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Selection and application of China environmental sustainability policy instrumental: a quantitative analysis based on "Dual Carbon" policy text

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The "Dual Carbon" policy is a strategic instrument for the realization of the "Dual Carbon"target. The quantitative analysis of the "Dual Carbon" policy can provide theoretical support and decision-making reference for the institutional design and adjustment of the policy, so as to further improve the "Dual Carbon" 1 + N policy system. By constructing a three-dimensional analysis framework of "instrument-goal-object", adopting the content analysis method, and combining the coding results of the "Dual Carbon" policy text to conduct multidimensional cross-analysis, we found that the overall design of the "Dual Carbon" policy is reasonable, but at the same time, there are problems such as unbalanced distribution of policy instruments, incomplete coverage of policy goals, insufficient synergy of policy objects, and low degree of matching between policy dimensions. In response to these problems, targeted mitigation measures are proposed.

KEYWORDS

environmental sustainability, "Dual Carbon" policy, quantitative analysis, policy instrument, policy goal, policy object

1 Introduction

Since the year 2006, China has been the world's largest emitter of carbon dioxide (Guan et al., 2021). China's CO_2 emissions grew 565 Mt in 2023 to reach 12.6 Gt. This represents an increase of 4.7%, as emissions from energy combustion increased 5.2% (IEA50,2024). China has actively implemented governance measures to mitigate climate change since the Paris Agreement (The Paris Agreement, 2015) came into effect in November 2016. China will increase its autonomous national contribution, adopt more aggressive policies and initiatives, and strive to achieve a peak in CO_2 emissions by 2030 and strive to achieve carbon neutrality by 2060 (herein referred to as "Dual Carbon"), General Secretary Xi J P stated at the 75th General Debate of the United Nations General Assembly on 22 September 2020. The promotion of China's economy's high-quality development is inherently reliant on the achievement of "Double Carbon" target. The decision to advance to a new stage in the development of economic society and energy technology is also inevitable (Jiang and Raza, 2023). China has constructed the "Dual Carbon 1 + N policy framework" as a timeline, roadmap and construction plan to achieve the "Dual Carbon" target, of which the"Opinions of the Central Committee of the Communist Party of China State Council on

the Complete and Accurate Implementation of the New Development Concept and the Good Work of Carbon Peaking and Carbon Neutrality" (hereinafter referred to as the "Opinions") is the top priority. The "Opinions" will serve as the top-level design, and will lead the formulation of a series of "Dual Carbon" policy, and on the basis of the existing "Dual Carbon" related policies, continuously extend the thickness, depth and breadth of the "Dual Carbon 1 + N policy framework". Although the basic structure of China's "Dual Carbon" 1 + N policy framework has been established (Lu, 2022), "Dual Carbon" encompasses a wide range of subjects, involves numerous fields, and will take place over the course of the next 3 decades or even longer. As a result, achieving the target of "Dual Carbon" is a multifaceted, lengthy, systematic project that calls for the Chinese government to continuously adjust, improve, and optimize the "Dual Carbon" policy. To enhance the stability and systemic nature of the "Dual Carbon" 1 + N policy framework and to identify the future "Dual Carbon" policy, it is crucial to understand the characteristics of the current layout, content, and structure of "Dual Carbon" policy and to analyze in depth which policy Instruments are used, what goal are achieved, and to whom these policies are applied. Finding the appropriate locations to execute future "Dual Carbon" regulations is also crucial. Based on this, this paper conducts a quantitative analysis of China's "Dual Carbon" policy, investigates their shortcomings, and suggests targeted relief countermeasures, with the goal of providing theoretical support for the quantitative analysis of China's "Dual Carbon" policy and other sides of policies and providing workable decision-making references for the design, adjustment, and improvement of China's "Dual Carbon" 1 + N policy framework.

2 Literature review

"Peak carbon dioxide emissions" refers to the peaking of CO_2 emissions, and "carbon neutrality" refers to the positive and negative offsetting of CO_2 emissions and removals, according to the UN Intergovernmental Panel on Climate Change (IPCC) report and the worldwide consensus (IPCC, 2018; Wei et al., 2018; Zou et al., 2021). The term "Dual Carbon" has gained significant attention from academics both domestically and internationally. It has also become a major topic of global concern. At this time, the majority of academic study on "Dual Carbon" is concerned with the advancement of technology, evaluation of its impacts, realization pathways, and advancement in practice. Nature examines many suggestions for how China could achieve neutrality before 2060 from significant research organizations that collaborate closely with the government. According to the two research groups, China must first start generating the majority of its electricity from emission-free sources, and then increase the usage of this clean energy wherever it is practical, such as by converting from gasoline-powered cars to electric ones (Mallapaty, 2020). Xiao et al. discussed the importance of AI technology in achieving carbon neutrality in the shipping industry (Xiao et al., 2024). Williams J. H. et al. Developed a roadmap for achieving deep decarbonization in the United States by modeling the energy and industrial systems of the country, simulating in detail the transition paths in a number of industries, including construction, electricity, transportation, and industry. According to research, the United States may attain zero emissions without changing its behavior by gradually increasing energy efficiency, switching to electrical technology, utilizing clean electricity (particularly wind and solar), and installing a tiny quantity of carbon capture equipment (Williams, 2021). By De La et al. Four ET scenarios are created using the Kaya Identity and "gradual" or "rapid" narratives, using Mexico as an example. The findings demonstrate that adhering to RTS moves Mexico one step closer to becoming carbon neutral. A number of tactics are suggested, such as lowering the carbon intensity of the energy supply mix, raising energy efficiency, giving environmental protection top priority, improving activities based on science, and fostering environmental education and awareness (De et al., 2022). Koondhar et al. found that bioenergy consumption could help achieve carbon neutrality (Koondhar et al., 2021). Lee et al. proposed a creative method of waste gasification treatment that could help achieve carbon-neutral cities (Lee et al., 2021). Safi et al. assessed using panel data econometric techniques and found that environmental taxes、credit financing、antitrust exemption and shipping alliances can contribute to achieving carbon neutrality targets in economies (Safi et al., 2021; Xu et al., 2024; Xiao et al., 2024). Abbasi showed that natural resource depletion can provide a significant stimulus to CO_2 emissions in the short term through dynamic autoregressive distributed lag (ARDL) models and robustness checks (Abbasi et al., 2021).

