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Optimizing ZSG-DEA for Provincial Carbon Quota Allocation: A Decision-Maker's Approach

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***Abstract* - In response to the global climate crisis, China is investigating a comprehensive carbon control system, with the distribution of carbon emission rights among provinces at the heart of implementing the total control objective. This review examines the research on the allocation of carbon emission rights among provinces in China regarding allocation methodologies. The findings indicate that in the allocation of carbon allowances among provinces, the indicator and optimisation methods are commonly utilised. The former can consider the various parties' interests, while the latter can enhance the allocation's effectiveness. The hybrid method's multi-method edge offers potential for development, whereas the game method's insufficient transparency makes it rare. There remains a disparity between the delegation of emission reduction obligations to individual provinces and their actual situations, a consequence of the current allocation outcomes. The leading optimisation technique, the ZSG-DEA model, is capable of increasing efficacy. This model predominantly employs carbon emission quotas and economic indicators as input and output measures, enhancing its impartiality. However, policy implementation typically takes into account not only the growth of the economy, but also is influenced by subjective factors such as the country's policies and the political goals of decision makers. To address this, the present study proposes incorporating a participation module for policymakers into the ZSG-DEA model. The participation module weighs objective indicators such as the economy before calculation, and a ZSG-DEA model with the participation module of policymakers is initially suggested.**

***Index Terms* - Total carbon control, Inter-provincial quotas, allocation methodology, Module for decision makers**

METHODOLOGY FOR ALLOCATING CARBON EMISSIONS BETWEEN PROVINCES IN CHINA

Since the inception of the IPCC in 1988, inter-country carbon quota allocation has emerged as a focal point of research among scholars worldwide [1]. In this context, the principles of equity and efficiency are widely acknowledged as the consensual bases for global carbon quota allocation.

None the less, various studies approach equity and efficiency differently, given diverse standpoints and perspectives, resulting in the generation of a wide range of allocation guidelines for inter-country quota allocation. The allocation guidelines for China's provincial carbon quota allocation have been adapted from relevant global studies. Various methods have been suggested for carbon allowance allocation among Chinese provinces using the above criteria, including the indicator method, optimisation method, game method and hybrid method [2] (refer to Table 1).

TABLE I
METHODOLOGY FOR ALLOCATING CARBON EMISSIONS BETWEEN PROVINCES IN CHINA

Methodologies	Vantage	Drawbacks
single-indicator approach	Simple rules and transparent process	Too one-sided and not easily accepted universally
Multiple Indicator Approach (MIA)	Distribution is balanced	Need for rational choice of indicators
optimisation method	Wide range of applications and optimal efficiency of distribution results	Difficulty in ensuring fairness of results
gamesmanship	Full integration of the needs of all parties	Complex calculations and lack of transparency
hybrid approach	Balancing equity and efficiency	computationally complex

I. 1indicator-Based Approach

The indicator method refers to an allocation method based on predetermined criteria. Relevant studies can be categorized into two types: those that utilize a single indicator method for allocation [3-5], and those that employ a comprehensive indicator method [6-9].

The single indicator method, which employs a single allocation criterion, provides benefits in terms of simplicity, ease of implementation, and greater reflection of decision-makers' preferences. However, the degree of preference for different criteria among provinces varies widely, and this can lead to extreme allocation results under some single criteria [1]. To improve compatibility and inclusiveness of allocation results, the composite indicator method, which considers multiple criteria, is widely employed [10]. In practice, the composite indicator method involves two crucial aspects: selecting the allocation criteria and determining indicator weights. Various studies have suggested the use of diverse allocation criteria based on various perspectives when selecting criteria that represent the interests of different types of provinces. When setting indicator weights, it is widely accepted to utilise the objective weighting method [7, 10-11], given its ability to minimise the impact of subjective factors.

II. Optimisation Method

The optimization method aims to maximise societal efficiency by seeking the best allocation result through linear or non-linear planning methods. The most widely-used model for this is the zero-sum-gain-DEA (ZSG-DEA) technique. ZSG-DEA is an optimization technique that maximizes resource allocation efficiency under a fixed total condition [12]. The method's core idea is that in the process of resource allocation, the gain of one decision-making unit must equal the loss of other decision-making units, while the sum of resources stays constant. This approach has been extensively applied to the carbon quota allocation efficiency optimization scheme in Chinese provinces [13-15]. The optimisation process for quotas, based on the ZSG-DEA method, aims to favour regions with high emissions efficiency in order to allocate more quotas to them. This method is comparable to the indicator method, which relies on the emissions efficiency criterion. However, it is more effective at ensuring maximum efficiency in the allocation results. Furthermore, the ZSG-DEA model extends the BCC-DEA model. However, using the "inverse transformation method" to handle undesired outputs can introduce bias in efficiency measurement. Thus, it is crucial to explore how to enhance the ZSG-DEA model to handle non-anticipated outputs effectively.

