporates a linear programming approach. A set of optimization policies is proposed to address the characteristics of the three major industries in the region (e.g., large carbon emissions from traditional industries and almost zero carbon emissions from modern services), and the results of the study can provide policy references as well as technical support for the region and other similar regions to achieve the dual-carbon goal. Some limitations, contributions, and implications of the study are identified in the course of the discussion. The development of financial products to establish a carbon trading market to realize the development of the whole economy and promote the mutual benefits of carbon emission reduction. The dual-carbon program needs to be realized by the government, enterprises, and the market with continuous adjustments.

1 INTRODUCTION

East China is promoting the dual-carbon goal to optimize the industrial structure, seeking to maximize the economic efficiency basin and control carbon emissions. The government also needs to consider the operating costs, labor requirements, and resource constraints of each industry to ensure sustainable development. There are three main types of industries in the region. First, traditional industries have the highest carbon emissions, the best economic performance, and the lowest labor costs. Second, the clean energy industry has low operating costs, low carbon emissions, and medium economic performance. Third, the modern service industry has the highest economic efficiency, zero carbon emissions, and high labor costs. The research on dual-carbon goals describes the background of dual-carbon goals, analyzes the challenges and opportunities brought by dual-carbon goals, and the realization path to achieve dual-carbon goals. The study of the dual-carbon strategy puts forward the analysis of the impact of the dual-carbon strategy on the real economy, and proposes that the industry focuses on the modernization of the real economy's mode of production and life; the governmental measures focus on the financial, legal and regulatory, standard system and institutional reforms. Studies related to the development of a dual-carbon economy reveal the background of the proposed dual-carbon goal while analyzing the challenges and opportunities brought about by the dual-carbon goal and further proposing a path to achieve the dual-carbon goal.

This paper studies how the three major industries in East China implement the dual-carbon target, aiming to propose a set of industrial structure optimization strategies based on carbon emission constraints. It provides policy reference and technical

[a] https://orcid.org/0009-0008-6199-7402
[b] https://orcid.org/0009-0001-3529-8033
[c] https://orcid.org/0009-0001-4033-4799

Fang, Y., Liu, X. and Tu, D.
A Linear Programming-Based Analysis of Dual-Carbon Implementation in East China's Major Industries.
DOI: 10.5220/0013815600004708

In *Proceedings of the 2nd International Conference on Innovations in Applied Mathematics, Physics, and Astronomy (IAMPA 2025)*, pages 145-151
ISBN: 978-989-758-774-0

support for this region and other similar regions to realize the dual-carbon target.

2 DEFINITION AND DEVELOPMENT OF DUAL-CARBON

2.1 Classification of Dual-Carbon

"Dual-Carbon" is the abbreviation of "Carbon Peak" and "Carbon Neutral", and it is an important strategic goal proposed by China to realize the green and low-carbon development. It is an important strategic goal proposed by China to realize green and low-carbon development. Peak Carbon refers to a point in time when carbon dioxide emissions reach a historical high, after which they gradually decline. This is the historical inflection point of carbon emissions from increasing to decreasing, marking the decoupling of economic development and carbon emissions. Carbon neutrality refers to the offsetting of carbon dioxide or greenhouse gas emissions directly or indirectly through tree planting, energy saving, and emission reduction within a certain period of time so as to realize "net-zero emissions".

2.2 China's Historical Process of Practicing Dual-Carbon

In 2015, the Opinions on Accelerating Energy Consumption and Emission Reduction put forward the goal of "dual-control" (controlling the total amount of energy consumption and total amount of carbon dioxide emissions). 2016 Opinions on the Implementation of the National Strategy for Addressing Climate Change set the goal of carbon peaking by 2030, with the proportion of non-fossil energy consumption reaching 20%. 2017 saw the proportion of non-fossil energy consumption reach 20%. In 2017, the "Opinions on Promoting Green Development" was issued to promote the energy revolution and green transformation of industries, and in 2020, President Xi Jinping announced China's goal of reaching peak carbon by 2030 and carbon neutrality by 2060, and in 2021, the top-level design of the dual-carbon "I+N" policy system was introduced (the "Opinions on Integrating and Fully Carrying Out the New Development Idea"). In 2021, the top-level design of the dual-carbon "I+N" policy system will be issued ("Opinions on Doing a Good Job in Peak Carbon Achievement and Carbon Neutrality Work", "Action Plan for Peak Carbon Achievement by 2030"). In 2024, detailed policies will be issued, such as "Guiding Opinions on Accelerating the Promotion of Manufacturing Industry's Greening" and "Action Plan for Energy Saving and Carbon Reduction in the Years of 2024-2025".