Scholars have also performed some research on"Dual Carbon" policy from various angles and using varied methods. Oh et al. contend that Korea's ability to meet its 2050 carbon neutrality goal will depend on the effectiveness of carbon pricing measures in attracting private climate finance (Oh et al., 2021). Dahal et al. study renewable energy policies using a multilevel perspective (MLP) and semi-structured interviews, and argue that the implementation of renewable energy policies is a key component in achieving carbon neutrality target (Dahal et al., 2018). Hussain et al. constructed a mathematical model of the duo-oligopoly game, and after analyzing various carbon neutral policies, they pointed out that green bonds, carbon taxes, carbon emission allowances, and capacity-sharing modes play a crucial role in carbon neutralization (Hussain and Lee, 2022; Xu et al., 2022). Huang R et al. based on the extended STIRPAT model and LEAP-Beijing model, this paper assesses the key areas and pathways for carbon emissions reduction in Beijing for the period of 2015–2060 under six different policy scenarios. The results show that energy structure upgrading and energy efficiency improvement are the key drivers for the city's emissions reduction (Huang et al., 2022). Chen et al. quantify the Arctic oil spill event impact with an ensemble framework supported by the analytic network process (ANP) and fuzzy comprehensive evaluation model. The proposed framework provides a novel and reasonable decision-making instrument, which can contribute to the achievement of carbon neutrality in the marine environment (Chen et al., 2022).

Compared with the research on "Dual Carbon" practice and technology, there is still a lack of research on "Dual Carbon" policy, and there is the following room for expansion in the current policy research: First, from the perspective of research methodology, the majority of the current studies are qualitative, concentrating on macro-level and theoretical discussions, while a small number of

TABLE 1 Summary of "Dual Carbon" policy texts (excerpt).

Number	Policy name	Regulatory authority	Date of issue
1	Higher Education Carbon Neutral Science and Technology Innovation Action Plan	Ministry of Education of the People's Republic of China	2021.7.12
2	Standardized Energy Peak Carbon Neutral Upgrading Action Plan	National Energy Administration	2022.9.20
...	...	...	...
176	Implementation Program for Peak Carbon Achievement in the Industrial Sector of the Tibet Autonomous Region	Department of Economy and Informatization of the Tibet Autonomous Region	2023.5.8

quantitative studies concentrate on the creation of policy models and the evaluation of the effects. The quantitative study of policy texts, in particular, primarily uses a one-dimensional or two-dimensional analytical framework. Second, the number of samples used in present studies' quantitative analyses, which use a single policy text as a sample, needs to be increased from the viewpoint of research objectives.

Therefore, this study uses China's "Dual Carbon" policy as its research subject, employs the content analysis method, builds a three-dimensional framework for policy analysis called "instrument-goal-object" and evaluates the "Dual Carbon" policy released by China's national and provincial governments. Theoretical support for the quantitative study of "Dual Carbon" policy and other sides of policies may be obtained from the quantitative study of "Dual Carbon" policy, which can also serve as a foundation for the best institutional design of China's "Dual Carbon"policy. At the same time, it can serve as a significant source of decision-making guidance and practical inspiration for China's "Dual Carbon" policy, helping to further enhance the "Dual Carbon" 1 + N policy framework".

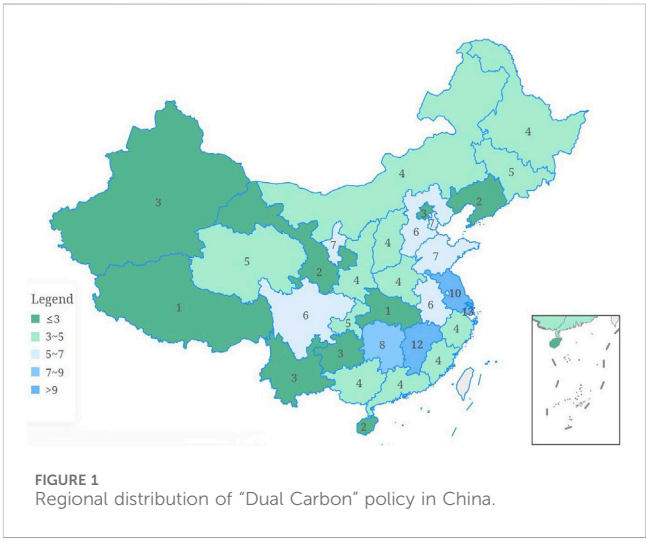

FIGURE 1
Regional distribution of "Dual Carbon" policy in China.

3 Materials and methods

3.1 Sample selection

Firstly, the policy texts were selected. The sources of the policy texts are the magic weapon of Peking University, Wan fang database, as well as Chinese government website, General Office of the State Council of the People's Republic of China, official websites of ministries and commissions (e.g., Ministry of Education of the People's Republic of China, Ministry of Finance of the People's Republic of China, etc.), and provincial local government websites. Republic of China, etc.) and provincial local government portals (e.g., The People's Government of Beijing Municipality, Shanghai Municipal People's Government, etc.). Search by full text, the keywords used were "Dual Carbon", "Carbon Neutrality", and "Carbon Peaking"; the policy text collection time was set from 30 September2020, to 31 December2023, with the announcement of the "Dual Carbon" targets as the starting point. Secondly, to ensure the authority, credibility, and representativeness of the selected policy texts, this study adhered to the following principles: (1) Policy texts are officially published opinions, decisions, notifications, plans, work plans, management measures, outlines, etc.; (2) Policy content is closely related to the "Dual Carbon"field; (3) Policy texts clearly state that achieving "Dual Carbon" targets is the policy orientation; (4) Only the latest versions of the same category of policies currently in effect were selected. Finally, according to the above standards and the principle of maximum effort sampling, 176 policy texts were ultimately screened (Table 1), including 23 central "Dual Carbon"policy texts and152 provincial "Dual Carbon"policy texts, covering relevant policies issued by 31 provincial administrative regions excluding Hong Kong, Macao, and Taiwan. The policy texts were numbered one by one in sequence by first central then regional (administrative region codes ascending) and release time (from earliest to latest) to construct a database of China's "Dual Carbon"policy texts, which serves as the foundation for quantitative analysis of policy texts. The regional distribution statistics of "Dual Carbon"policies show that more policies have been released in regions like Shanghai, Jiangxi, Jiangsu, and Hunan (Figure 1).

