Research on the Green Transformation Mechanism of the Chinese Manufacturing Industry under the Double-carbon Target

---based on the ISM-MICMAC model

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Abstract. China proposed the double-carbon goal of "3060", which outline the path for the greening manufacturing business. To meet this requirement, China's manufacturing sector urgently requires green transformation to boost competitiveness. Several case studies on the Chinese manufacturing industry were conducted using grounded theory to investigate the mechanism of the Chinese manufacturing industry's green transformation under the dual-carbon goal. The significant influencing factors of the manufacturing industry's green transformation development under the dual-carbon goal were then extracted. The internal logic of China's manufacturing industry's green development under the dual-carbon goal was further elaborated using the ISM-MICMAC construction mechanism model. It concludes that: Common technology supply platform, technology ecological innovation, and carbon emission reduction technology are the basic guarantees for a green economy.

Keywords: Carbon dioxide emissions; Carbon neutralization; Manufacturing industry; Green transformation; ISM-MICMAC introduction

1 Introduction

China proposed a dual-carbon goal in 2020, which will further guide the development of ecological civilization by achieving carbon neutrality in 2060 and peak CO2 emissions in 2030. In China's three macroeconomic areas, businesses play a significant role. While enjoying a lot of social wealth, they should also undertake corresponding corporate social responsibilities. As an industry with high carbon emissions, the manufacturing industry should conform to the trend of green development, accelerate the green transformation of businesses and assist China in establishing a new low-carbon economy.

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2 Literature review and theoretical basis

2.1 Literature review

Scholars both domestically and internationally primarily investigate the influence mechanism of the green transformation of the manufacturing industry from the angle of influence mechanism, which primarily encompasses the following three levels: (1)Technology innovation. Scholars like, Feng Zhitan[1], Khan[2], and Sun Haibo[3] believe that technological and scientific advancement can aid in the green transformation of Chinese manufacturing businesses. (2) Environmental regulation. Chen Xiaohong[4], Yang Lan[5], Zhu, and others[6] think that environmental regulation can significantly promote the green vitality of China's manufacturing industry. Additionally, they examine the impact of various forms of environmental regulation on the green transformation of the manufacturing industry and divide environmental regulation into three categories. (3) Government governance capacity. Zhangyan[7], Li[8], and Li Xiaoyi[9] examined the influence of government governance capacity, as well as the green transformation of the manufacturing industry from the point of view of the government, government governance intensity and local fiscal expenditure on the green transformation and upgrading of manufacturing industry, and also put forward feasible suggestions for local governments to implement policies.

To sum up, many scholars have accumulated a large number of research results on the influencing factors of manufacturing green transformation, which laid an important theoretical foundation for this paper to explore the green transformation mechanism of the Chinese manufacturing industry under the background of "3060". Realizing the green transformation and development of the manufacturing industry is crucial to achieving the objective of "peak carbon dioxide emissions, carbon neutrality" as well as the key to maintaining the global economy's core competitiveness. Based on previous studies, this paper regards the green transformation of the Chinese manufacturing industry under the dual-carbon goal as a complex system and starts with the in-depth interview data of 30 manufacturing industries, which are among the top 30 manufacturing industries in China's top 500 industry in 2021. Their practices in green transformation are more representative and meaningful for reference. Using grounded theory to extract the influencing factors of green upgrading of the manufacturing industry under the dual-carbon goal, and using ISM to construct the green transformation mechanism model of the Chinese manufacturing industry under the dual-carbon goal, this paper explores the influence relationship and path among various factors, and further classifies the influencing factors with MICMAC to open the "black box" of the cause and effect, systematically and comprehensively examines the Chinese manufacturing industry' green transformation mechanism in light of the dual-carbon goal and offers guidelines for the growth of green transformation and industry upgrade.

2.2 Theoretical basis

ISM Model.

System science research method ISM (Interpretive Structural Modeling Method) presents the analyzed total system's subsystems in the simplest hierarchical directed topological graph without sacrificing system functions. ISM has a wide range of application scenarios, ranging from international problems such as energy to personal problems, which can be effectively analyzed and solved by the ISM method.

MICMAC Model.

MICMAC, the multiplication of cross-influence matrix, is mainly used to analyze the influence and dependence of various factors in the system, and the results can be expressed by coordinate axes. Summing the rows and columns of the reachable matrix yields the driving force and dependence values, and the average's horizontal and vertical error lines divide the influencing factors into four categories[10]: spontaneity, dependence, linkage, and independence.

