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Evaluation of fiscal policy with text mining under "dual carbon" target in China

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ABSTRACT

The establishment of “dual carbon” goals exemplifies China’s global commitment as a responsible sovereign and the methodical advancement toward these aims is illustrative of China’s capable governance in countering climate transformation. The actualization of “dual carbon” targets is contingent upon the foundation of robust fiscal policies, and meticulous assessments of policy documentation are instrumental in reflecting the foreseen efficacies of these measures. The study employs text mining techniques to articulate evaluative benchmarks for fiscal policy scripts under the “dual carbon” framework and engages a bidirectional fixed-effects model to corroborate the linkage between fiscal policy implements and carbon emissions, alongside a holistic appraisal using the PMC-CRITIC index model. The research corroborates that fiscal instruments, such as tax reliefs and green fiscal transfers, significantly encourage the diminution of carbon emissions. The average PMC-CRITIC index of the policy specimens assessed is 0.62, indicating a level that is permissible yet indicating potential for further refinement. Of the reviewed policy samples, the preponderance adheres to satisfactory thresholds, with an ensuing tier demonstrating exceptional policy. The average evaluations of policy timeliness, nature, and evaluation are laudable, notwithstanding the necessity for ameliorations in the precision of policy objectives, the credibility of the policy objects, and the targeted applicability of policy tools. Accordingly, in the trajectory of impending policy development, there should be an amplification of the collaborative mechanisms both horizontally among sundry tiers of local governance and vertically across disparate bureaucratic strata, the adoption of a systemized approach to elucidate and resolve the fundamental dissonances in actualizing “dual carbon” objectives.

1. Introduction

Given the increasing severity of environmental and economic impacts due to global climate change, no country on earth can avoid the problem of excessive carbon emissions, China, as a courageous power, has proposed a solution with Chinese characteristics to this problem. President Xi Jinping, on behalf of the Chinese government, solemnly announced at the 75th session of the United Nations General Assembly that China will peak its carbon emissions by 2030 and aim to achieve the strategic development goal of carbon neutrality by 2060. The current energy structure in China is heavily reliant on coal; deploying clean energy on a broad scale necessitates substantial effort and time. This involves a massive transition and phase-out mechanism for the extensive coal-powered industry, as well as the construction and upgrade of technologies and facilities for renewable energy. Enhancing the rigor of ecological governance in the future is expected to promote the upgrading of China’s industrial structure, which, in turn, holds considerable

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potential for internal optimization [1].The accomplishment of carbon peak and carbon neutrality targets will not only boost societal awareness of low-carbon efficiency and green development but will also guide industrial upgrades and technological innovations. Importantly, it demonstrates the proactive stance of a major developing country in addressing global climate change to the international community. The report of the 20th National Congress of the Communist Party of China (CPC) has explicitly stated that China needs to actively and prudently "advance the twin goals of peaking carbon emissions and achieving carbon neutrality." This commitment is not only a fulfillment of international obligations but also an intrinsic requirement for China's pursuit of high-quality development and the construction of ecological civilization. Given China's unique energy structure and its current high dependency on fossil fuels, conceiving a "consolidate before dismantling" strategy is essential to balance immediate economic development needs with long-term environmental goals. China must plan coherent medium to long-term actions, precisely capturing the timelines and roadmaps to carbon peak and carbon neutrality. At the collective study session of the Political Bureau of the CPC Central Committee in 2024, General Secretary Xi Jinping further emphasized accelerating the green transformation of development modalities to ensure the achievement of the targets for carbon peaking and carbon neutrality. On February 4, 2024, Premier Li Qiang of the State Council signed the "Interim Regulations on Carbon Emission Trading Management." This policy marks another significant step for China in establishing a low-carbon development path supported by economic policy and market mechanisms, which will robustly drive the healthy development of the carbon market and ensure marketized, legal safeguards for carbon peak and carbon neutrality.

Policymakers, entrepreneurs, and residents share the significant responsibility of minimizing carbon emissions to the greatest extent possible [2]. The Sustainable Development Goals (SDGs) serve as a collective agenda for nations and serve as a focal point for progressive policy discussions [3]. The analysis and monitoring of the Sustainable Development Goals are crucial measures in assessing potential remedial actions. Pursuing sustainability within economic development presents multifaceted challenges due to its intricate nature, featuring a complex web of interdependent connections [4]. The multifaceted trajectories for achieving China's "dual carbon" goals, namely carbon peaking and carbon neutrality, have been extensively explored in academic discourse. Wen Lei and Diao Peixin (2022) delineated the carbon neutrality process into three distinct stages: the carbon peak phase (2020–2030), the deep decarbonization phase (2030–2050), and the zero-carbon phase (2050–2060) [5]. In an innovative approach, Yang Meng and Liu Yisheng (2023) introduced a hybrid forecasting methodology leveraging the Elman neural network (ENN) in conjunction with the sparrow search algorithm (SSA). Their research indicates promising opportunities for China to attain its carbon peak within the window of 2028–2030, with carbon neutrality achievable by 2060 under a neutral scenario—contingent upon renewable energy constituting over 80 % of the energy mix, an urbanization rate reaching 85 %, and energy consumption being restricted to within 6.5 billion tons [6]. Jiang Q (2023) posits that with the synergistic effect of dampened economic growth and policy orientation, it is feasible for China to peak its carbon emissions before 2030, all the while sustaining a comparatively elevated level of carbon intensity and circumventing complete adherence to traditional societal development paradigms [7]. The large-scale deployment of wind energy is identified as one of the primary conduits to meet China's objectives of carbon peaking and neutrality. By the year 2030, the implications of climate change on the wind power assimilation capacity are projected to be minimal, although some increments are anticipated in select southern provinces [8]. Natural gas, as a clean and low-carbon energy resource, also plays a pivotal role in the low-carbon transition, garnering considerable attention. Zhang He et al. (2023) employed a quantile cumulative grey model to forecast natural gas consumption across China's 30 regions (provinces, cities, and autonomous areas) from 2022 to 2030, predicting a continued rise in natural gas consumption for most regions, barring a few special cases [9]. Regarding the major trends in energy consumption and carbon emissions, China's primary energy consumption is anticipated to peak around 2035, while carbon emissions from energy consumption are projected to peak circa 2025, and natural gas consumption is expected to reach its zenith around 2040, with the power and industrial sectors experiencing the highest growth rates [10]. Railway transportation has been identified as a significant source of greenhouse gas emissions within the transport sector, with energy-saving technologies such as regenerative braking and lightweight materials enhancing the sustainability of railway operations [11]. Hu Yu et al. (2022) found that within the total carbon emissions of Beijing, the residential and transport sectors constitute a considerable share. To attain carbon neutrality, substituting fossil fuels with electric power and a high proportion of external electricity is essential measures [12], while the concepts of a circular economy and sustainable smart cities stand as viable solutions. Wu Meifen et al. (2023) observed that since the introduction of the "dual carbon" targets, public attention to climate change issues has become more widespread, with coast and economically developed areas engaging in more frequent discussions and communication activities related to environmental issues [13]. This finding indicates a variation in the awareness and concern for climate change topics. Media coverage and attention can also indirectly affect climate change issues. On the one hand, media focus can enhance the negative impact of climate risk on corporate ESG (Environmental, Social, and Governance) factors [14]. On the other hand, media reports can also reinforce the role of institutional investors' ESG actions in promoting corporate green innovation [15].

The assurance of meeting the dual carbon goals, to a large extent, relies on the effective formulation and implementation of fiscal policies. Environmental governance represents a fundamental responsibility of governmental administration, with finance, serving as a cornerstone of national and local governance. The issuance of fiscal policies about the "Dual carbon" initiative signifies the government's efficient and organized advancement of environmental governance. By discerning the objectives and strategies of governance, the text of fiscal policy offers insights, while its quantitative evaluation enables an assessment of the anticipated outcomes of the policy at its inception. The study by Niu Bingcheng (2024) suggested that an increase in government environmental protection expenditure leads to a surge in green innovation, which in turn has a positive impact on national ESG performance [16].Therefore, to effectively address the "dual carbon" target of this formidable challenge, the central government must foster harmonious coordination among local governments and administrative bodies of all tiers. This collaboration is crucial for achieving a delicate equilibrium between the magnitude of carbon reduction, the pace of structural adjustments, and the sustainable affordability of the economy and society. Serving as the vital nexus between market regulations and governmental objectives, fiscal policy assumes a pivotal role as a buffer to strike this balance. With its dual functions of providing incentives and imposing constraints, fiscal policy plays a guiding role in shaping the desired outcomes. The enactment and execution of targeted fiscal policies exert direct influence on various stakeholders within the economy and society, efficiently addressing both positive and negative externalities. By rectifying such externalities, the fiscal policies enable the alignment of private and social costs, consequently inducing changes in the economic actions of these stakeholders either directly or indirectly. Notably, fiscal policy assumes a critical role in optimizing the industrial structure, leveraging its attributes of incentives and constraints to stimulate technological innovations within enterprises and encourage environmentally beneficial practices in governance. Simultaneously, fiscal policy operates in synchronization with the timely implementation of other public policies. It exerts its influence across multiple domains, ensuring smooth functioning and collaboration among these policies. This synergistic approach enhances the overall effectiveness of implementing various public policies while concurrently meeting the satisfaction levels of the populace.