3.2 Construction of "instrument-goal-object" framework

Policy is the process of designing, selecting, and applying various policy instruments by governments. Policy instruments have clear objectives and operational guidance, and the policy instrument dimension focuses on the specific means utilized by the government in the policy process, involving the effectiveness of policy formulation and the operability of policy implementation.

Operable policy instruments can help the government guide the development of relevant industries and fields more clearly, to realize the policy goals (Furlan et al., 2018). However, policy instruments cannot characterize the elements or content of policies, and policy analysis based on a single dimension of policy instruments will lead to an incomplete policy analysis. (Yi and Feiock, 2014). To better reflect the means adopted by policies, the process of goal realization, as well as the inherent laws and characteristics of policies, this paper introduces the dimensions of policy goals and policy objects, which are useful to complement the single perspective of policy instruments. The policy goal dimension focuses on the specific goals established in the process of policy formulation and the desired realization effects. Policy goals should be closely related to policy instruments and have clarity to facilitate the assessment of the effectiveness of policy implementation. The policy object dimension focuses on the subjects, industries, and fields targeted by the policy. In the process of policy formulation, the policy object will change according to the different policy goals, and the government needs to choose the appropriate policy object according to the actual situation (Huang et al., 2020). The framework has the following characteristics: (1) Systematic. It can systematically integrate the core elements of the policy process. By focusing on the three key dimensions of policy instruments, goals, and objects, the policy background, formulation process, and implementation effectiveness can be analyzed comprehensively, thus avoiding the one-sidedness caused by research based solely on policy instruments. (2) Coherence. Policy formulation, implementation, and evaluation can be linked together, helping to analyze the interconnections and roles between policies at different stages. By tracking the selection of instruments, target setting, and object positioning of policies in the formulation process, and examining the actual application and impact of these elements in the policy implementation and execution stages, it is possible to more accurately assess the effects of policies, and further understand the completeness and consistency of the policy system. (3) Operationalization. Enables policymakers and practitioners to identify the relationship between policy instruments, goals, and objects, to introduce targeted policy measures, and improve the enforceability, effectiveness, and relevance of policies. (4) Insight ability. Provides policy research with a method for comprehensively sorting out and analyzing policy elements, thus helping to dig deeper into the internal laws and characteristics of policy formulation and implementation. Utilizing this framework, it is possible to better interpret the intentions, policy orientations, and practical effects behind policies, thereby providing insightful views and suggestions for policy improvement and innovation.

3.2.1 Dimension X: policy instrument

The many methods and instruments that governments use to accomplish their goals in terms of public policy are known as policy instruments (Howlett, 1991). The innovation and optimization of policy Instruments can improve the practice of public management, but the premise is to define the sides of policy instruments in a reasonable way (Li and Gu, 2016). McDonnell et al. divide them into four categories: systemic transformation, capacity building, inducing and motivating, and empowering and commanding (McDonnell and Elmore, 1987). Schneider et al. based on the goals of the policy, divide them into five categories: learning, capacity building, authority, motivation, and exhortation (Schneider, 1990). Howlett et al. classify them into three categories: mandatory, mixed, and voluntary, based on the degree of policy intervention (Howlett et al., 1995). Hughes et al. classified government functions into four categories: government supply, production, subsidy, and regulation (Hughes, 2017). The most representative of these is Rothwell and Zegveld's classification of supply-side, demand-side, and environment-side (Rothwell and Zegveld, 1984). Rothwell and Zegveld's classification of policy instruments has a more systematic and comprehensive policy analysis viewpoint (Hu et al., 2019), which is relevant given the broad variety of topics covered by "Dual Carbon" policy. Therefore, in order to assess the X dimension of China's "Dual Carbon" policy, this research utilizes Rothwell and Zegveld's classification of policy instruments. This study defines the sides of policy instruments from the supply, environment, and demand levels, which are grouped into 12 policy instruments (Table 2).

Supply-side refer to the top-down method used by the government to actively influence "Dual Carbon" related domains or links, including talent training, financial support, infrastructure, and information services. The environment-side policy instruments refers to the institutional framework that the government has established to support the development, implementation, monitoring, and direction of"Dual Carbon"policy, including target planning, regulatory control, advocacy guidance, and tax benefits. Demand-side policy instruments, which include government purchases, strategy measures, cooperation and outsourcing, and market control, refer to the efforts made by the government to lessen opposition to the carbon market and boost the vitality of carbon market participants. To achieve the"Dual Carbon"target, multiple policy instruments will interact with one another (Figure 2).

3.2.2 Dimension Y: policy goal

The desired consequences of policy formulation and implementation, as well as the underlying assumptions and standards for policy implementation and evaluation, define the scope of the decision-making process when choosing policy goals Wang et al. discovered that policy goals are the topics that need to be focused on in the current research on China's "Dual Carbon" policy through the research on the boundaries of China's "Dual Carbon" policy. To analyze "Dual Carbon" policy, policy objects are used as the Y dimension in this paper. The "Dual Carbon" target encourage high-quality development that strikes a balance between the benefits to the environment and the economy and seeks to accomplish a thorough ecological, economic, and social green transformation. Based on the above discussion, The ecological, economic, and social green transitions are viewed as the specific evolution and sub-target of the "double carbon" strategic goal based on this and the main layout of the opinions (Table 3).