2.3 Role and Challenges of Dual-Carbon

The Chinese government promotes green transformation through policy guidance (e.g. manufacturing greening, energy saving, and carbon reduction actions), technological innovation, and international cooperation. Typical examples: Chenming Paper reduces carbon emissions in its supply chain through green technology (Sohu.com); the China Meteorological Administration (CMA) points out that dual-carbon is the "golden key" to sustainable development.

The transformation of energy structure constitutes the main difficulty in switching from chemical energy to clean energy. Disputes over the allocation of responsibility for emission reduction stem from uneven regional development and need to be resolved through regional and industry coordination. Technological innovation: Low-carbon technology, R&D and industrialization are insufficient (e.g., carbon capture, hydrogen energy) are technological innovations. The main element of international competition is the challenge of global green technology standards and trade barriers.

There are some coping strategies here, such as strengthening top-level design, coordinating regional and industry synergies, deepening the energy revolution and investment in technological innovation (e.g., for the low-carbon transformation of the petrochemical industry, see the White Paper on China's Petrochemical Industry in the Context of Dual-Carbon 2024); and perfecting the market mechanism (e.g., carbon trading, green finance).

3 METHODS

3.1 Mathematical Programming Model for the Tertiary Industry: A Linear Programming Template

Assume that the production decision variables of the three industries are (x_1, x_2, x_3), that is, n=3. To maximize profits, the objective function is:

$$\text{Maximize } Z = \sum_{i=1}^{n} c_i x_i \quad (1)$$

The parameters satisfy:

$$\sum_{i=1}^{n} a_{1,i} x_i \leq b_1 (Labor\ Constraints) \quad (2)$$

$$\sum_{i=1}^{n} a_{2,i} x_i \leq b_2 (Resource\ Constraints) \quad (3)$$

$$\sum_{i=1}^{n} a_{3,i} x_i \leq b_3 (Carbon\ Emission\ Constraints) \quad (4)$$

$$x_i \geq 0\ for\ all\ i (Non-negativity\ Constraints) \quad (5)$$

As shown in Table 1, this is the parameter description and instance value

Table 1: The parameter description and instance value

Symbol	Meaning	Example Value
c_i	Unit product profit	$[12, 7, 10]$
$a_{i,j}$	Resource consumption coefficient	$[[1,1,1]\ [30,10,0]\ [2,1,3]]$
b_i	Total resources	$[300, 3000, 500]$

3.2 Data Preparation Methodology

3.2.1 Data Source Selection

Government statistical databases (such as the National Bureau of Statistics of China and the OECD official data platform) can obtain macro data such as industry capacity ceiling through public channels. The data sources are collected by government departments through standardized processes such as sampling surveys and direct reporting by enterprises. They are regularly audited by third parties and comply with international statistical standards. They have legal effect and reference value for policy formulation.

Annual reports can be viewed through official platforms such as the U.S. Securities and Exchange Commission's EDGAR system or the China National Enterprise Credit Information Publicity System. These audited financial reports disclose detailed micro-operation data such as raw material costs and management expenses. Information disclosure by listed companies is subject to the Securities Law and other regulations, and they must bear legal liability for fraud.

The standard values of industry technical coefficients can be referred to the annual white papers released by McKinsey, Boston Consulting Group, and other institutions. These reports are based on field surveys of leading global companies and use input-output models and machine learning algorithms for cross-validation. Their methodology has been peer-reviewed by academic journals such as Nature and has been incorporated into the industry benchmark indicator system by international organizations such as the World Bank.

3.2.2 Sample Selection Strategy

In the sample selection strategy, stratified sampling is suitable for the analysis of industrial portfolios with significant heterogeneity. For example, the China National Survey Database (CNIS) covers industrial enterprises in 31 provinces across China through a multi-stage probability proportional sampling method. Its sample frame is dynamically updated based on the economic census directory, and the weight distribution refers to the proportion of industry added value and is calibrated through the chi-square test, which can effectively reduce the estimation bias between heterogeneous groups.