3 Multi-case analysis of influence factors

As a typical qualitative research method, grounded theory's basic principle is to integrate the collected original data, establish the internal relations among them, directly summarize the original data statements, and summarize the core concepts that reflect the research object, then develop into categories and finally sublimate into theories. This paper uses NVIVO12.0 software to deploy and code the original data of 30 Chinese manufacturing industries. In this paper, following the coding method proposed by Strauss and Corbin in 2007, the influencing factors of the Chinese manufacturing industry' green transformation under the dual-carbon goal were extracted, and the original data of five other industries were collected for theoretical saturation test. None of them produced new concepts and categories, which indicated that the rooted research could be stopped. The research results are shown in Table 1.

Table 1. Factors influencing the green transformation of the Chinese manufacturing industry under the dual-carbon target (Table Credit: Original)

IF	Explain
International economy and trade G1	International economic ties are caused by the flow of production factors.
Climate Cooperation G2	International cooperation to mitigate climate deterioration.
Carbon trading market G3	A market artificially created by the government to control greenhouse gas emissions from the energy-consuming industry.
Industrial structure adjustment G4	The adjustment made by the state to the industrial organization of the manufacturing industry for industrial upgrading.

Green fiscal policy G5	The policy of giving preferential tax to green products.
Carbon emission reduction policy G6	Policies to guide the industry to take emission reduction measures.
Common technology supply platform G7	Provide a platform for widely used technology in the manufacturing industry and bring huge economic and social benefits to it.
New infrastructure G8	Infrastructure such as 5G infrastructure, big data centers, and artificial intelligence.
Energy infrastructure construction G9	Energy-related facilities such as municipal utilities and public life services are shared by industry.
Ecological innovation G10	Integrating ecological concepts into technology research and development and innovation.
Carbon emission reduction technology innovation G11	Technologies that can reduce greenhouse gas emissions.
Technological innovation to improve energy efficiency G12	Technologies that can improve energy efficiency.
Technology introduction configuration system G13	The configuration system of technology introduction, digestion, and absorption in industry.
Financing capacity G14	Under certain conditions, the size of the financing that an enterprise may finance.
Willingness to Green Transformation G15	The attitude of industry towards green transformation.
Supply Chain Management G16	Management to optimize supply chain operation.
The energy structure of the enterprise G17	The proportion of all kinds of energy used by industry in the total amount.
Business model innovation G18	Change the basic logic of enterprise value creation to realize the process of green manufacturing in the whole life cycle of products.

4 Research process based on ISM-MICMAC

4.1 ISM model construction of green transformation of Chinese manufacturing industry under the dual-carbon target

This study constructs the 18*18 adjacency matrix A after determining the logical relationship among the influencing factors using the correlation table from NVIVO12. The construction rules of the adjacency matrix are as follows: if the factor Gi has a direct influence on G_j, the value of a_{ij} is 1, otherwise, it is 0, and vice versa. MATLAB software is used to calculate the reachable matrix M based on the adjacency matrix A. The reachable matrix M is determined using the following Boolean algebra operation rules: $(A+I)\ (k-1) \neq (A+I)\ (k+1) = M$. If the adjacency matrix A satisfies, then

M is the desired reachable matrix, as shown in Table 2(k=1,2…,18, I presents identity matrix). The hierarchical division is carried out based on the reachable matrix M, and the set reachable set $P(G_i)$ and the antecedent set $Q(G_i)$ the common set $S(G_i)$ are obtained. The highest-level factors, which can be found at the first level L1 of the ISM model diagram, are the ones that have the same reachable set and common set after the initial hierarchical processing. The factors of the L1 layer are eliminated after the factors of the first layer are determined, and the factors set off the second layer are then determined using the aforementioned methods, until all the factors are layered, and the iteration ends. After many iterations, the influencing factors of the Chinese manufacturing industry' green transformation under the dual-carbon goal are divided into five levels. According to the hierarchical results, the ISM model of the Chinese manufacturing industry' green transformation mechanism under the dual-carbon goal is constructed by reaching matrix M and adjacent matrix A, as shown in Figure 1 below.