3.2.3 Dimension Z: policy object

Different policy objects have different behavioral characteristics, rights, and responsibilities, which interact with one another in various policy stages, areas, and links and are the requirement and cornerstone for achieving policy functions. Policy objects are the target groups of policy implementation. As a result, the primary element used to describe the policy's attributes is the policy object. The government, businesses and organizations, and the general people are referred to in this paper as the Z dimensions of the

TABLE 2 Sides, names, descriptions and sources of policy instruments.

Sides	Name	Description
Supply-side	Talent training	Promoting "Dual Carbon"education and training and building a talent pool (De, 2021)
	Financial support	Direct government funding in the form of different financial grants and specialized subsidies (Kang, 2019)
	Infrastructure	To ensure the smooth implementation of energy saving and emission reduction activities in urban and rural areas improve various infrastructure and services (Li et al., 2021; Ma et al., 2021)
	Information services	Government publishes technical guidelines, standards and other information related to "Dual Carbon" (Hu et al., 2020)
Environmental-side	Target planning	Overall planning and requirements to achieve the "Dual Carbon" target (Liao, 2016; Hu et al., 2021)
	Regulatory controls	supervising and controlling diverse topics' activity in accordance with rules and regulations (Li et al., 2023)
	Advocacy guidance	Encourage everyone to be environmentally conscious and to reduce their carbon footprint (Xie et al., 2021)
	Tax benefits	The government offers tax breaks to businesses, organizations, and people who accomplish "Dual Carbon" in certain industries (Li et al., 2021)
Demand-side	Government purchases	Government spending programs intended to achieve the "double carbon" target (Yue et al., 2020)
	Strategy measures	To achieve the "Dual Carbon" target, there are incentives and disincentives at all levels of government, sectors, and industry (Ma et al., 2019; Meng and Wang, 2022)
	Cooperation and outsourcing	Sharing of expertise, collaboration in scientific research, outsourcing of services, etc. Between multiple organizations (Meng and Wang, 2022)
	Market control	Enhance the market system and encourage everyone to take an active role in energy conservation and emission reduction efforts (Zhang and Liu, 2016)

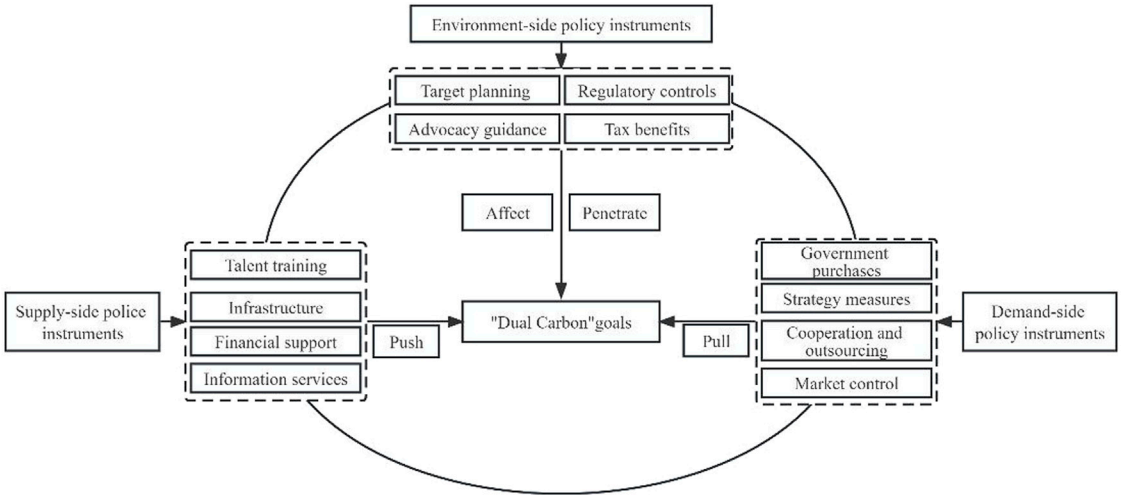

FIGURE 2
Interaction between policy instruments.

TABLE 3 Policy goals and descriptions.

Policy goal	Descriptions
Ecological green transition	boost carbon sinks, strengthen ecological and environmental management, and promote green ecology
Economic green transition	Establish a green industrial system, carry out green manufacturing initiatives, enhance green development mechanisms, and create a green, low-carbon, and circular development economic system
Social green transition	creating a culture of environmentally friendly living, awareness of low-carbon consumption, and green travel

TABLE 4 Policy objects and descriptions.

Policy object	Descriptions
The government	The central government, ministries, local governments, and line ministries at the provincial level are the objects of the policy
Businesses and organizations	The policy is intended for use by businesses, public organizations, nonprofit organizations, etc
The public	The public is the object of the policy

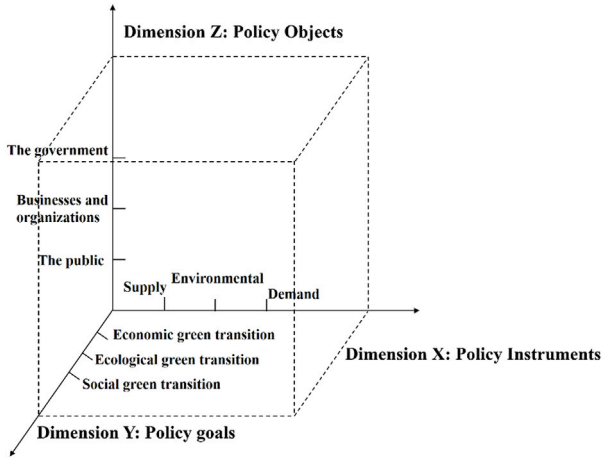

FIGURE 3
Three-dimensional framework for analysis of "Dual Carbon" policy.

"Dual Carbon" policy analysis framework, which was based on research by Zhang (Zhang et al., 2021) (Table 4).

By merging the three dimensions of the "instrument-goal-object" of the policy, a three-dimensional analysis framework of the "Dual Carbon" policy is created based on the analysis and description provided above (Figure 3).