Indeed, fiscal policy research has been extensively conducted within the academic community. However, there remains ample room for discussion concerning the analysis and evaluation of fiscal policy texts, particularly those formulated in alignment with the “double carbon” objective. As a result, the initial objective of policy evaluation should focus on retracing the origin and establishing a distinctive and rigorous index system that can effectively assess the content of the policy texts. This enables a more comprehensive evaluation of fiscal policies aimed at achieving the dual goals of economic development and carbon reduction. In this research paper, our objective is to attain scientific and objective evaluation outcomes by refining the PMC index model and subsequently conducting a quantitative analysis of fiscal policy texts. Universally, countries and regions are confronted with the challenge of addressing global climate change. By offering a quantitative evaluation of fiscal policies under the “dual carbon” targets, this study provides references and lessons for other nations and regions. Different countries can adopt similar assessment methods based on their specific circumstances to measure the contribution of fiscal policies towards carbon reduction and sustainable development goals, contributing to the enhancement of experience sharing on a global scale, and promoting the global process of carbon reduction and sustainable development.

The paper is structured as follows: The second section entails a comprehensive literature review to provide a contextual background and understanding of existing studies related to fiscal policy evaluation. The third section focuses on the analysis process of the model, outlining the methods employed to enhance the accuracy and reliability of the evaluation model. The fourth section involves the utilization of ROST CM6.0 software to extract high-frequency words and select policy evaluation indicators. This section also encompasses the evaluation and analysis of representative fiscal policies using the refined model. Finally, the fifth section presents the conclusion of the entire paper, summarizing the findings, and offering recommendations based on the evaluation results. By following this structured approach, we aim to produce comprehensive and valuable insights into the evaluation of fiscal policy texts, generating objective and scientifically sound assessment results.

2. Literature review

2.1. Fiscal policy in the context of “dual carbon”

Academics have also conducted in-depth analyses of fiscal policy, particularly at the macroeconomic level. There are two contrasting viewpoints regarding the role of fiscal policy in macroeconomics. Prescott P. And Paulson Gjerde K (2023) argues that fiscal authorities can effectively address recessions or facilitate economic recovery by reducing consumption and corporate income taxes while increasing public welfare spending [17].On the other hand, Ji J (2023) presents an opposing perspective, asserting that the ability of fiscal policy to counteract economic fluctuations has diminished, and its effectiveness in mitigating uncertainty in economic performance has waned [18]. Furthermore, if fiscal authorities excessively prioritize the policy objectives of debt stabilization and output stabilization, it may lead to persistent fluctuations in macroeconomic variables and policy instruments [19]. At the microcosmic level, Li, S. et al. (2023) undertake an extensive examination of the ramifications of fiscal policy on the environment [20].They contend that governmental expenditures exacerbate CO_2 emissions, while tax revenues exhibit a diminishing effect. Conversely, Kaharudin, I. H. And Ab-Rahman, M. S. 2022) present a contrary perspective, positing that environmental transformations will transpire at a measured pace [21]. Research on fiscal policy in achieving the "double carbon" target primarily revolves around the evaluation of fiscal policy implementation, such as carbon taxes [24] and different environmental regulations [22,23].Many studies explore the theoretical and empirical pathways through which fiscal policy can effectively promote carbon emission reduction. Specifically, fiscal policy doesn’t only play a primary role in stabilizing economic activities, but also contributes to the conservation of non-renewable resources and the enhancement of environmental quality. Expansionary fiscal policies have been found to exacerbate carbon dioxide emissions, whereas contractionary fiscal policies have been associated with a reduction in carbon dioxide emissions. Conversely, The scholarly attention has predominantly focused on the evaluation of the actual effects of fiscal policy, with the assessment criteria to some extent detached from the policy text itself, overlooking the origin of evaluation in policy texts and neglecting the scientific systematicity of policy content.

2.2. Text mining techniques in policy assessment

As an advanced data analysis technique, text mining constitutes the extraction of valuable information and knowledge from unstructured textual data. Within the text preprocessing stage, academia focuses on improving techniques such as text cleaning, tokenization, part-of-speech tagging, parsing, and named entity recognition. To enhance the performance of these techniques, deep learning methods have been explored [25]. Word embedding models like GPT-3 [26], which employ pre-trained language models to capture the contextual information of words, are widely used in feature representation, thereby more accurately expressing the semantic relationships between words. In the domain of pattern learning, a variety of statistical learning and machine learning techniques have been employed, such as Support Vector Machines, Random Forests, and Neural Networks [27]. Machine learning techniques are commonly applied to predictive models, such as predicting the response of freshwater ecosystems to multiple anthropogenic pressures [28], forecasting hunger crises before their onset [29], and projecting the spatially explicit development potential of land within greenbelt boundaries [30]. Text mining, despite its many advantages, still faces challenges in handling the complexity, ambiguity, and metaphorical nature of natural language [31]. Cheng Zhe et al. (2022) evaluated water policies using text mining methods based on multi-source data, finding that policy texts tend to focus on the macro level and are geared towards national development and long-term planning, while public opinion feedback tends to concentrate on micro-level and economic aspects, revealing varying degrees of media bias [32]. In the field of new energy vehicle policy, Liu Qin et al. (2023) pointed out issues such as insufficient policy consistency, declining policy balance, and an expansion of the negative policy convexity index [33]. Zhu Mengyao et al. (2023) utilized text mining for visual analysis of the annual changes in Japan's maritime policies, discovering that expert opinions and shifts in policy emphasis generally aligned with the results of unsupervised analyses [34]. In the research concerning China's photovoltaic power policy, Chong Zhaotian et al. (2023) found through quantitative analysis using text mining that there is a trend towards consistency in policy objectives and measures, with photovoltaic policies gradually shifting towards integrating a variety of measures [35]. Song Min et al. (2023) discussed the evolution of China's land use policies over the past 35 years, identifying three distinct phases where the number, focus, and themes of the policies underwent significant changes [36]. Overall, these studies demonstrate the potential of text mining techniques in analyzing policy texts, identifying trends, and formulating policy recommendations, as well as the importance of promoting sustainable policymaking.

2.3. The update of the PMC index model

This approach places greater emphasis on the comprehensiveness and coherence of policy content. Scholars often employ the PMC index model as a method for evaluating policy texts, offering notable advantages. One significant advantage lies in its flexibility, as there are no explicit restrictions on the number of secondary variables within the evaluation index system. Moreover, all secondary variables are assigned equal weight, thereby circumventing the potential for non-scientific outcomes that could arise from subjective weight assignments. Scholars have also made modifications and expansions to the traditional PMC index model by incorporating advanced techniques. For example, the construction of semantic networks using data analysis software Gephi has been employed to refine and augment the technical methods underlying this model [37]. The PMC index model, characterized by uniform weights for both primary and secondary indicators, offers the advantage of mitigating subjective interventions and veering away from the distortion of objective facts. However, it has a drawback in that it may lack the capacity for subjective intervention when necessary. To address this limitation, Wang B et al. (2022) classified wind power industry policy texts into three distinct categories: supply policy instruments, demand policy instruments, and environmental policy instruments [38].This categorization aids in the focused analysis of particular aspects. Indeed, the segmentation logic used in categorizing policy texts can introduce a degree of subjectivity. However, the CRITIC weighting method offers the advantage of being independent and objective. This method effectively highlights the aspects of the policy sample that exhibit actual inclinations.

Based on the existing studies, this paper adopts a quantitative evaluation approach. To accomplish this, text analysis methods, social network analysis methods, and the PMC-CRITIC index model are utilized. By employing these approaches, the study aims to provide a realistic theoretical foundation for the evaluation of fiscal policy texts. This comprehensive evaluation method incorporates various analytical techniques to assess the effectiveness and impact of fiscal policies, allowing for a more robust and evidence-based evaluation process.

3. Materials and methods

The PMC index model, proposed by Estrada, is a quantitative research framework utilized for policy modeling. Furthermore, it incorporates the unique characteristics of the policy itself to construct a corresponding evaluation indicator system. The PMC-CRITIC index model represents an improvement upon the original model.

3.1. Data sources

To ensure a comprehensive sample of relevant research, the study initially employed specific keywords such as "carbon neutral," "finance," and "carbon emission reduction" in professional policy databases like the PKULAW database [39]. Additionally, the full text and attachments were obtained from relevant government websites. This approach aimed to obtain the widest possible range of relevant information for analysis. To ensure the credibility and validity of the policy documents, a screening process was implemented for the collected policy texts. In this process, policy texts that pertained to topics such as low-carbon city pilot, technology promotion, and carbon emission right registration were excluded. Additionally, informal policy texts, including news articles, letters, and approvals, were filtered out. This rigorous screening and filtering process aimed to guarantee the authority and reliability of the policy texts that were ultimately included for analysis. By focusing on formal policy documents, the study can maintain the integrity and trustworthiness of the collected policy texts. After screening and sorting, this study finally obtained 62 policy documents.

3.2. Variable identification and index selection

The policy evaluation system encompasses ten primary evaluation indicators, which are as follows: policy nature (X_1), policy audience (X_2), policy issuing organization (X_3), policy timeliness (X_4), policy area (X_5), policy evaluation ($\times_6$), policy objective (X_7), policy synergy (X_8), policy instrument (X_9), and policy disclosure (X_{10}). The difference between this indicator system and other studies is that we redesigned the three first-level indicators [40], X_7, X_8, and X_9, according to the content characteristics of the fiscal policy. By the collected policy samples and relevant scholarly research, secondary evaluation index variables have been established under each primary evaluation index variable, resulting in a total of 46 variables. This information is illustrated in Table 1.

3.3. Multi-input-output table established

By assigning equal weights to the aforementioned 46 secondary variables and establishing a multi-input-output table, as presented in Table 2, this approach is implemented.