Table 2. Reachability Matrix M (Table Credit: Original)

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18
G1	1	0	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1
G2	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
G3	0	0	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
G4	0	0	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1
G5	0	0	1	0	1	0	1	0	0	1	1	1	1	1	1	1	1	1
G6	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1
G7	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
G8	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1
G9	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1
G10	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
G11	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
G12	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
G13	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
G14	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
G15	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1
G16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18
G17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
G18	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1

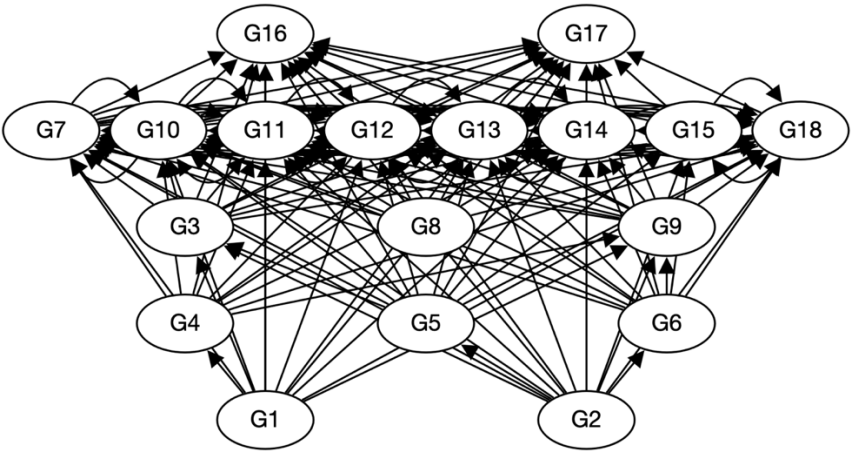

Fig. 1. MICMAC analysis quadrant of green transformation mechanism of the Chinese manufacturing industry under the dual-carbon target

(Photo credit: Original)

Table 3. Hierarchical decomposition (Table Credit: Original)

LEVEL	IF
First Layer	G16, G17
Second Layer	G7, G10, G11, G12, G13, G14, G15, G18
Third Layer	G3, G8, G9
Fourth Layer	G4, G5, G6
Fifth Layer	G1, G2

4.2 ISM analysis of the green transformation of the Chinese manufacturing industry under the dual-carbon target

As can be seen from Figure 1 and Table 3, the influencing factors of the Chinese manufacturing industry' green transformation under the dual-carbon goal can be divided into five levels. The interpretive structural model method of ISM divides the model into

three layers: the fundamental layer, the intermediate layer, and the representation layer. The fifth layer is the fundamental layer, while the third and fourth layers are intermediate layers and the first and second layers are representation layers, respectively.

The Fundamental layer.

The international economy is the basic influencing factor, which provides economic regulation for the green transformation of the Chinese manufacturing industry to achieve the double-carbon goal. The manufacturing industry leads the whole national economy and is the industry most closely linked with the international economy. The international economic turmoil will affect China's implementation strategy of the "two-carbon" goal, prompting China to speed up the adjustment of the industrial structure of the manufacturing industry and upgrade from a labor-intensive to a technology-and capital-intensive industrial structure. Climate cooperation is the most fundamental factor affecting China's realization of the dual-carbon goal, and it is the deepest reason in the ISM model. China should actively seek opportunities to collaborate on climate issues. For example, conducting a series of studies on peak CO_2 emissions and carbon neutrality, and demonstrating its importance as a large nation in light of the changing international climate. We should learn from the experience in developed countries. Strengthening the policy path design of carbon neutrality, and providing a reference value for the green transformation of the domestic manufacturing industry and the realization of double carbon goals.

The Intermediate layer.

The fourth layer of influencing factors are industrial structure adjustment, green fiscal policy, and emission reduction policy; The third layer of influencing factors are the carbon trading market, new infrastructure, energy infrastructure construction, and the industry' green transformation willingness. The change in factor supply will affect the construction of energy infrastructure, industrial restructuring will encourage the transformation and green upgrading of manufacturing, and carbon neutrality will be achieved by 2060. The willingness of manufacturing company executives to make the transition to a greener business model and the transaction prices of buyers and sellers in the carbon trading market will be affected by green fiscal policy's tax incentives for green manufacturing products. To set emission standards for manufacturing industries and encourage businesses to significantly reduce emissions, the state develops emission reduction policies. The emission reduction policy will also affect the construction of energy infrastructure, improve related energy facilities such as municipal engineering and living services shared by industry, and urge the manufacturing industry to actively carry out energy conservation and emission reduction.