3.3 Coding process

3.3.1 Coding classification

The first step was to divide the policy texts down into policy clauses, which served as the smallest unit of analysis. Clauses that did not pertain to the article's subject were eliminated, and the remaining clauses were coded with "policy number - order of policy clauses"; The second step was to carefully examine the policy's texts and create a preliminary summary of the provisions' contents. Finally, the policy clauses were categorized into various coding categories to form a complete policy coding framework. The same policy provision may use multiple policy instruments simultaneously, fail to display the goal or object; or achieve multiple objectives concurrently, act on multiple objects concurrently, etc., so that some policy provisions may not cover all dimensions but all cover X dimensions (Table 5).

3.3.2 Reliability and validity testing

This study conducted a reliability test to ensure sure the coding was of high quality and to strengthen the scientific rigor of the policy texts analysis. According to the coding consistency formula established by Viney: E = 4C/(n1 + n2 + n3 + n4) (Viney, 1983), four academics who are familiar with the "Dual Carbon" target and have a high coding foundation were first permitted to carry out the independent coding checking system. Where n1, n2, n3, and n4 are the number of codes produced by each coder and C is the total number of coders producing the same number of codes. When E [0.8, 0.9] shows that the confidence result is adequate, and when a >0.9 shows strong confidence. The coding results in this research are believable because the confidence value of the results is 0. 84 after calculation. In this study, the policy samples were chosen by conducting a text search and screening against the ten key elements of the "Opinions" actions. At the same time, the policy texts were supplemented and gathered in Baidu and other search engines by grouping the names of the central government, ministries, and commissions, as well as the names of the party and government leader agencies in each province, with the search terms. In order to guarantee the accuracy of the policy assessments, the policy texts were also reverse-engineered in terms of the links between policies' inheritance and citation.

4 Empirical analysis

4.1 One-dimensional linear analysis

4.1.1 Analysis of X dimensional results

In terms of the X dimension (Figure 4), the "Dual Carbon" policy texts use a variety of supply-side, environment-side, and demand-side policy instruments, they are often characterized by strong supply, light environment, and weak demand. Nearly half of them (43.52%) fall within the supply-side category, with the environment coming in second (35.82%) and demand-side (20.67%) falling in third. Financial support (64.14%) is the largest supply-side policy instrument; target planning (33.1%), publicity and guidance (28.28%), and regulation and control (27.01%) are the largest environment-side instrument; market control (37.45%) and government purchases (36.85%) are the largest demand-side instrument. As can be shown, the following characteristics best describe the distribution of policy instrument dimensions: (1) Tax incentives are underemphasized among environmental policy instruments, accounting for only 4.16% of all policy instruments. (2) Tax incentives are underemphasized among supply-side policy instruments, accounting for more than twice as much as demand-side ones. (3) The pulling effect of demand-side policy instruments is weak, with policy synergy (1.93%) accounting for the smallest share of all policy instruments. (4) There is an imbalance in distribution within policy instruments, and a sizable gap between supply and demand. Fourthly, the usage of a single policy

TABLE 5 Example of policy texts coding.

Texts analysis unit	Summarization	Coding categories		
		Instruments	Goals	Objects
To ensure that the primary objectives, development directions, major policies, and major projects for the implementation of carbon peaking and carbon neutrality are coordinated across all regions and areas, strengthen the interaction and coordination between various planning levels	All levels of government have to coordinate their policies	Strategy measures	Ecological green transition	The Government
Encourage sustainable, low-carbon lifestyle and resource efficiency. Encourage the reuse of mulch and the intelligent use of livestock manure and crop straw	Encourage and direct low-carbon and cost-effective agricultural production technologies	Advocacy guidance	Social green transition	The public
standardize the green design's construction. For greening projects that receive financial support, the construction unit is responsible for creating an operational design (also known as a greening program), and the department in charge of the project collaborates with other departments as needed to assess the operational design's logic in terms of land use, water use, and technical measures, as well as to oversee its implementation	Demand that the relevant government departments supervise and coordinate business activity related to the green economy	Regulatory controls	Economic green transition	The Government Businesses and organizations

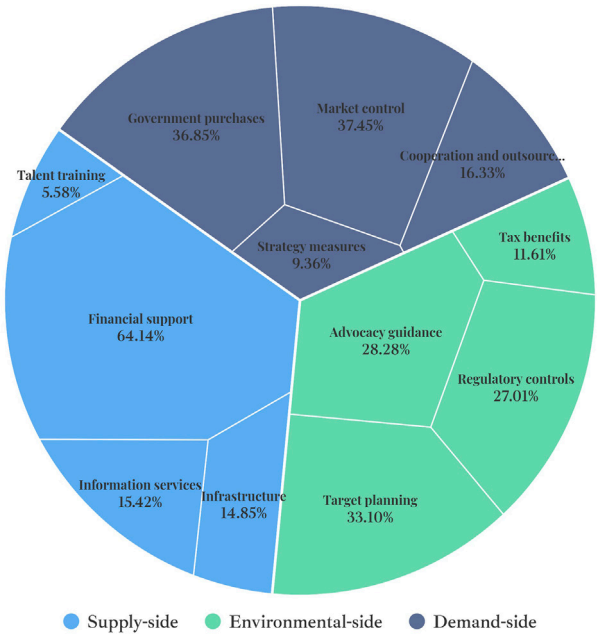

FIGURE 4
Distribution of "Dual Carbon" policy goals.

TABLE 6 Distribution of "Dual Carbon" policy goals.

Policy goals	Amount	Overall percentage (%)
Ecological green transition	1,408	61.08
Economic green transition	588	25.51
Social green transition	309	13.41
Total	2,305	

TABLE 7 Distribution of "Dual Carbon" policy objects.

Policy object	Amount	Overall percentage (%)
The government	1,199	53.72
Businesses and organizations	814	36.47
The public	219	9.81
Total	2,232	

instrument is excessive, and the distribution within each policy instrument is unbalanced, talent training is more than ten times more expensive than financial support.