Cluster sampling is more suitable for regional industrial cluster research scenarios. For example, the World Bank Development Indicators Database uses a geographic grid clustering algorithm to define the collection of enterprises within a 30-kilometer radius of national special economic zones and industrial chain supporting facilities as sampling units. The data comes from the location entropy and supply chain coupling indicators reported by the statistical bureaus of various countries in a standardized manner. It has been verified by OECD-DAC for consistency and supports cross-national panel data comparison, which can systematically characterize the spatial agglomeration effect and coordination cost characteristics of industrial clusters.

3.2.3 Verification Tool Chain

The verification toolchain includes multiple tools, each with different purposes and documentation support. Python-scipy-linprog is a tool for library function verification, LpSolve is used for model verification, Gurobi is a commercial-grade optimization tool for high-performance solvers, and Pyomo is an open source modeling tool for a variety of optimization problems.

3.2.4 Operation Results

When the input data and sample parameter values are the same, the optimal output is 40.0 for agriculture, 180.0 for industry, 80.0 for services, and the optimal value is 2540.0. Through data visualization, these results can be displayed more intuitively, helping us better understand the output distribution of each industry and its contribution to the overall optimal value.

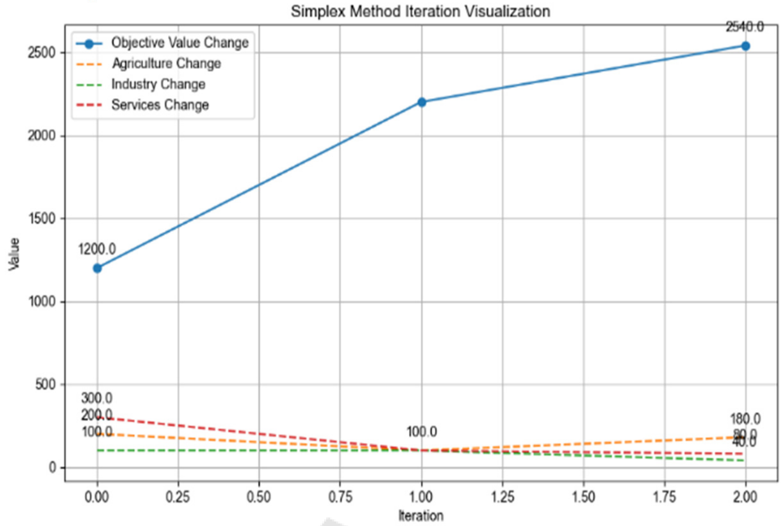

Figure 1: The simplex method's iterative process (Photo/Picture credit: Original).

Figure 1 shows the iterative process of solving the linear programming problem using the simplex method, specifically presenting the changes in the objective function value and the changes in output caused by the three variables of agriculture, industry, and services.

3.3 Results Analysis

In a region committed to achieving carbon peak and carbon neutrality goals, optimizing the industrial structure to maximize economic benefits and control carbon emissions is an important task. By establishing a linear programming model and solving the optimal industrial configuration plan, it has drawn the following important insights: In terms of industrial upgrading, the proportion of clean energy industry and modern service industry has increased significantly, reflecting the transformation trend from traditional industries with high carbon emissions to modern industries with low carbon emissions; in terms of resource utilization, the optimized resource allocation has made the total production, carbon emissions and labor reach the upper limit, making full use of existing resources; in terms of sustainable development, by increasing the proportion of clean energy and modern service industries, it have successfully achieved maximization of economic benefits while controlling carbon emissions.

Based on this, the following policy recommendations are put forward: First, increase support for the clean energy industry, formulate preferential policies, encourage enterprises to invest in the research and development and application of clean energy technologies, and enhance the market competitiveness of the clean energy industry; second, promote the green transformation of traditional industries, provide financial subsidies and technical support, and encourage traditional industrial enterprises to adopt low-carbon technologies and clean production processes to reduce carbon emissions; in addition, improve the carbon trading market mechanism, establish and improve the carbon trading market, regulate carbon emissions through market mechanisms, and stimulate the enthusiasm of enterprises to reduce emissions; finally, promote the development of modern service industries, cultivate new forms of modern service industries, promote the development of industrial structure towards high added value and low emissions, and enhance the sustainability of the overall economic structure.