3.4. Fiscal policy tools' impact on carbon emission reduction model design

To investigate the impact of fiscal policy tools on carbon emissions, a two-way fixed effects model is constructed, which is presented as follows:

$$\ln CO_{2it} = \beta_0 + \beta_1 Fiscal_{it} + \sum_i \beta_i Z_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{1}$$

Where i denotes the stock code of listed companies or the provincial index number, t represents the year, $\ln CO_{2it}$ is the carbon emission volume, $Fiscal_{it}$ the fiscal policy tool, Z_{it} includes control variables, μ_i, γ_t represents unobservable firm or area and time effects, respectively. The random disturbance term ε_{it} captures the impact of other factors on carbon emissions that is not observed.

3.4.1. Dependent variable

Carbon dioxide emissions (CO_{2it}). It can be divided into corporate carbon emissions and provincial carbon emissions. Data on corporate carbon emissions is derived from annual reports of listed companies, social responsibility reports, environmental reports, etc., and is log-transformed. The carbon emissions data for listed companies is accounted for in the following ways: combustion and escape emissions, production process emissions, waste emissions, and emissions caused by land-use changes. In addition, provincial carbon emissions are calculated based on the categories of final energy consumption as defined in the "China Energy Statistical Yearbook," divided into nine types including raw coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil, natural gas, and electricity. The carbon emissions of each province are obtained through the conversion factors and carbon emissions coefficients for these nine types of energy. Specific details can be seen in Table 3.

3.4.2. Core explanatory variables

Fiscal policy tools($Fiscal_{it}$).According to the content of the primary index X_9, fiscal policy tools can be classified into fiscal subsidies ($Subsidy_{it}$), tax incentives(Tax_{it}), green procurement($Grbuy_{it}$), transfer payments($Transf_{it}$), and fiscal financing($Fund_{it}$). Fiscal subsidies

Table 1
Fiscal policy indicator system under the "dual carbon" goals.

First-Level Variables	Second-level Variables	Foundation
X_1: Policy nature	$X_{1\text{-}1}$ Forecasting, $X_{1\text{-}2}$ Regulation $X_{1\text{-}3}$ Recommendations, $X_{1\text{-}4}$ Guidance	Literature
X_2: Policy subjects	$X_{2\text{-}1}$ State Council Ministries, $X_{2\text{-}2}$ local people's governments, $X_{2\text{-}3}$ Directly Affiliated Institutions, $X_{2\text{-}4}$ Local Finance Bureaus, $X_{2\text{-}5}$ Enterprises, $X_{2\text{-}6}$ Residents	Literature
X_3: Policy objects	$X_{3\text{-}1}$ State Council, $X_{3\text{-}2}$ National Development and Reform Commission, $X_{3\text{-}3}$ Ministry of Ecology and Environment, $X_{3\text{-}4}$ Ministry of Finance, $X_{3\text{-}5}$ Local Finance Bureau	Literature
X_4:Policy timeliness	$X_{4\text{-}1}$ Long-term, $X_{4\text{-}2}$ Mid-term, $X_{4\text{-}3}$ Short-term, $X_{4\text{-}4}$ Current	Literature
X_5:Policy Area	$X_{5\text{-}1}$ Energy, $X_{5\text{-}2}$ Construction, $X_{5\text{-}3}$ Transportation, $X_{5\text{-}4}$ Ecology, $X_{5\text{-}5}$ Industry, $X_{5\text{-}6}$ Forestry	Literature
X_6:Content Evaluation	$X_{6\text{-}1}$ adequate basis, $X_{6\text{-}2}$ clear objectives, $X_{6\text{-}3}$ scientific program, $X_{6\text{-}4}$ detailed planning	Literature
$\times_7$:Policy Objectives	$X_{7\text{-}1}$ Cleaner production, $X_{7\text{-}2}$ Green consumption, $X_{7\text{-}3}$ Environmentally friendly investment $X_{7\text{-}4}$ Low carbon technology research, $X_{7\text{-}5}$ Public awareness of low carbon	According to the previous text mining results
X_8:Policy Coordination	$X_{8\text{-}1}$ Environmental Policy, $X_{8\text{-}2}$ Energy Policy, $X_{8\text{-}3}$ Financial Policy, $X_{8\text{-}4}$ Science and Technology Policy, $X_{8\text{-}5}$ Transportation Policy, $X_{8\text{-}6}$ Industrial Policy, $X_{8\text{-}7}$ Trade Policy	According to the previous text mining results
X_9: Policy Tools	$X_{9\text{-}1}$ Financial subsidies, $X_{9\text{-}2}$ Tax incentives, $X_{9\text{-}3}$ Green procurement, $X_{9\text{-}4}$ Transfer payments, $X_{9\text{-}5}$ Financial financing	According to the previous text mining results
X_{10}:Policy Disclosure	None	

Table 2
Multi-input-output table.

First-Level Variables	Second-level Variables
X_1	$X_{1\text{-}1}$ $X_{1\text{-}2}$ $X_{1\text{-}3}$ $X_{1\text{-}4}$
X_2	$X_{2\text{-}1}$ $X_{2\text{-}2}$ $X_{2\text{-}3}$ $X_{2\text{-}4}$ $X_{2\text{-}5}$ $X_{2\text{-}6}$
X_3	$X_{3\text{-}1}$ $X_{3\text{-}2}$ $X_{3\text{-}3}$ $X_{3\text{-}4}$ $X_{3\text{-}5}$
X_4	$X_{4\text{-}1}$ $X_{4\text{-}2}$ $X_{4\text{-}3}$ $X_{4\text{-}4}$
X_5	$X_{5\text{-}1}$ $X_{5\text{-}2}$ $X_{5\text{-}3}$ $X_{5\text{-}4}$ $X_{5\text{-}5}$ $X_{5\text{-}6}$
X_6	$X_{6\text{-}1}$ $X_{6\text{-}2}$ $X_{6\text{-}3}$ $X_{6\text{-}4}$
X_7	$X_{7\text{-}1}$ $X_{7\text{-}2}$ $X_{7\text{-}3}$ $X_{7\text{-}4}$ $X_{7\text{-}5}$
X_8	$X_{8\text{-}1}$ $X_{8\text{-}2}$ $X_{8\text{-}3}$ $X_{8\text{-}4}$ $X_{8\text{-}5}$ $X_{8\text{-}6}$ $X_{8\text{-}7}$
X_9	$X_{9\text{-}1}$ $X_{9\text{-}2}$ $X_{9\text{-}3}$ $X_{9\text{-}4}$ $X_{9\text{-}5}$
X_{10}	

Table 3
Descriptive statistics.

VARIABLES	(1)	(2)	(3)	(4)	(5)
	N	Mean	SD	Min	Max
Firm-level data					
CO	16,941	11.78	1.556	2.398	18.68
tax	12,570	0.0625	0.0116	0.0429	0.226
subsidy	16,032	0.0585	0.00708	0.0414	0.310
sale	16,906	0.201	0.568	−5.578	8.494
cap	16,984	−0.0213	0.840	−6.304	6.548
CFO	13,447	−3.014	1.022	−10.35	0.798
firmage	16,955	2.483	0.676	0	3.466
digital	16,411	−2.430	1.213	−6.872	0
ESG	16,809	−1.866	0.189	−2.197	0
TOP1	16,732	3.452	0.487	−1.238	4.564
Provincial-level data					
CO	210	10.46	0.754	8.613	11.93
Grbuy	210	0.0611	0.0174	0.0408	0.185
Transf	210	5.045	1.196	1.807	10.07
Fund	210	−3.568	1.212	−6.451	1.244
envir	210	0.0703	0.00292	0.0632	0.0790
pgdp	210	10.98	0.408	10.16	12.14
resotax	210	3.111	1.574	−4.605	6.202
scice	210	4.568	1.056	2.339	7.064
cond	210	3.920	1.382	0	5.413
forestry	210	4.757	1.117	2.006	6.288
internet	210	6.890	0.835	4.410	8.361
ecom	210	7.823	1.248	4.716	10.54
fianpre	210	−0.819	0.393	−1.888	−0.0770

and tax incentives are data at the corporate level, while green procurement, transfer payments, and fiscal financing are provincial-level data. Due to the frequent absence of tax incentive data, the study uses data on corporate tax and fee refunds as a proxy, which is sourced from the "various taxes and fees refunded" section of the corporate financial statements. Fiscal subsidies are measured by government grants, with data coming from the non-operating income—government grants line item in corporate financial statements. Green procurement data is obtained from the Chinese government procurement website by using Python techniques to extract green-related information from government purchase contract orders, yielding the contract amount data of green procurement awarded to listed companies in each province. This paper uses the total amount of transfer payments received by provincial-level regions as a measure of transfer payments. In terms of green transfer payment, it applies the logarithm of the ratio encompassing the transfer payment to the completed investment in industrial pollution management. Fiscal financing related to the dual carbon targets is mainly composed of government fund revenue and local debt balances. As for green financial financing, the approach involved the selection of the logarithm of the ratio between the financial financing and the completed investment in industrial pollution governance. Specific details can be seen in Table 3.

3.4.3. Control variables

To alleviate the estimation bias caused by omitted variables, a series of variables that have an impact on carbon emissions are controlled, including the following: the degree of digital transformation (digital), which is measured based on text analysis and word frequency statistics and is log-transformed; Corporate Social Responsibility (ESG), which is measured by the average score of 1–9 points assigned by Huatai Securities' ESG quarterly ratings and is log-transformed; the growth rate of the enterprise (sale), measured by the proportion of operating income to operating income of the previous period, log-transformed; the ratio of cash assets (CFO), which is measured by the net cash flow from operating activities to year-end total assets, log-transformed; equity concentration

Table 4
Classification of policy levels.