4.1.2 Analysis of Y dimensional results

In terms of the Y dimension (Table 6), the ecological green transformation goals (61.08%) are the most widely distributed, followed by the economic green transformation goals (25.51%), and the social green transformation goals (13.41%) are relatively less widely distributed, with the distribution of the three sides of policy goals being roughly 4.5:1.9:1. This shows that the current emphasis on the social green transformation goals is inadequate. When formulating policies, attention should be paid to the comprehensive promotion of several objectives.

4.1.3 Analysis of Z dimensional results

In terms of the Z dimension (Table 7), the government, businesses and organizations, and the general public account for 53.72%, 36.47%, and 9.81%, respectively. This accurately reflects the government's dominant role in the process of achieving the "double carbon" target as the policymaker, overseer, and implementer, acting in a macro-guidance role. However, businesses, organizations, and

TABLE 8 Distribution of policy instruments used for "Dual Carbon" goals.

Goals instruments	Ecological green transition	Economic green transition	Social green transition	Subtotal	Total
Talent training	30	20	6	56	Supply-side (1,002)
Financial support	430	198	40	668	
Infrastructure	66	38	28	132	
Information services	80	51	15	146	
Target planning	158	50	73	281	Environmental-side (818)
Regulatory controls	129	52	42	223	
Advocacy guidance	127	43	50	220	
Tax benefits	37	39	18	94	
Market control	120	49	9	178	Demand -side (485)
Government purchases	158	9	16	183	
Strategy measures	34	8	3	45	
Cooperation and outsourcing	39	31	9	79	
Total	1,408	588	309	2,305	
percentage	61.08%	25.51%	13.41%	100%	

the general public are also important factors in achieving the "double carbon" target, so it is crucial to develop and enhance the participation mechanism to encourage and direct all different sides of subjects to actively participate in the process of achieving the "double carbon" target.

4.2 Two-dimensional cross-tabulation analysis

4.2.1 Analysis of X-Y dimensional results

Cross-tabulation analysis of the X-Y dimensions was carried out (Table 8). A total of 2,429 items made up the overall X dimension, whereas 2,305 items made up the cross-coding with the X-Y dimension, showing the existence of numerous policy instruments working on the same goal.

Cross-sectionally, supply-side policy instruments (43.47%) were most effective in achieving the policy goals, followed by environmental-side policy instruments (35.49%) and demand-side policy instruments (21.04%). The three sides of policy instruments that were used the most frequently were financial support, target planning, and government purchases, showing that the government favors promoting the "double carbon" target through various special or green project subsidies, important pilot projects, and regulations.

Cross-vertically, the frequency of ecological transition, economic green transition, and social green transition are 408, 588, and 309, respectively. Figure 3 shows that the government primarily supports the achievement of ecological and economic green transition goals by providing resources like talent, information, and infrastructure; social green transition goals, on the other hand, use more target planning, regulatory controls, and advocacy guidance policy instruments, showing that the government primarily creates awareness of energy conservation and emission reduction in the entire society.

4.2.2 Analysis of X-Z dimension results

Cross-tabulation analysis of the X-Z dimensions was carried out (Table 9). A total of 2,429 items made up the overall X dimension, whereas 2,232 items made up the cross-coding with the X-Z dimension, suggesting there may be several-side acting on the same object.

Cross-sectionally, the majority of instruments employed in supply-side (44.09%) are financial support, infrastructure, and information services, with talent training being utilized much less frequently than other instruments (and at a much lower rate overall); A moderate amount of environmental-side (34.77%) are used, with a use ratio of 3.3:1 and a significant difference between target planning and tax benefits. Demand-side (21.15%) made up the smallest percentage, in which market control and government purchases were closely tracked. This shows how highly the government regarded the resource and energy market trading system, as well as green pilots and important initiatives.

Cross-vertically, the most common sides of policies used by businesses, governments, and other organizations are supply-side, followed by environment-side and demand-side. Of the policy sides that are directed at the general public, environment-side account for the largest share (984), while supply-side and demand-side strategies account for the next largest shares (776) and 472, respectively. This is consistent with the roles played by governments, businesses, organizations, and the general public in achieving the "Dual Carbon" target: the government, as the main decision-maker, primarily offers ideological and practical guidance on policy-making, technological research and development, public awareness, etc., but it is also the primary source of carbon

TABLE 9 Distribution of policy instruments used by "Dual Carbon" policy objects.

Objects instruments	The government	Businesses and organizations	The public	Subtotal	Total
Talent training	22	30	1	53	Supply-side (984)
Financial support	330	310	21	661	
Infrastructure	56	49	21	126	
Information services	58	78	8	144	
Target planning	168	78	52	298	Environmental -side (776)
Regulatory controls	145	46	34	225	
Advocacy guidance	86	14	63	163	
Tax benefits	0	85	5	90	
Market control	82	82	14	178	Demand-side (472)
Government purchases	168	0	0	168	
Strategy measures	35	0	0	35	
Cooperation and outsourcing	49	42	0	91	
Total	1,199	814	219	2,232	
percentage	53.72%	36.47%	0.0981	100%	

TABLE 10 Distribution of "Dual Carbon" policy objects in achieving policy goals.

Objects instruments	Ecological green transition	Economic green transition	Social green transition	Total	Percentage (%)
The government	934	115	116	1,165	52.81
Businesses and organizations	336	429	49	814	36.90
The public	56	29	142	227	10.29
Total	1,326	573	307	2,206	100

dioxide production and emission. One way to promote and direct their engagement in energy-saving and emission-reduction initiatives is to strengthen tax profits. On the other side, China need control, monitor, and assess their behavior in order to foster a positive work environment. For the general public, it is essential to directing citizens' behavior in daily life through publicity, education, and appropriate acknowledgment, reward, and punishment.

4.2.3 Analysis of Y-Z dimension results

Cross-tabulation analysis of the Y-Z dimensions was carried out (Table 10), The total coding for policy goals and objects was 2,303 and 2,232, respectively, while they were cross-coded with 2,206, indicating the presence of one-to-many and many-to-one relationships.