III. Gamesmanship

The game method involves various subjects playing the game based on their individual interests, ultimately determining allocation results through the game's equilibrium solution. Shapley value serves as a prominent game theory method in the area of carbon quota allocation [16]. Certain scholars have employed this method in China's provincial carbon quota allocation [17-18].

However, when compared to the indicator and optimisation methods, the game method is less transparent and more complex to operate, preventing it from gaining widespread use as an allocation method.

IV. Hybrid Approach

In order to amalgamate the benefits of the indicator and optimisation methods, certain scholars have adopted a model which combines the two for allocation [20-22]. This paper terms these techniques as hybrid methods. The hybrid method's methodological design varies across studies. For instance, one method takes the comprehensive indicator method as the primary aspect and measures its local indicators using the optimisation method [19]. Another approach uses the optimisation method as the primary feature while considering individual indicators as constraints [20-21]. Additionally, one method applies the indicator method to locate an initial solution and modifies it using the optimisation method [22]. Other methods also exist. In conclusion, whilst the hybrid method has a complex calculation process, it holds significant theoretical value in terms of harmonising equity and efficiency.

COMMON INPUT AND OUTPUT INDICATOR SETTINGS IN DEA MODELLING

There are typically three options when choosing indicators to evaluate the effectiveness of carbon emission rights allocation through DEA models. One option is to use CO_2 emissions as input indicators, as seen in Wang et al.'s research where the CO_2 emissions serve as inputs in the ZSG-DEA model with GDP and population as outputs [23]. Another approach uses CO_2 emissions as an undesired output indicator, like in the study conducted by Pang et al. In the study by <<Author's Last Name>>, population and energy consumption were employed as input indicators, while CO_2 emissions and GDP served as output indicators [24]. Similarly, Fang et al. utilized carbon emission rights as an input indicator, alongside population and energy consumption, and GDP and carbon emissions as output indicators [25].

The input and output variables in the aforementioned DEA models mainly consist of economic indicators like GDP, which are objective in assessing the multifaceted effects, but overlook certain subjective factors during practical implementation such as national policies, long-term planning and political objectives of decision-makers. For instance, a majority of China's high-speed railway projects incur losses and function primarily on state subsidies [26]. This initiative considers the country's strategic development and the welfare of its citizens, instead of relying solely on economic indicators such as GDP.

ZSG-DEA MODEL WITH PARTICIPATION MODULE FOR DECISION MAKERS

For the allocation of carbon emission rights, this study tries to construct a ZSG-DEA model with the participation of decision makers in the expectation of achieving the optimal efficiency of each unit, while taking into account some policy and decision-making factors, see Figure 1.

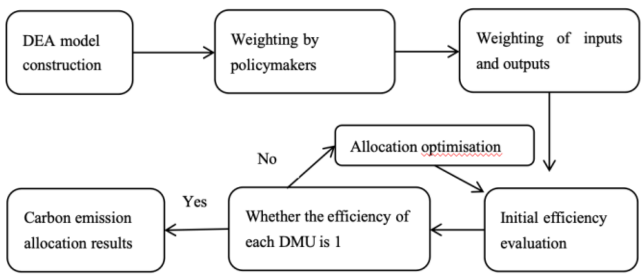

FIGURE 1 ZSG-DEA CARBON ALLOCATION PROCESS WITH PARTICIPATION MODULE FOR DECISION MAKERS

This model would allow policy makers to assign different weights to economic factors, reflecting their preferences for different economic goals. The calculation steps are as follows.

Decision maker participation module: a module is set up to obtain the decision maker's importance scores for each input and output indicator prior to the efficiency evaluation.

Weighted scoring: Decision makers give scores based on the importance of each economic factor, e.g. the importance of GDP may be closely related to regional development strategies and objectives.

Weighted indicator data: Input and output data are weighted according to the weights given by the decision maker. This can be done by adjusting the values of the indicators to reflect the relative importance of different indicators.

DEA calculations: DEA calculations are carried out using the weighted data to obtain efficiency evaluation results that take into account the preferences of policy makers.

PROPOSE

The computational model presented in this study has not undergone empirical analysis with surrogate data. Consequently, conducting separate calculations using the models of decision makers' participation and non-participation for the same data set will yield more revealing results. To obtain the weights of the indicators assigned by decision makers, hierarchical analysis can be utilised at the indicator weighting stage.

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