PMC Index	[0,0.5)	[0.5,0.7)	[0.7,0.9)	[0.9,1)
Evaluation grades	Low	Acceptable	Excellent	Perfect

(TOP1), represented by the shareholding ratio of the largest shareholder, log-transformed; capital intensity (cap), which uses the ratio of equity to income, log-transformed; the leverage ratio (lev), which is the ratio of assets to liabilities, log-transformed; and the age of the enterprise (firmage), which is the current year minus the year of enterprise registration, log-transformed. The firm-level data aforementioned were derived from financial statements such as annual reports, aggregated from the WIND database, with supplemental missing data sourced from the CSMAR database. Variables include environmental protection expenditure (envir), per capita gross regional product (pgdp), local fiscal resource tax (resotax), local fiscal expenditure on science and technology (scice), average number of air conditioning units owned per 100 households at year-end (cond), total value of forestry outputs in billions (forestry), subscribers to internet broadband access (internet), and e-commerce sales revenue (ecom) were all subject to logarithmic transformation. Fiscal pressure (fianpre) is quantified using the ratio of local general budgetary revenue to local general budgetary expenditure. Provincial data were retrieved from the China Statistical Yearbook spanning the years 2015–2021. Specific details can be seen in Table 3.

3.5. *CRITIC method assigning weights to primary variables*

The conventional PMC index model operates under the assumption that all primary variables hold equal significance, with absolute equality indicating a neutral evaluation. On the other hand, the CRITIC method serves as an objective weighting approach grounded in evaluation indicators, considering both the comparative strength among samples and the conflicting nature of the indicators [41]. As a result, the calculation outcomes derived from this method are more objectivy and reasonably determined. The allocation of secondary variables can effectively capture the diversity present within the policy text. By employing the CRITIC method, it is possible to evaluate the significance of primary variables through the allocation of secondary variables. Let us assume that there are m samples, n indicators, and X_{ij} represents the value of the j-th evaluation indicator for the i-th sample. The objective weights are calculated as follows: the correlation coefficient matrix is equation (2), and the objective weight is equation (3).

$$\rho_{ij} = \frac{cov(y_k, y_l)}{(S_k, S_l)} \tag{2}$$

where ρ_{ij} is the correlation coefficient between the i-th indicator and the j-th indicator, and $cov(y_k, y_l)$ denotes the covariance between the kth indicator and the lth indicator.

$$\gamma_{ij} = \frac{S_j \Big/ (\overline{x_j}) \sum_{K=1}^{n} (1-\rho_{ij})}{\sum_{i=1}^{n} S_j \Big/ (\overline{x_j}) \sum_{K=1}^{n} (1-\rho_{ij})} \tag{3}$$

where, S_j represents the standard deviation, and $\overline{x_j}$ represents the mean.

3.6. *PMC-CRITIC index calculation*

Based on the modeling principle of PMC-CRITIC index model, the policy evaluation indicator variables are measured. The following steps are mainly followed: The values of each primary evaluation indicator variable are calculated according to Eq. (4), and the primary variable is the sum of the corresponding secondary variable values, which are strictly controlled from 0 to 1; Finally, by summing the scores of all the first-level evaluation indicators after being assigned the weights, the PMC-CRITIC index for each carbon emission policy to be evaluated is obtained. As can be seen from the above formula, the score range of the policy PMC-CRITIC index should be [0,1], as shown in equation (5).

$$X_i = \sum_{j=1}^{n} \frac{X_{ij}}{T(X_{ij})} \tag{4}$$

Where, i = 1, 2, 3, …, n, i is a primary variable and j is a secondary variable.

$$PMC - CRITIC = \gamma_1\left(\sum_{a=1}^{4}\frac{X_{1i}}{4}\right) + \gamma_2\left(\sum_{b=1}^{6}\frac{X_{2i}}{6}\right) + \gamma_3\left(\sum_{c=1}^{5}\frac{X_{3i}}{5}\right) + \gamma_4\left(\sum_{d=1}^{4}\frac{X_{4i}}{4}\right) + \gamma_5\left(\sum_{e=1}^{6}\frac{X_{5i}}{6}\right) + \gamma_6\left(\sum_{f=1}^{4}\frac{X_{6i}}{4}\right) + \gamma_7\left(\sum_{g=1}^{5}\frac{X_{7i}}{5}\right) + \gamma_8\left(\sum_{h=1}^{7}\frac{X_{8i}}{7}\right) + \gamma_9\left(\sum_{k=1}^{5}\frac{X_{9i}}{5}\right) + X_{10} \tag{5}$$

Based on the results of the PMC-CRITIC index calculation, an evaluation level is set as a reference to evaluate the merits of the policy, as shown in Table 4 below.

3.7. Drawing PMC-CRITIC surface

By drawing the PMC-CRITIC surface diagram, we visualize the strengths and weaknesses of each policy in three dimensions, to conduct a comprehensive evaluation of the policy sample. The concave degree of the surface plot and the PMC-CRITIC index of each policy are combined to determine the consistency level and rational structure of the policies, and the strengths and weaknesses of the corresponding policies are proposed based on this.

$$PMC - \text{CRITIC} = \gamma_i \begin{bmatrix} X_1 & X_2 & X_3 \\ X_4 & X_5 & X_6 \\ X_7 & X_8 & X_9 \end{bmatrix} \tag{6}$$

4. Empirical analysis of fiscal policy evaluation under "double carbon" target

In order to analyze the characteristics and problems of fiscal policy texts under the "double carbon" objective, we selected a sample of policies, calculated CRITIC weights and PMC-CRITIC index, evaluated and analyzed a representative policy text, and proposed an optimal path.

4.1. Policy sample selection

Given the considerable number of policy documents and the limited space available in this article, the present study, grounded in an analysis of the content of policy texts, has taken into consideration the types, forms, and substance of policies, and has selected the most recent representative policies for a quantitative evaluation [42].12 policy samples with wide coverage, comprehensive content and strong representativss were selected from the 62 policy texts for quantitative evaluation, as shown in Table 5. Given that the Dual

Table 5
Fiscal policies under the 12 "double carbon" targets (typical).

Serial number	Policy Text	Publishers	Promulgation time
P1	State Council on the issuance of the "14th Five-Year Plan" comprehensive work program of energy conservation and emission reduction notice	State Council	December 28, 2021
P2	Notice of the State Council on the Issuance of the Action Plan for Carbon Peaking of 2030	State Council	October 24, 2021
P3	Ministry of Finance Notice on the Issuance of the Opinions on Financial Support for Good Carbon Neutral Work in Carbon Dumping	Ministry of Finance	May 25, 2022
P4	Notice of the Ministry of Ecology and Environment, Development and Reform Commission, Ministry of Industry and Information Technology, etc. on the Issuance of the Implementation Plan for the Synergistic Effectiveness of Reducing Pollution and Reducing Carbon	Ministry of Ecology and Environment and other departments	June 10, 2022
P5	National Development and Reform Commission, National Energy Administration on improving the institutional mechanisms and policy measures for green and low-carbon energy transition	National Development and Reform Commission, National Energy Administration	January 30, 2022
P6	The State Council on speeding up the establishment of a sound green low-carbon cycle development of the economic system guidance	State Council	February 2, 2021
P7	Notice of the State Administration of Institutional Affairs, the National Development and Reform Commission, the Ministry of Finance and the Ministry of Ecology and Environment on the Issuance of the Implementation Plan for the In-depth Implementation of Green and Low Carbon Leading Action for Public Institutions to Promote Carbon Peaking	National Development and Reform Commission and other departments	November 16, 2021
P8	The Ministry of Finance on the issuance of the "comprehensive promotion of the Yangtze River Economic Belt development of fiscal support policies" notice	Ministry of Finance	September 2, 2021
P9	The State Council on supporting Shandong to deepen the transformation of the old and new dynamic energy to promote green, low-carbon and high-quality development of the views	State Council	August 25, 2022
P10	Hunan Provincial Department of Finance on the issuance of the "Hunan Provincial Financial Support for the Implementation of Carbon Neutral Work in Carbon Dafeng	Hunan Provincial Department of Finance	October 31, 2022
P11	Fujian Provincial Department of Finance on the issuance of "Fujian Province, financial support to do a good job in the implementation of the carbon peak carbon neutral work" notice	Fujian Provincial Department of Finance	December 22, 2022
P12	Notice on the Issuance of "Jiangsu Province Carbon Dafeng Carbon Neutral Science and Technology Innovation Special Funds Management Measures (Temporary)	Jiangsu Provincial Department of Finance	June 24, 2022

Carbon objectives were first proposed in the year 2020, the related policies are predominantly concentrated within the 2021–2022 period.

4.2. Calculation of CRITIC weights

The CRITIC weighting method considers both the contrast strength and conflict between evaluation indicators to determine the objective weight of each indicator. It takes into account the variability of the indicators and also considers the correlation between them. In this method, a larger number does not necessarily imply greater importance. Instead, the objective properties of the data itself are utilized to ensure a scientific evaluation of the indicators. This approach helps obtain more accurate and reliable weights for the evaluation process.

The CRITIC weight method calculates the values of secondary variables indicators to derive the weights of primary variables indicators: the weight of X_1 is 9.008 %, the weight of X_2 is 18.195 %, the weight of X_3 is 7.874 %, the weight of X_4 is 8.965 %, the weight of X_5 is 10.652 %, the weight of X_6 is 0.0 %, the weight of X_7 is 7.739 %, the weight of X_8 is 27.212 %, and the weight of X_9 with a weight of 10.354 %, see Table 5 where the maximum value of indicator weight is X_8 (27.212 %), the most prominent correlation and variability among sub-variables under the first-level indicator policy synergy; The minimum value is X6 (0.0 %), the sub-variables under the first-level indicator policy evaluation are assigned a value of 1, resulting in no correlation and variability among subvariables.