The Representation layer.

Technology ecological innovation, carbon emission reduction, energy efficiency enhancement, technology introduction and allocation system, financing capability, and business model innovation all interact with one another, and they all act on supply chain management and energy structure of the industry, and are all affected by carbon trading

market, new infrastructure, energy infrastructure construction and industry' green transformation willingness. The industry needs to improve its financing capacity, improve its financial situation, strengthen technology introduction, improve technology introduction and allocation system, provide basic support for technology ecological innovation and business model innovation, incorporate the long-term development of carbon emission reduction technology and energy efficiency improvement technology into key technology development strategies of industry, actively take measures such as supply chain management optimization and energy structure adjustment to improve the production efficiency of industry, realize green transformation and upgrading, and form new market competitiveness under the goal of peak carbon dioxide emissions and carbon neutrality.

4.3 MICMAC Analysis

Each influencing factor's dependency and driving force are calculated using the reachable matrix M. The driving force in a reachable matrix is the sum of the rows, and the dependency is the sum of the columns. Check out Table 4 below. Find the average value of dependence and driving force, take the error line of the average value as the quadrant dividing line, divide all factors into four quadrants in turn, and draw the MICMAC analysis quadrant diagram of the green transformation mechanism of the Chinese manufacturing industry under the dual-carbon target, as shown in the following figure 2.

Table 4. Driving force and dependency (Table Credit: Original)

Factors	Driving force	Dependency
G1	14	1
G2	15	1
G3	11	4
G4	12	2
G5	12	2
G6	12	2
G7	10	16
G8	11	1
G9	11	5
G10	10	16
G11	10	16
G12	10	16
G13	10	16
G14	10	16
G15	10	16
G16	10	16
G17	1	17
G18	1	17
G19	10	16
AVG	10	10.32

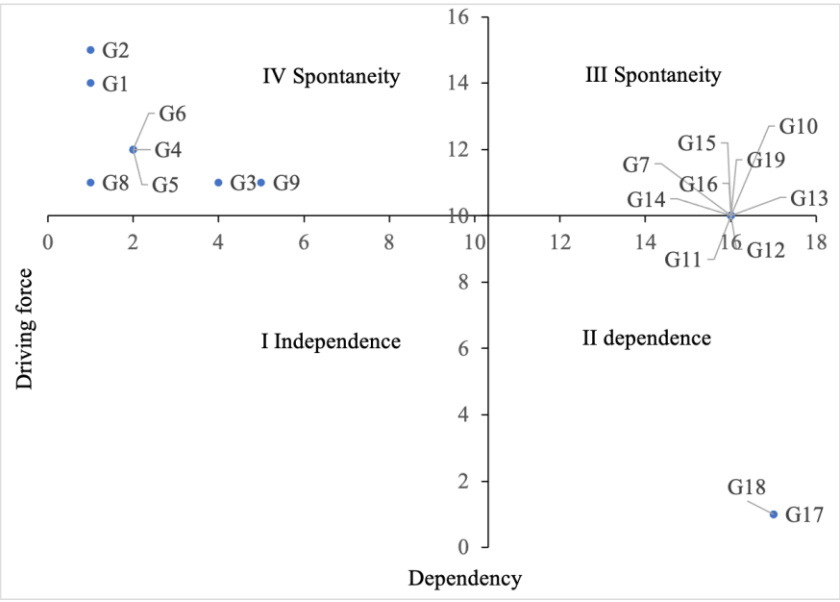

Fig. 2. MICMAC analysis quadrant of green transformation mechanism of the Chinese manufacturing industry under the dual-carbon target

(Photo credit: Original)

The first quadrant is independent, and the influencing factors in this area have nothing to do with the system. The study's findings indicate that there are no influencing factors in the first quadrant's independent region. The dependence quadrant, in which the influencing factors are highly dependent but have little driving force, is the second quadrant. In this quadrant, the ISM model's first- and second-layer factors depend on the lower-layer factors and are influenced by their driving force. The linkage quadrant, in which the influence factors are highly dependent and driven, is the third quadrant. It frequently plays a role in transmitting the influence of lower factors to the system's upper level. Although common technology supply platforms, technology ecological innovation, carbon emission reduction technology, energy efficiency improvement technology, technology introduction and allocation system, financing capability, and business model innovation are located in dependent areas, they are very close to linkage areas. It can be seen from the ISM model diagram that the influence of low-level factors on high-level factors is transmitted through these factors, which is consistent with the model results. The influencing factors that are situated in the spontaneous quadrant of the fourth quadrant have a low dependence and a high driving force. The factors of the third, fourth and fifth layers in the ISM model are all located in this area, which has a strong driving force for the high-level influencing factors. It is not only difficult to control other influencing factors indirectly but also a series of butterfly effects will be produced once these factors are destroyed, so we should pay attention to them.