Inferred from the cross-tabulation data, the policy objects with the highest frequency of response for the government, businesses and organizations, and the general people are, respectively, ecological green transformation, economic green transformation, and social green transformation. The tasks of the government, businesses, and organizations, and the general public in the "Dual Carbon" tracks are aligned with this situation: the government is primarily responsible for resource, environmental, and ecological issues, and focusing on the implementation of ecological green transformation is its top priority; Businesses and organizations are more concerned with enhancing economic efficiency and lowering the costs associated with energy conservation and emission reduction due to their role in pursuing economic benefits and development; consequently, policies for businesses and organizations place a focus on achieving the goals of economic green transformation, such as industrial upgrading, innovation in the green financial system, and optimization of the energy structure; Since the public is the driving force behind the social green transition, encouraging and enabling them to actively participate in ecological and environmental sustainability is essential to accomplishing the "Dual Carbon" target.

4.3 Results of the three-dimensional cross-tabulation analysis

Cross-tabulation analysis of the X-Y-Z dimensions (Table 11), discovered that there were significant disparities in the kinds of policy instruments that acted on various policy objects and were put into place in response to various policy goals. Among the policies to achieve the goal of ecological green transformation, supply-side

TABLE 11 Use of "Dual Carbon" policy instruments by policy objects to achieve policy goals.

Instruments		Ecological green transition			Economic green transition			Social green transition			Total
		The government	Businesses and organizations	The public	The government	Businesses and organizations	The public	The government	Businesses and organizations	The public	
Supply-side	Talent training	15	12	0	4	16	0	3	2	1	980
	Financial support	261	167	2	47	138	13	18	5	6	
	Infrastructure	34	18	8	6	25	7	16	6	6	
	Information services	53	21	4	2	49	0	3	8	4	
	Subtotal	363	218	14	59	228	20	40	21	17	
	percentage	39.29%	61.24%	27.45%	51.30%	56.58%	68.97%	38.46%	42.86%	12.23%	
Environmental-side	Target planning	118	35	5	14	35	1	23	2	46	745
	Regulatory controls	116	6	7	8	33	1	9	7	26	
	Advocacy guidance	67	5	19	13	5	4	6	4	40	
	Tax benefits	0	37	0	0	39	0	0	9	5	
	Subtotal	301	83	31	35	112	6	38	22	117	
	percentage	32.58%	23.31%	60.78%	30.43%	27.79%	20.69%	36.54%	44.9%	84.17%	
Demand-side	Market control	82	32	6	0	46	3	0	4	5	445
	Government purchases	138	0	0	9	0	0	16	0	0	
	Strategy measures	24	0	0	8	0	0	3	0	0	
	Cooperation and outsourcing	16	23	0	4	17	0	7	2	0	
	Subtotal	260	55	6	21	63	3	26	6	5	
	percentage	28.14%	15.45%	11.76%	18.26%	15.63%	10.34%	25%	12.24%	3.6%	
Total		924	356	51	115	403	29	104	49	139	2,170
total percentage		42.58%	16.41%	2.35%	5.3%	18.57%	1.34%	4.79%	2.26%	6.41%	

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acting on the government, businesses, and organizations are more frequently used, whereas the public uses environmental-side more frequently; among the policies to achieve the goal of economic green transformation, the policies acting on the three sides of objects are concentrated on the supply-side; among the policies to achieve the goal of social green transformation, the supply-side affecting the government are more frequent, whereas the environmental-side affecting businesses, organizations, and the general public are more prevalent. It is evident that the supply-side have a stronger influence and penetration power on governments, businesses, and organizations; the environmental-side have a stronger influence and penetration power on the public to achieve social green transformation, and the pulling power of the demand-side needs to be strengthened.

5 Discussion

5.1 The analysis of results

5.1.1 Differences in the popularization and implementation of provincial "Dual Carbon" policies

Currently, China's local "Dual Carbon"" policy system is in its infancy. As of 31 December 2023, 31 provincial-level administrative regions, excluding Hong Kong, Macao, and Taiwan, have issued relevant policies. Among them, Shanghai (13), Jiangxi (12), Jiangsu (10), and Hunan (8) have issued a relatively large number of policies, indicating that these provinces have a high awareness of the need to take action to address climate change and to achieve the goals of carbon peaking and carbon neutrality, as well as strong policy implementation. These regions tend to have heavier responsibilities for carbon emissions, and the effect of policy implementation is of great significance to the realization of the "Dual Carbon" target of the country as a whole. Hubei and Tibet, on the other hand, have only issued one special policy on carbon emissions, reflecting the relatively low level of resource investment and policy attention in the formulation and implementation of carbon policies in these regions. These regions may need to strengthen their efforts in policy development and implementation in order to maintain overall synchronized progress with the achievement of the national "Dual Carbon""target.

5.1.2 Uneven distribution of policy instruments and internal and external disproportionality

It is found that the supply-side policy instruments account for a relatively high proportion (43.52%), followed by the environment-side (35.82%), and the demand-side policy instruments (20.67%) are relatively low. Demand-side policy instruments are seriously insufficient, and the gap between the use of the other two sides of policy instruments is large; internally, there is a polarized phenomenon of overflow and serious underuse of policy instruments, with only the three sides of policy instruments of financial support, target planning and publicity and guidance accounting for 50% of all policy instruments, but the four sides of talent cultivation, tax incentives, policy synergies and exchange platforms account for a total of only 11.9%. Among environment-oriented policy instruments, tax incentives account for only 4.16% of all policy instruments, indicating that insufficient attention is paid to tax incentives.

5.1.3 Incomplete coverage of policy goals and shortcomings in layout

Statistically, the ratio of policy provisions covering the three sides of policy goals is 4.6:1.9:1, which indicates that the current focus on the goal of a green transformation of society is insufficient. To advance multiple goals simultaneously, policymakers should consider increasing the attention paid to the goal of a green societal transition to ensure that policy goals are holistic and comprehensive.