4.3. Empirical analysis of fiscal instruments' impact on carbon emissions

4.3.1. Empirical results of the effect of fiscal subsidies on carbon emissions

The regression outcomes for the effect of fiscal subsidies on carbon emissions are presented in Table 6. As control variables were incrementally introduced, the coefficient of the variable $Subsidy_{it}$ markedly manifested as negative, indicating that fiscal subsidies have a diminishing influence on corporate carbon emissions.

Following the econometric model estimation principles, the credibility of the estimated results from Equation (1) is contingent on the exogeneity of the mined indicators. Bi-directional causality and missing variables could potentially affect the unbiased estimation outcomes. To verify the reliability of the conclusions, this study employs various methods for robustness tests. Initially, it replaces the dependent variable in Equation (1) with carbon emission intensity (co2), which is the ratio of the total carbon emissions of the operating income of listed companies. Additionally, unobserved portions of the total sample may possess correlations that could manifest across multiple dimensions; hence, the study further employs clustered standard errors to conduct robustness verification. Moreover, an omitted variable, financing constraint (FC), is introduced, and lastly, the analysis retains samples from 2012 onwards. As exhibited in columns (1)–(4) of Table 7, the core conclusions remain unchanged, ensuring the robustness of the baseline regression outcomes. Namely, fiscal subsidies can reduce corporate carbon emissions.

4.3.2. Empirical evidence of the impact of tax incentives on carbon emissions

The regression results on the impact of tax incentives on carbon emissions are presented in Table 8. Throughout the process of

Table 6
Regression results for the impact of Fiscal subsidies on carbon emissions.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CO	CO	CO	CO	CO	CO	CO
subsidy	−27.821***	−29.766***	−29.699***	−30.168***	−27.138***	−23.757***	−23.671***
	(-27.36)	(-26.38)	(-26.48)	(-28.55)	(-23.09)	(-22.56)	(-22.46)
digital		−0.107***	−0.109***	−0.106***	−0.104***	−0.095***	−0.095***
		(-14.49)	(-14.76)	(-15.26)	(-13.86)	(-14.10)	(-14.05)
ESG			−0.273***	−0.286***	−0.242***	−0.325***	−0.329***
			(-7.25)	(-8.06)	(-6.35)	(-9.54)	(-9.65)
sale				0.440***	0.440***	0.453***	0.453***
				(42.53)	(36.22)	(41.70)	(41.64)
CFO					0.043***	0.011**	0.011**
					(7.60)	(2.20)	(2.20)
cap						−0.608***	−0.603***
						(-52.35)	(-50.67)
firmage							0.039*
							(1.78)
Constant	13.025***	12.965***	12.391***	12.306***	12.425***	11.911***	11.828***
	(202.30)	(176.77)	(123.21)	(129.82)	(118.58)	(126.42)	(112.51)
Observations	15,986	15,555	15,446	15,435	12,354	12,353	12,353
R-squared	0.287	0.304	0.318	0.396	0.409	0.528	0.528
Number of id	1387	1387	1383	1383	1380	1380	1380
ID FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

(T-statistics in parentheses***$p < 0.01$, **$p < 0.05$, *$p < 0.1$).

Table 7
Test results on the effect of Fiscal subsidies on carbon emissions.

VARIABLES	(1)	(2)	(3)	(4)
	co2	CO	CO	CO
subsidy	−0.949***	−23.671***	−19.996***	−19.475***
	(-14.22)	(-10.11)	(-18.67)	(-16.09)
FC			0.125***	
			(15.84)	
Constant	−0.621***	11.828***	11.514***	11.764***
	(-93.40)	(60.85)	(103.51)	(75.28)
Observations	12,353	12,353	11,814	9611
R-squared	0.400	0.528	0.556	0.488
Number of id	1380	1380	1378	1379

Table 8
Regression results on the impact of Tax incentives on carbon emissions.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CO1	CO1	CO1	CO1	CO1	CO1	CO1
tax	−11.774***	−11.877***	−11.776***	−12.047***	−12.268***	−9.824***	−9.754***
	(-17.53)	(-17.45)	(-17.42)	(-19.15)	(-19.38)	(-17.11)	(-17.00)
digital		−0.114***	−0.115***	−0.108***	−0.106***	−0.099***	−0.097***
		(-13.93)	(-14.09)	(-14.14)	(-13.93)	(-14.38)	(-14.16)
ESG			−0.244***	−0.266***	−0.252***	−0.329***	−0.344***
			(-5.85)	(-6.87)	(-6.44)	(-9.31)	(-9.71)
sale				0.512***	0.510***	0.515***	0.514***
				(40.75)	(40.35)	(45.13)	(45.07)
TOP1					0.068***	0.085***	0.112***
					(2.68)	(3.72)	(4.74)
cap						−0.566***	−0.553***
						(-48.70)	(-46.40)
firmage							0.107***
							(4.84)
Constant	12.182***	11.983***	11.463***	11.353***	11.156***	10.726***	10.415***
	(254.86)	(235.19)	(124.98)	(132.93)	(92.98)	(98.60)	(82.55)
Observations	12,541	12,260	12,177	12,173	11,959	11,957	11,957
R-squared	0.276	0.293	0.306	0.399	0.402	0.512	0.513
Number of id	1359	1357	1354	1354	1350	1350	1350
ID FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

incrementally including control variables, the coefficient associated with the variable Tax_{it} is significantly negative. This indicates that tax incentives exhibit a decreasing effect on corporate carbon emissions.

The regression analysis conducted using Two-Stage Least Squares (2SLS) shows that the first-stage regression results for the lagged one-period tax incentives can be seen in Table 9, column (1), where the instrument variables are significantly positively correlated with the independent variables, confirming the "relevance" assumption for the instrument variables. The second-stage results are presented in column (2) of the same table, where the independent variable exhibits a significant negative influence on carbon emissions, consistent with the benchmark regression results. Finally, the sample is restricted to the years after 2015. Column (3) of Table 9 indicates that the core findings remain unchanged, ensuring the robustness of the benchmark regression outcomes, that is, fiscal subsidies can reduce corporate carbon emissions.

Table 9
Test results on the impact of Tax incentives on carbon emissions.

VARIABLES	(1)	(2)	(3)
	first	second	
	tax	CO	CO
L.tax	0.251***		
	(22.52)		
tax		−30.936***	−4.704***
		(-10.13)	(-6.38)
Observations	10,145	10,145	6362
R-squared		0.446	0.408
Number of id	1193	1193	1299

4.3.3. Empirical results of government green procurement's influence on carbon emissions

The regression outcomes on the effect of government green procurement on carbon emissions are depicted in Table 10. With the progressive inclusion of control variables, the coefficient for the variable $Grbuy_{it}$ is significantly negative, suggesting that government green procurement leads to a reduction in carbon emission.

Within the total sample, unobserved components may exhibit correlation, which could manifest across multiple dimensions. To address this, cluster-robust standard errors are employed to conduct a robustness check. Additionally, an interaction term between government green procurement and per capita GDP (Grbuy*pgdp) is introduced. As observed in columns (1) and (2) of Table 11, the core conclusions remain unaltered, affirming the robustness of the benchmark regression findings that government green procurement can reduce carbon emissions.

4.3.4. Empirical findings on the effect of green transfer payments on carbon emissions

The regression results for the impact of green transfer payments on carbon emissions are summarized in Table 12. Throughout the process of incremental inclusion of control variables, the coefficient for $Transf_{it}$ is significantly negative. This indicates that green transfer payments contribute to a decrease in corporate carbon emissions.

To test the reliability of the conclusions, this paper employs a variety of methods to perform robustness checks. Firstly, we introduce an omitted variable, namely the local fiscal general budget revenue(bugrev). Secondly, an interaction term between green transfer payments and the added value of forestry (Transf*forestry) is incorporated. Lastly, to address potential endogeneity and estimation bias inherent in static panel results, the paper estimates a system GMM using green transfer payments lagged by one period. As shown in column (3) of Table 13, the coefficients of the impact of green transfer payments on carbon emissions are significantly negative. The benchmark regression results are validated once again, confirming that green transfer payments can achieve carbon reduction and emissions mitigation.

4.3.5. Empirical analysis of the impact of green fiscal financing on carbon emissions

The regression results concerning the effect of green fiscal financing on carbon emissions are presented in Table 14. As control variables are progressively introduced, the coefficient for the variable $Fund_{it}$ remains significantly negative. This pattern suggests that green fiscal financing has a diminishing effect on carbon emissions.

To ensure the robustness of the findings, this study adopts various methods for robustness testing. We include omitted variables such as the intensity of financial activities(intfina), measured as the ratio of the value added by the financial sector to the regional GDP. Furthermore, to address potential issues of endogeneity and estimation bias associated with static panel results, the study conducts system GMM estimations using green fiscal financing lagged by one period. As indicated in column (2) of Table 15, the coefficient reflecting the impact of green fiscal financing on carbon emissions is significantly negative. These results reinforce the benchmark regression findings, suggesting that green fiscal financing can effectively contribute to carbon reduction and emission control.