4 DISCUSSION

4.1 Study Limitation

By constructing linear programming models for different industries, this study provides a scientific and effective method for optimizing the industrial production structure to control carbon emissions and maximize economic returns. However, the research data comes from the macro data obtained from stratified sampling and cluster sampling in a certain region, which is limited to the industry situation in a single region. Therefore, the conclusion cannot meet the applicability of industries in different regions and the universality of the research results Secondly, the constraints on labor, resources and carbon emissions in the model cannot be matched with government policy intervention in specific regions and market economy fluctuations, which cannot reflect the significant impact of market fluctuations on industrial decision-making shown in international experience, which affects the feasibility of this study. Thirdly, the dual carbon plan is advancing rapidly, and the development of various technologies may change the relationship between carbon emissions and economic benefits after the optimization of industry types, but this study cannot predict and simulate the impact caused by the emergence of different technologies.

4.2 Improvement & Suggestion

To ensure that major enterprises further promote and strengthen the optimization of industrial structure under the dual carbon goals, this paper will put forward the following suggestions for the government and enterprises:

4.2.1 Government Policy Recommendations

The government needs to improve and innovate the system according to the local situation, and at the same time need to improve the scientificity, rigor and implementability of laws and policies related to carbon emissions, the government should increase its support for the clean energy industry, providing energy subsidies and carbon tax policies for enterprises based on clean energy industry (Zhang, et al., 2023). And encourage enterprises to research and develop high-tech clean energy with high performance and low energy consumption (Wang, et al., 2020). And then， government can let some enterprises with relatively complete production structures to be the demonstration projects， Provide suggestions for improvement to other clean energy companies to increase the competitiveness of the clean energy market; increasing demand for clean energy products and improve the trading mechanism of the carbon trading market (Guan, et al., 2022). This will help more enterprises participate in carbon trading and improve technological innovation capacity in clean energy. For the modern service industry, the government can encourage enterprises to develop the digital economy, smart production, and green finance through preferential fiscal and tax policies (Zhou, et al., 2021). Compared with the other two industries, the government should strictly manage the carbon emissions of traditional industrial enterprises, set carbon emission caps, and introduce policies that require an increase in carbon taxes beyond a specific emission level, so as to guide traditional industrial enterprises to carry out green transformation through economic means (Yao, et al., 2020). At last, the government can suggest that traditional industrial enterprises reduce the waste of production resources through recycling, and carry out technological transformation of energy conservation and emission reduction, which can improve the utilization value and efficiency of resources (Chen, et al., 2019).

4.2.2 Communication Between Government and Business

The government can formulate a communication mechanism with enterprises to help enterprises understand the relevant policies issued by the state at the first time, ensure that the production objectives of enterprises are in line with the national strategic objectives, achieve information exchange, and help enterprises to adjust and optimize their own industrial structure according to the development trend of the country (Chen, et al., 2022). At the same time, universities can provide enterprises with the latest technical support and innovative resources in the first time, which improves the efficiency of achieving the double carbon goal and ensures the sustainability of industrial applications.

4.2.3 Companies Should Make Green Transition

As the main body of carbon emissions, enterprises should adapt to the relevant policies issued by the government, transform the internal structure of the industry according to the current environment and situation, and actively promote the development of low carbon emission goals. Enterprises can reduce carbon emissions by increasing investment in continuous improvement of production equipment, reducing the use of chemical energy, increasing the development and utilization of clean energy, and improving the efficiency of resource reuse. Secondly, each company can set up a carbon emission monitoring system according to its own products, which helps enterprises to understand and detect which parts of the production process will produce more carbon emissions and resource waste(Dong et al., 2023). This can help enterprises to carry out point-to-point optimization, improve production efficiency, ensure the maximization of economic benefits, but also reduce carbon emissions (Skrynkovskyy et al., 2022).