5.1.4 The combined role of policy objects is underutilized

Through statistics, it is found that the policies that act on the government are overused, accounting for a total of 52.72%, enterprises and organizations for 36.47%, and the public for 9.81%. This indicates that the current policy text lacks mechanisms and institutions for enterprises organizations and the public to participate in "Dual Carbon"" actions, resulting in a distribution pattern in which multiple parties are not able to participate, and causing resistance to the "Dual Carbon"" implementation path of synergistic participation by multiple actors.

5.1.5 Low degree of matching between policy dimensions

The key to achieving a balanced match between policy instruments, policy goals, and policy objects is improving the high degree of coupling of policy instruments with multiple objects and goals and expanding the comprehensiveness of the coverage of the three main sides of instruments with policy objects and policy goals. To bring into play the cross-cutting effects and strengthen the scientific nature of the "Dual Carbon" policy, the synergistic use of supply-side, demand-side, and environment-side should be encouraged. Policies should also be applied precisely and effectively to the government, society, organizations, and the public following the pattern of ecological, economic, and social development.

5.2 Policy recommendations for the government

5.2.1 Strengthening the popularization and implementation of "Dual Carbon"" policies nationwide

In response to the results of the analysis, it is necessary to strengthen the popularization of the "Dual Carbon"" policy nationwide, improve the implementation of the policy, and encourage local governments to formulate and adjust policy measures according to the actual situation. At the same time, it is necessary to promote cross-regional policy experience sharing and cooperation, facilitate policy transparency and communication, and establish an effective multi-party collaboration mechanism. In addition, monitoring and evaluation of policy implementation should be strengthened, and a comprehensive performance evaluation system for policy implementation should be

established to ensure that the effectiveness of regional "Dual Carbon"" policies is clearly and comprehensively assessed. The combined application of these recommendations will help to improve the promotion and implementation of regional "Dual Carbon"" policies in China and facilitate the formation of a favorable atmosphere for national policy implementation.

5.2.2 Adjusting the structure of policy instruments to realize the combined effect

Through analysis, it is found that the current sides of "Dual Carbon"" policy instruments are characterized by strong supply, light environment, and weak demand. Although the supply-side policy instruments account for a large proportion of the policy instruments and provide strong support for the realization of the "Dual Carbon"" goal, the insufficiency of demand-side policy instruments also restricts the policy effect. To balance the configuration of policy instruments, it is necessary to adjust the external and internal structure of policy instruments, to form a combination effect of "Dual Carbon"" policies and play a clustering role. In addition, we note that green tax incentives are relatively underutilized among environmental policy instruments. To unleash their incentive potential, policymakers should pay more attention to and implement green tax incentives and other preferential policies to create a market environment conducive to carbon emission reduction.

5.2.3 Optimizing the layout of policy goals and enhancing the comprehensiveness of policies

In terms of policy goals, the ecological green transformation goal is more prominent, while the attention to the social green transformation goal needs to be improved. In the future, attention to policies for realizing social green transformation goals should be increased, focusing policies on establishing a green public service system and carrying out green education for all, establishing and improving the support system for urban and rural residents to live green, strengthening citizens' low-carbon beliefs, and cultivating public low-carbon consumption behavior. In addition, policies for regulating and punishing behaviors that harm the ecological environment need to be increased, and a strategy combining incentives and guidance with punishment needs to be adopted, to Form a healthy and orderly policy environment.

5.2.4 Strengthen the synergy of policy objects and consolidate the support system of policies

Regarding policy objects, the results show that the government, enterprises, and organizations account for a relatively large proportion, but the public accounts for a relatively small proportion. We propose to build and improve a multi-participation mechanism to encourage and guide enterprises, organizations, and the public to participate in achieving the "Dual Carbon"" goal. First, at the level of enterprises and organizations, policies should be focused on stimulating the participation of enterprises and organizations in energy saving and emission reduction activities, strengthening the financial and tax support for enterprises to participate in energy saving and emission reduction activities; increasing the intensity of government projects and government purchasing; improving the carbon trading market mechanism and green financial system; introducing the Interim Regulations on the Administration of Carbon Emission Trading to regulate the behavior of enterprises and the market order; and encouraging colleges, universities, and scientific research institutions to carry out research and development of green and low-carbon technologies and accelerating the transformation of scientific and technological achievements. Technology research and development and accelerate the transformation of scientific and technological achievements. Secondly, at the public level, we should explore innovative policies for public participation in energy conservation and emission reduction activities, build a national action system to promote the greening of lifestyles, and formulate corresponding commendations, rewards, and penalties, to guide citizens' behavior and turn low-carbon concepts into conscious actions by the public.

5.2.5 Improving the coupling and coverage of policy matching to leverage cross-cutting effects

According to the two-dimensional and three-dimensional cross-tabulation analysis, we find that there are obvious differences between policy instruments across policy goals and objects. It is recommended to improve the high degree of coupling of policy instruments with multiple objects and goals and to expand the comprehensiveness of the coverage of the three major sides of instruments with policy objects and policy goals. The synergistic use of supply-side, demand-side, and environmental-side policy instruments should be promoted, and policies should be applied accurately and efficiently to the government, society, organizations, and the public following the pattern of ecological, economic and social development, to give full play to the cross-cutting effects and enhance the scientific nature of the "Dual Carbon" policy.

6 Conclusion

Based on the three-dimensional analysis framework of policy instruments, goals and objects, this paper selects 203 "Dual Carbon" policy texts, carries out a multi-dimensional quantitative analysis of "Dual Carbon" policy, and puts forward targeted relief strategies, which is not only of innovative significance in expanding the orientation of theoretical research, but also of practical value in optimizing the purpose of practical governance. The number of strategies is rather small because the "Dual Carbon"target plan has only been available for 2 years. We will continue to expand the samples of policy analyses and integrate them with the logic of policy evolution to better understand how China's "Dual Carbon" policy framework is evolving and how policy effects are manifesting going forward. We will keep expanding the sample of policy analyses and conduct ongoing, multi-dimensional research and explorations by fusing the logic of policy evolution, policy system, and policy effectiveness in the future with the continuous improvement of China's "Dual Carbon" policy system and the further manifestation of policy effects.

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Conflict of interest

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Supplementary material

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