4.4. PMC -CRITIC index calculation

The policies were divided into words by ROST CM6.0 software, and the secondary variables were assigned values based on the policy text and the keywords of the policy text, e.g., X_{1-1} to determine whether the policy is predictive, yes for 1, and vice versa for 0;

Table 10
Regression outcomes on the influence of government green procurement on carbon emissions.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	CO	CO	CO	CO	CO	CO
Grbuy	−1.872***	−1.864***	−1.767***	−1.686***	−1.526***	−1.740***
	(-4.50)	(-4.54)	(-4.33)	(-4.57)	(-4.16)	(-4.82)
pgdp		0.326**	0.334**	0.362***	0.470***	0.419***
		(2.27)	(2.34)	(2.79)	(3.53)	(3.22)
resotax			−0.026**	−0.025**	−0.029***	−0.032***
			(-2.35)	(-2.48)	(-2.93)	(-3.30)
cond				0.229***	0.220***	0.208***
				(6.19)	(6.01)	(5.82)
scice					−0.064***	−0.080***
					(-2.69)	(-3.41)
ecom						0.062***
						(3.42)
Constant	10.541***	7.037***	7.024***	5.893***	5.030***	5.258***
	(314.38)	(4.55)	(4.58)	(4.21)	(3.57)	(3.84)
Observations	209	209	206	206	206	206
R-squared	0.443	0.460	0.483	0.580	0.598	0.624
Number of province_id	30	30	30	30	30	30
ID FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Table 11
Test results on the impact of government green procurement on carbon emissions.

VARIABLES	(1)	(2)
	CO	CO
Grbuy	−1.740**	
	(-2.61)	
Grbuy* pgdp		−0.154***
		(-4.63)
Constant	5.258***	9.464***
	(3.09)	(46.40)
Observations	206	206
R-squared	0.624	0.594
Number of province_id	30	30
ID FE	YES	YES
Year FE	YES	YES

Table 12
Regression results for the impact of green transfer payments on carbon emissions.

VARIABLES	(1)	(2)	(3)	(4)	(5)
	CO	CO	CO	CO	CO
Transf	−0.016**	−0.014*	−0.013*	−0.012*	−0.012*
	(-2.11)	(-1.86)	(-1.78)	(-1.73)	(-1.79)
pgdp		0.279*	0.414***	0.306*	0.455***
		(1.81)	(2.65)	(1.92)	(2.80)
forestry			−0.108***	−0.111***	−0.110***
			(-3.09)	(-3.24)	(-3.30)
internet				0.145**	0.131**
				(2.60)	(2.39)
scice					−0.080***
					(-3.14)
Constant	10.468***	7.467***	6.501***	6.738***	5.568***
	(299.39)	(4.51)	(3.95)	(4.15)	(3.43)
Observations	210	210	210	210	210
R-squared	0.398	0.409	0.440	0.462	0.492
Number of province_id	30	30	30	30	30
ID FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Table 13
Test results on the impact of green transfer payments on carbon emissions.

VARIABLES	(1)	(2)	(3)
	CO	CO	CO
Transf	−0.012*		−0.434***
	(-1.70)		(-8.19)
bugrev	0.131*		
	(1.80)		
Transf* forestry		−0.067**	
		(-2.12)	
Constant	5.312***	6.470***	10.464***
	(3.28)	(3.96)	(6.65)
Observations	210	210	180
R-squared	0.501	0.462	0.591
Number of province_id	30	30	30
ID FE	YES	YES	YES
Year FE	YES	YES	YES

$X_{6\text{-}1}$ to determine whether the basis for policy formulation is sufficient, yes for 1, and vice versa for 0. The PMC-CRITIC index values and the concave index values were derived (The results are retained to two decimal places), and the depression index is negatively correlated with the PMC-CRITIC index, and finally the policies are ranked and ranked according to Table 4, and the results are shown in Table 16.

Table 14
Regression results on the impact of green Fiscal financing on carbon emissions.

VARIABLES	(1)	(2)	(3)	(4)	(5)
	CO	CO	CO	CO	CO
Fund	−0.020**	−0.013*	−0.013*	−0.014*	−0.013*
	(-2.52)	(-1.82)	(-1.74)	(-1.97)	(-1.76)
cond		0.234***	0.228***	0.242***	0.241***
		(5.93)	(5.80)	(6.22)	(6.21)
scice			−0.048**	−0.055**	−0.063**
			(-2.01)	(-2.34)	(-2.54)
fianpre				0.239***	0.238***
				(2.75)	(2.75)
envir					−5.059
					(-1.00)
Constant	10.304***	9.489***	9.718***	9.868***	10.272***
	(261.11)	(66.71)	(53.55)	(52.98)	(23.00)
Observations	210	210	210	210	210
R-squared	0.404	0.505	0.517	0.537	0.540
Number of province_id	30	30	30	30	30
ID FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

Table 15
Test results of the impact of green Fiscal financing on carbon emissions.

VARIABLES	(1)	(2)
	CO	CO
Fund	−0.014*	−0.262***
	(-1.90)	(-6.49)
intfina	−0.271***	
	(-3.43)	
Constant	8.803***	1.640*
	(20.79)	(1.14)
Observations	210	180
R-squared	0.570	0.389
Number of province_id	30	30
ID FE	YES	YES
Year FE	YES	YES

4.5. PMC-CRITIC surface mapping and policy text evaluation

The PMC-CRITIC surface chart presents the degree of merit of each policy in the form of images. Based on the 10 first-level evaluation indicator variables set, the paper considers the symmetry of the 3x3 matrix and the balance of the surface plot. Since the policy disclosure (X_{10}) of the 12 policies is necessarily the same, the policy disclosure indicator variables are eliminated, and the matrix is constructed based on the scores of the remaining 9 first-level evaluation indicators to draw the PMC-CRITIC surface plot. According to the classification of policy evaluation grade in Table 4 and considering the representativeness of policy and the differences reflected in the policy issued by different subjects [43], three policies are selected from P8(the top-ranked excellent policy), P2 (the top-ranked acceptable policy), and P12(the undesirable policy), respectively, and presents the surface plots of these 3 policies, and conducts a comprehensive evaluation of the representative policies in each level, and proposes the corresponding optimization paths.

Among the selected policy samples, the level II outstanding policies encompass P3, P8, P9, and P10. P9 attains a commendable score of 0.83, accompanied by a concave index of 0.17, securing the topmost position in the overall assessment. Fig. 1 exhibits the PMC surface plot illustrating policy P9, characterized by a seamlessly smooth graph. This feature signifies the remarkably well-balanced performance of its nine level I indicator variables, exemplifying a noteworthy level of internal coherence and structural rationality within the policy framework. This policy has been devised to provide substantial backing to Shandong in its endeavor to consolidate the transformation of both old and new forms of dynamic energy. It aligns closely with the guidance provided by the State Council's Opinions on Supporting Shandong in Deepening the Transformation of New and Old Dynamic Energy to Promote Green, Low-Carbon, and High-Quality Development. Remarkably, the policy encompasses an array of incentivizing and constraining mechanisms, acknowledging the interconnectedness and beneficial interaction of several policies. It offers comprehensive coverage across various policy domains and is built upon a solid foundation of well-defined policy regulations. Nevertheless, it is noteworthy that the performance of the policy objective and policy tool indicators falls below the average level, and the policy target exhibits a lack of strength. To enhance the policy further, the suggested approach for prioritizing areas of improvement involves addressing the variables with the most significant deviation from the mean value first. So the order of improvement is $X_9 \rightarrow X_7$. It is important to note that this ranking is not absolute and should be considered in conjunction with the specific context and circumstances surrounding the policy.

Table 16
12 Policies PMC-CRITIC index.

Policy Indicator	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
X_1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
X_2	1.00	1.00	0.50	0.50	1.00	1.00	0.83	1.00	1.00	0.50	0.50	0.50
X_3	0.20	0.20	0.20	0.20	0.20	0.20	0.60	0.20	0.20	0.20	0.20	0.20
X_4	0.75	1.00	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.50
X_5	0.83	1.00	1.00	1.00	0.67	0.67	0.50	0.67	0.83	1.00	1.00	0.67
X_6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
X_7	0.60	0.60	0.80	0.80	0.80	1.00	0.80	0.60	0.60	0.80	0.80	0.40
X_8	0.14	0.14	0.86	0.14	0.00	0.00	0.00	1.00	1.00	0.86	0.14	0.14
X_9	0.40	0.40	0.80	0.40	0.20	0.60	0.40	0.60	0.40	0.80	0.60	0.40
PMC Index	0.57	0.61	0.77	0.53	0.53	0.59	0.53	0.74	0.83	0.77	0.56	0.38
Depression Index	0.43	0.39	0.23	0.47	0.47	0.41	0.47	0.26	0.17	0.23	0.44	0.62
Ranking	7	5	2	10	10	6	9	4	1	2	8	12
Policy Level	Acceptable	Acceptable	Excellent	Acceptable	Acceptable	Acceptable	Acceptable	Excellent	Excellent	Excellent	Acceptable	Low

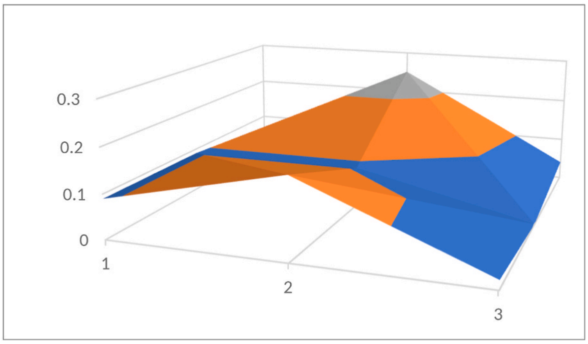

Fig. 1. P9 Excellent policy PMC-CRITIC surface diagram.