5 CONCLUSION

According to the characteristics of the industrial structure of traditional industry, clean energy industry and modern service industry in a region, a linear programming model is constructed in this study. With labor, resources and carbon emissions as constraints, it provides new ideas and optimized analysis on how to maximize economic benefits for the industry. The study shows that the industrial structure continues to develop from high carbon emissions to low carbon emissions, especially the proportion of clean energy industry and modern service industry has increased significantly, but the proportion of traditional industry has decreased compared with the former. This trend shows that the production volume, carbon emissions, and labor allocation after the optimization of the industrial structure have reached the upper limit, and the resources are extremely well utilized. This phenomenon reflects the unlimited potential of low-carbon enterprises to optimize and rationalize the allocation of resources.

It summarizes the goal of industrial structure optimization as the goal of realizing the dual carbon strategic policy of enterprises, optimizing their internal structure to continuously develop in the direction of low carbon and high added value. With the constraints of carbon emissions and the continuous reduction of resource waste,labor and production through continuous adjustment to achieve appropriate optimal allocation, and finally maximize economic benefits. In addition, the study finds that the proportion of clean energy industry and modern service industry has increased, indicating that while ensuring normal economic growth, effective control of carbon emissions can lay the foundation for green development and achieve sustainable industrial green transformation.

This study provides enlightenment and policy theoretical support and suggestions for how different industries can optimize their economic benefits by adjusting their industrial structure and types under the background of carbon peaking and carbon neutrality. The results encourage the government to increase support for the clean energy industry, provide subsidies and technical support for the green transformation of traditional industries, and establish a unified national carbon trading legal system. expanding the industrial coverage of the carbon market. Develop carbon financial products to establish a sound carbon trading market, so as to achieve a win-win situation that promotes the development of the entire economy and achieves carbon emission reduction goals. Therefore, the results of this study can provide ideas and valuable guidance for the government to establish green economic policies, and help the government to formulate more environmentally friendly economic policies with the help of different industries to change the way enterprises operate.

The two-carbon plan needs the continuous adjustment and joint efforts of the government, enterprises and the market to achieve. The government should play a leading role, formulate reasonable plans for the green transformation of enterprises with a supervisory role. For enterprises, they need to have the independent initiative of green transformation, and improve their production technology and innovation ability through continuous research and development. In response to different market conditions, various industries should combine their own characteristics, take economic growth and carbon reduction as the ultimate goal, and formulate cooperation plans to achieve a common win-win situation. Through the continuous improvement of the industrial structure and system, China's dual carbon development plan will be more perfect and lay a solid foundation for the sustainable development of the dual carbon structure.

AUTHORS CONTRIBUTION

All the authors contributed equally and their names were listed in alphabetical order.

REFERENCES

Zhang, Y., et al. (2023). The role of digital services in achieving low-carbon industrial chains: Evidence from smart logistics. *Sustainable Cities and Society*, 94,104532.

Wang, H., et al. (2020). Smart energy systems for sustainable modern service industries: A review. *Renewable and Sustainable Energy Reviews*, 132,110060.

Guan, D., et al. (2022). Sector-specific strategies for achieving carbon neutrality: A global multi-regional input-output analysis. *Nature Climate Change*, 12(2), 148-155.

Zhou, K., et al. (2021). The role of green finance in industrial structure optimization: Evidence from China. *Energy Policy*, 157,112508.

Yao, X., et al. (2020). Policy-driven structural changes in the energy-intensive industries under carbon peaking constraints. *Energy Economics*, 92,104957.

Chen, Y., et al. (2019). Decoupling industrial growth from carbon emissions: A case study of China's steel sector. *Resources, Conservation and Recycling*, 151,104479.

Chen, Y., et al. (2022). Industrial structure optimization under carbon neutrality: A case study of hydrogen energy clusters. *Nature Communications*, 13(1), 5980.

Dong, F., et al. (2023). Carbon neutrality challenges in heavy industries: Technology gaps and policy implications. *Journal of Cleaner Productio*n, 382,135232.

Geng, Y., et al. (2020). Industrial sustainability in China: Practices and drivers for resource efficiency improvement. *Journal of Cleaner Production*, 263,121389.

Skrynkovskyy, R., Pavlenchyk, N., Tsyuh, S., Zanevskyy, I., & Pavlenchyk, A. (2022). Economic-mathematical model of enterprise profit maximization in the system of sustainable development values. *Agricultural and Resource Economics: International Scientific E-Journal*, 8(4), 188-214.