5 Conclusion

From a systematic perspective, the green transformation mechanism of China's manufacturing industry is influenced by 18 factors under the goal of carbon peak and carbon neutrality. Using the ISM model to define each factor's logical link and action flow. Based on this, a green transformation model for the manufacturing industry is built. The influencing factors are categorized and the indirect relationship between them is further examined using the MICMAC method. The findings demonstrate that technology ecological innovation, carbon emission reduction technology, energy efficiency improvement technology, technology introduction and allocation system, supply chain management, enterprise energy structure, common technology supply platform, financing capability, and business model innovation are highly dependent on the underlying influencing factors, and common technology supply platform, technology ecological innovation, carbon emission reduction technology, energy efficiency improvement technology, technology introduction, and allocation system, financing capability and business model innovation have the effect of transmitting influence. Carbon trading market, new infrastructure, energy infrastructure construction, industry' green transformation will, industrial structure adjustment, green fiscal policy, emission reduction policy, and international economic and climate cooperation have great influence, and once they are damaged, they will have a butterfly effect. The following three countermeasures and suggestions are made in light of the research findings presented in this paper to enhance the effectiveness of the green transformation of the manufacturing industry by the double-carbon target.

Firstly, improve the structure system of green technological innovation and accelerate the integration of technological innovation. (1) We should create a good environment for green technological innovation. Promote the innovation, application, and transfer of green technology through economic activities such as the use, transaction, and compensation of natural and social resources. (2) It is necessary to speed up the integration of technological innovation, deeply integrate the new generation of information technology with new energy technologies such as carbon emission reduction technology and energy efficiency improvement technology, and give birth to new formats such as new energy internet and comprehensive energy service platform, promote the development of energy system towards cleaner and lower carbon, and accelerate the pace of carbon neutrality. (3) The carbon market plays a significant role in promoting energy conservation, emission reduction, and green manufacturing transformation to construct a carbon market holistically. Promoting the green transformation of the manufacturing industry and achieving coordinated development of green low carbon and economic benefits requires accelerating the pace of the construction of carbon markets.

Secondly, make laws, rules, and other supporting policies that will help reach the dual-carbon goal. On the one hand, to protect the green transformation of the manufacturing industry to achieve the goal of double carbon, the government should establish a comprehensive system of laws and regulations, a precise implementation system of the rule of law, a strict supervision system of the rule of law, and a strong guarantee system of the rule of law. To encourage the green transformation of Chinese industry,

businesses can bear the costs of destroying the natural environment and abusing social and public resources through legislation. On the other hand, we should continue to innovate and enhance preferential policies and systems to support green transformation following industrial green development needs. The government should strengthen the loan support for the emerging green industry in the manufacturing industry, give incentive tax preferential policies, attract investors to support green start-up companies, reduce the difficulty for the green industry to enter the securities market, and support them to set up incubators to conduct green science and technology development experiments.

Finally, strengthen international climate cooperation and jointly tackle climate change. (1) We should advocate ideas first and build a beautiful homeland together. The concept of a "Community of Shared Future for Mankind" should be established by all nations, and multi-level and diverse international climate cooperation should be strengthened by the principle of "common responsibility but different responsibilities." (2) International organizations should urge developed and developing nations to actively join the global climate action to make commitments to peak carbon dioxide emissions and carbon neutrality. They should view these commitments as an important strategic goal for the economic development of all nations worldwide. This will make the target's content clearer. It has become a broad consensus among people all over the world to promote carbon neutrality. (3) To strengthen cooperation in green low-carbon technology, CCS and CCUS are the key areas of low-carbon technology development in China at present, which are characterized by high-risk, high-energy consumption, high cost, and difficulty. China will jointly exchange experiences with advanced regions in the world, get national scientific and technological support, and develop low-carbon technology through joint research and innovation, to achieve win-win cooperation with low-carbon life.

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