The top-ranked acceptable policies are P1, P2, P4, P5, P6, P7, and P11. The top-ranked acceptable policy is P2. policy P2 has a score of 0.61 and a concavity index of 0.39, ranking 5th overall. its PMC-CRITIC surface plot (Fig. 2) has a large degree of concavity and deviates significantly from the excellent policy P9 (Fig. 1). The policy is promulgated by the State Council, and the policy objective is very clear, but ignores other objectives that need to be considered, such as low-carbon technology R&D. The policy text is thin in terms of fiscal policy, and it does not reflect the coordination between public policies, thus the policy is weak in terms of synergy, biased policy instruments, and vague policy objectives. Therefore, the proposed optimization path for this policy is $X_8 \rightarrow X_7 \rightarrow X_9$.

There is only one remaining policy, P12, which attains a score of 5.31 and a concavity index of 4.69. With a 12th position in the overall ranking, it is positioned at the lower end of the policy sample assessment. Fig. 3 demonstrates that the PMC-CRITIC surface plot of this policy exhibits a combination of concave and convex characteristics, indicating numerous shortcomings. Specifically, this policy is issued by the Jiangsu Provincial Department of Finance and is targeted exclusively towards the province. Additionally, it is noteworthy that the policy has a relatively short duration, spanning only two years. From a policy objectives standpoint, the policy exhibits a narrow and exclusive focus, disregarding crucial factors like sustainable consumption practices. The policy's emphasis predominantly lies within the technical domain, neglecting the extensive coverage of fiscal policy. Furthermore, the primary policy instruments utilized revolve mostly around financial subsidies, inadequately accounting for the interconnection and coordination between various public policies, consequently resulting in a feeble policy synergy. The PMC index scores for policy synergy (X_8), policy audience (X_2), policy effectiveness (X_4), policy nature ($\times_1$), and policy objectives (X_7) are significantly below the mean value. Consequently, to address this, it is imperative to not only extend the duration of policy effectiveness to allow sufficient planning and preparation time for the target audience, but also enhance public awareness regarding low-carbon practices. Additionally, it is essential to foster innovation among businesses, building upon the policy's direction and objectives, to stimulate their enthusiasm and vitality. Therefore, the suggested optimization path for this policy is $X_8 \rightarrow X_2 \rightarrow X_4 \rightarrow X_1 \rightarrow X_7 \rightarrow X_5 \rightarrow X_9$.

4.6. Overall evaluation and analysis of fiscal policy

In summary, out of the 12 representative policies assessed, 4 policies have received an excellent rating, 7 policies are deemed acceptable, and one is considered low. Referring to Table 16, the PMC-CRITIC index value for these 12 policies is 0.62, indicating an acceptable level. This suggests that fiscal policy's overall performance about the "double carbon" target is commendable, as it successfully formulates practical policies. Worth noting is that policy evaluation (X_6) has attained a score of 0, as all secondary indicators hold the same value of 1 and possess no differentiation. Hence, due to the lack of linkage, foresight, and systematization of fiscal policy under the "double carbon" objective, the primary indicators reveal varying scores. Fig. 4 demonstrates that among the primary indicators, the scores of policy audience (X_2), policy synergy (X_8), policy area (X_5), and policy timeliness (X_4) are all high, while the scores of policy issuing agency (X_3), policy target (X_7), and policy instrument ($\times_9$) are all low, indicating the lack of linkage, foresight, and systematization of fiscal policy under the "double carbon" objective. The policy issuing agencies involved in the formulation and implementation of fiscal policies under the "dual carbon" objective include the State Council, the Ministry of Finance, the National Development and Reform Commission, local finance bureaus, and others. However, most of these agencies function independently, lacking a coordinated and integrated approach. The lack of clarity in policy objectives has had a certain impact on the accuracy of fiscal policy formulation and the effectiveness of its implementation under the "dual carbon" target. Within the realm of policy tools, there is a wide array of financial subsidies and tax incentives available to promote energy transformation and industrial structure upgrading. These tools have proven to be effective in driving sustainable development. However, there is a need to establish mechanisms for green government procurement and ecological compensation. These mechanisms will further contribute to the overall goal of achieving a low-carbon, environmentally sustainable economy.

The policies that have received an excellent evaluation rating, such as P3 and P8, along with four others, demonstrate a well-balanced performance across the first-level policy evaluation indicators. These policies do not significantly fall below the mean value of the first-level variables. This indicates that these policies have been formulated synergistically and consistently, with a thorough understanding of the policy's focal point. Moreover, these policies exhibit high levels of rationality and feasibility in their design and implementation. 7 policies such as P1 and P2 are acceptable policies, and some of the PMC-CRITIC indices of the above

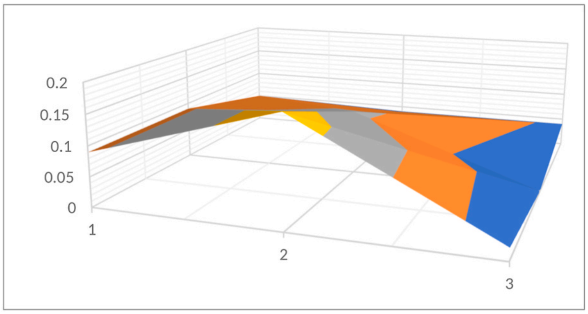

Fig. 2. P2 Acceptable policy PMC-CRITIC surface diagram.

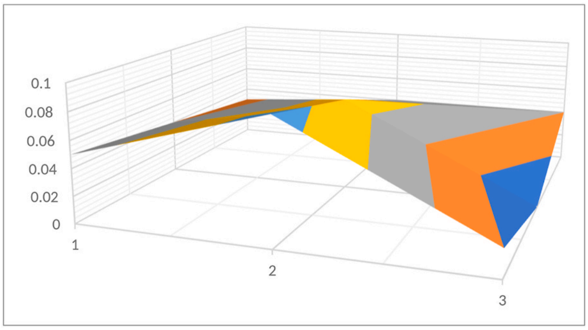

Fig. 3. P12 Low policy PMC-CRITIC surface diagram.

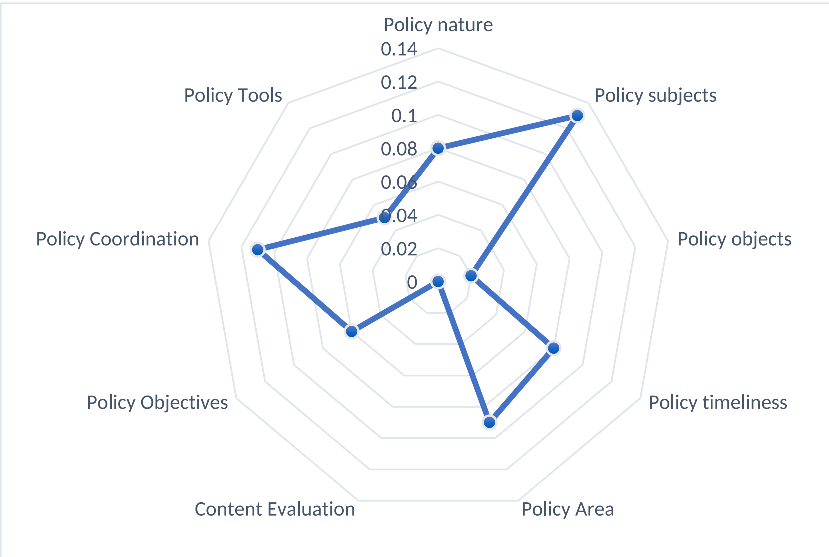

Fig. 4. Radar chart of the mean value of primary evaluation indicator variables.

policies are slightly below the average level, and their scores of the first-level evaluation indicators such as policy synergy (X_8) are low, due to the different policy focuses of different sectors, which leads to the fact that some of the first-level evaluation indicators of the acceptable policies have different scores. Policy12 is deemed undesirable due to its characteristics being formulated by specific provincial departments. These policies typically have a narrow focus and are geographically limited to specific regions. Consequently, the policies formulated under P12 tend to be highly targeted and restrictive. This limited scope may impede their effectiveness at a broader national or systemic level.

5. Conclusions

5.1. Conclusions and suggestions

By analyzing 62 representative policy texts on fiscal policies related to the "double carbon" target, the paper utilizes ROST CM6.0 text mining software to establish an index system. This index system is then used to construct the PMC-CRITIC policy index model. With this model, 12 representative policies are selected based on their relevance and significance. Further analysis involves calculating the weight of each policy level indicator and the PMC-CRITIC index. This allows for a quantitative evaluation of the effectiveness of the 12 representative policies. This paper evaluates the impact of fiscal policies under the "dual carbon" target on carbon emissions. Additionally, a PMC-CRITIC surface diagram is drawn to provide a visual representation of the evaluation results. This comprehensive approach aims to provide a rigorous assessment of the selected policies in achieving the "double carbon" target. The PMC-CRITIC index reveals that the average value of the 12 fiscal policies aligned with the "double carbon" objective stands at 0.62. In the sample of these policies, it is noteworthy that P4 is deemed exemplary, P7 is considered acceptable, and only P1 is deemed subpar. A substantial proportion of these policies exhibit a commendable level of comprehensiveness, spanning multiple domains. Such findings indicate that these policies are formulated under the guidance of two overarching design documents. The collective effort of ministries and finance departments culminates in the integration of strategic documents, thereby facilitating the formulation of relevant policies. Moreover, due consideration is given to the prevailing regional economic development trends. As a result, the policy solutions proposed are informed by sound scientific principles, demonstrating a high level of rationality and feasibility.

Based on the above study, it is found that the three first-level indicators of policy objectives (X_7), issuing institutions (X_3), and policy instruments ($\times_9$) have low scores, indicating that the current fiscal policy under the "double carbon" objective is less involved in this area and the policy system is lacking. Consequently, this study presents the following recommendations: Firstly, concerning policy objectives, diverse departments and local governments must allocate greater attention towards cutting-edge technologies. The government should augment its support for technological research and development efforts by establishing a dedicated fund for low-carbon technology assistance. Collaborative partnerships with key enterprises, universities, and research institutes ought to be fostered to facilitate the attainment of this objective. This can be achieved through the establishment of a three-tier framework encompassing provinces, cities, and counties. To enhance the efforts, the government should amplify its support for research and development in technology. A low-carbon technology support fund should be established to facilitate these endeavors. Furthermore, it is imperative to establish a research platform operating across three levels: provincial, city, and county. This platform should rely on key enterprises, universities, and research institutes, harnessing their collective expertise. By harnessing the guiding role of the government, we can effectively optimize the structure of financial expenditure over time. A green financial budget system should be gradually established to ensure sustainable fiscal practices aligned with environmental objectives. Second, at present, most of the fiscal policies under the "double carbon" target are issued by the State Council, the Development and Reform Commission, the Ministry of Ecology and Environment, local governments, etc. The policies are highly targeted and mainly address specific problems in different aspects or areas in the process of achieving the "double carbon" target. Therefore, in future policy formulation, it is recommended that the central government intensify inter-governmental coordination to bolster the concerted effort in carbon emission reduction across different regions. Additionally, it is imperative to address the existing imbalance in the current fiscal policies aligned with the "double carbon" target. Presently, the focus is primarily on implementing specific measures in industries such as transportation and construction materials. These measures encompass energy conservation, environmental protection taxes, consumption taxes, corporate income taxes, and preferential tax policies for renewable energy utilization. However, there is a notable lack of transfer payments aimed at enhancing carbon sinks in the forestry and marine industries. Therefore, it is crucial to introduce policies that incentivize and support these industries in fulfilling their role as effective carbon sinks. Indeed, the current policy landscape appears to be limited in scope. It is important to recognize that fiscal policy tools should not be confined to specific aspects or isolated components. Instead, a comprehensive approach should be adopted, taking into account the main challenges and critical issues encountered during the pursuit of the "double carbon" goal. By encompassing a holistic perspective, a cohesive and integrated package of fiscal policies can be developed, planned, and implemented to address these challenges effectively. This approach will enable a more robust and encompassing response to the complexities of carbon reduction efforts.

5.2. Limitations and prospect

This study presents certain limitations. Firstly, the focus is predominantly on fiscal policy enacted by the central government, with only three fiscal policies issued by local governments in China being assessed. This may result in an evaluation that is not entirely comprehensive, potentially overlooking the crucial role and specificity of local fiscal policy in achieving China's "Dual carbon" targets. Secondly, due to divergent starting points, backgrounds, and operational environments between central and local policies, there may be a lack of sufficient comparability when both are analyzed within the same framework. Furthermore, local fiscal policies are often fine-tuned based on central directives to fit specific local conditions; however, the present article does not fully reflect such differences and their unique impacts on carbon reduction. Additionally, while the study evaluates the carbon reduction effects of fiscal policy instruments, the analysis of the inherent mechanism through which fiscal policy affects carbon reduction is not sufficiently explored.

Given the deficiencies in the existing research, future studies should be conducted in the following areas. Expansion of the scope of the research to include more fiscal policy evaluations at the provincial and municipal levels, thereby providing a more comprehensive and detailed analysis of policy outcomes. A detailed comparison of the interaction and adaptability between central and local fiscal policies should be undertaken to assess the synergistic effect of policy coordination among different levels of government and their contributions to the "Dual carbon" objectives. There should be an in-depth analysis of the internal mechanisms behind fiscal policy's impact on carbon reduction, examining effects on industrial upgrading, energy efficiency improvements, and adaptability to climate change. In constructing a multi-dimensional evaluation model, the integration of machine learning and econometric methods would allow for more accurate predictions and quantification of the impact of fiscal policy on achieving the "Dual carbon" goals. These research endeavors hold the promise of providing a more robust policy basis for low-carbon development and climate governance in China and potentially on a global scale.

Funded Project

Independent Research Project for Doctoral Students at Minzu University of China "Advancing the Modernization of Harmonious Coexistence Between Humans and Nature Through New Productive Forces: Constituent Dimensions and Practical Directions" (BZKY2024051)

Data availability statement

The data that support the findings of this study are openly available in professional policy databases such as PKULAW database, at https://www.pkulaw.com/, and The full text and attachments were retrieved from relevant government websites, such as at http://czt.hunan.gov.cn/; http://czt.jiangsu.gov.cn/.

Ethics approval

The study obtained ethical approval from Minzu University of China, Beijing 100081, China.

Consent to participate

Not applicable.

Consent for publication

The author has provided consent to publish this work.

CRediT authorship contribution statement

Jiaoyu Zhang: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table A1
Multi-input-output of 12 policies

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
X_1	$X_{1\text{-}1}$	1	1	1	1	1	1	1	0	1	1	1	0
	$X_{1\text{-}2}$	1	1	1	1	1	1	1	0	1	1	1	0
	$X_{1\text{-}3}$	1	1	1	1	1	1	1	1	1	1	1	1
	$X_{1\text{-}4}$	1	1	1	1	1	1	1	1	1	1	1	1
X_2	$X_{2\text{-}1}$	1	1	0	0	1	1	0	1	1	0	0	0
	$X_{2\text{-}2}$	1	1	0	0	1	1	1	1	1	0	0	0
	$X_{2\text{-}3}$	1	1	0	1	1	1	1	1	1	0	0	0
	$X_{2\text{-}4}$	1	1	1	0	1	1	1	1	1	1	1	1
	$X_{2\text{-}5}$	1	1	1	1	1	1	1	1	1	1	1	1
	$X_{2\text{-}6}$	1	1	1	1	1	1	1	1	1	1	1	1
X_3	$X_{3\text{-}1}$	1	1	0	0	0	1	0	0	1	0	0	0
	$X_{3\text{-}2}$	0	0	0	1	1	0	1	0	0	0	0	0
	$X_{3\text{-}3}$	0	0	0	0	0	0	1	0	0	0	0	0

(*continued on next page*)

Table A1 (*continued*)

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
	$X_{3\text{-}4}$	0	0	1	0	0	0	1	1	0	0	0	0
	$X_{3\text{-}5}$	0	0	0	0	0	0	0	0	0	1	1	1
X_4	$X_{4\text{-}1}$	0	1	1	1	1	1	1	0	1	1	1	0
	$X_{4\text{-}2}$	1	1	1	1	1	1	1	0	1	1	1	0
	$X_{4\text{-}3}$	1	1	1	1	1	1	1	1	1	1	1	1
	$X_{4\text{-}4}$	1	1	1	1	1	1	1	1	1	1	1	1
X_5	$X_{5\text{-}1}$	1	1	1	1	1	1	1	1	1	1	1	1
	$X_{5\text{-}2}$	1	1	1	1	0	1	1	0	1	1	1	1
	$X_{5\text{-}3}$	1	1	1	1	1	1	1	0	1	1	1	0
	$X_{5\text{-}4}$	0	1	1	1	1	0	0	1	0	1	1	0
	$X_{5\text{-}5}$	1	1	1	1	1	1	0	1	1	1	1	1
	$X_{5\text{-}6}$	1	1	1	1	0	0	0	1	1	1	1	1
X_6	$X_{6\text{-}1}$	1	1	1	1	1	1	1	1	1	1	1	1
	$X_{6\text{-}2}$	1	1	1	1	1	1	1	1	1	1	1	1
	$X_{6\text{-}3}$	1	1	1	1	1	1	1	1	1	1	1	1
	$X_{6\text{-}4}$	1	1	1	1	1	1	1	1	1	1	1	1
X_7	$X_{7\text{-}1}$	1	1	1	1	1	1	1	1	1	1	1	0
	$X_{7\text{-}2}$	0	0	1	0	1	1	1	0	0	1	1	0
	$X_{7\text{-}3}$	1	0	1	1	1	1	1	1	1	1	1	1
	$X_{7\text{-}4}$	0	1	1	1	1	1	1	1	1	1	1	1
	$X_{7\text{-}5}$	1	1	0	1	0	1	0	0	0	0	0	0
X_8	$X_{8\text{-}1}$	1	1	1	1	0	0	0	1	1	1	1	1
	$X_{8\text{-}2}$	0	0	1	0	0	0	0	1	1	1	0	0
	$X_{8\text{-}3}$	0	0	1	0	0	0	0	1	1	1	0	0
	$X_{8\text{-}4}$	0	0	1	0	0	0	0	1	1	1	0	0
	$X_{8\text{-}5}$	0	0	1	0	0	0	0	1	1	1	0	0
	$X_{8\text{-}6}$	0	0	1	0	0	0	0	1	1	1	0	0
	$X_{8\text{-}7}$	0	0	0	0	0	0	0	1	1	0	0	0
X_9	$X_{9\text{-}1}$	1	1	1	1	0	1	1	1	1	1	1	1
	$X_{9\text{-}2}$	1	0	1	0	0	1	0	0	1	1	1	0
	$X_{9\text{-}3}$	0	0	1	0	0	0	1	0	0	1	0	0
	$X_{9\text{-}4}$	1	0	0	1	0	0	0	1	0	0	0	0
	$X_{9\text{-}5}$	0	1	1	0	1	1	0	1	1	1	1	1

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