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Original Research

Operation Effect of a Regional Carbon Market Based on Analytic Hierarchy Process-Fuzzy Comprehensive Evaluation: A Case Study of the Environmental and Energy Exchange in Fujian Province

Junjie Lin[1, 2], Wenyue Wei[3], Qun Zhang[1, 2], Yuanzhu Wei[1, 2]*

[1]College of Economics and Management, Ningde Normal University, Ningde 352100, Fujian Province, China
[2]Research Center for the Road to Rural Revitalization with Characteristics of East Fujian, Ningde 352100, Fujian Province, China
[3]College of Earth and Environmental Sciences, Lanzhou University, Lanzhou 730106, Gansu Province, China

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Abstract

As an important market-based emission reduction tool, the carbon market plays an important role in China's ability to meet its "30·60" goal[1]. Deeply analyzing the evaluation system of the carbon market in Fujian province is of great reference value for other regions when formulating carbon exchange policies. This paper aims to analyze the evaluation index system of the carbon market based on the analytic hierarchy process (AHP)-fuzzy comprehensive evaluation model and the development level of each factor in the environmental energy exchange platform in Fujian province. The results are as follows: (1) the evaluation results of the exchange platform are at an average level. There are significant differences in the level of internal indicators in the carbon market. Therefore, multi-dimensional efforts should be made to promote the operational effect of the carbon market. (2) The evaluation results of some indicators are at a poor level of excellence, such as the exchange rules, measurement work, and professional management personnel, which are important factors affecting the operation effect of the carbon market. Based on the above findings, this paper proposes several suggestions in terms of enhancing the influence of platform, setting convenient exchange

[1] The "30.60" target refers to China's response to climate change by promoting the reduction of greenhouse gases, especially carbon dioxide. China has proposed that its carbon dioxide emissions should peak by 2030 and that it should become carbon neutral by 2060.

*e-mail: weiyz@ndnu.edu.cn

rules, establishing a standardized and effective carbon financial system, and establishing an effective mechanism to improve the skills of professional personnel.

Keywords: AHP-fuzzy comprehensive evaluation method, regional carbon markets, operation effect, Environmental and Energy Exchange in Fujian province

Introduction

The carbon emission trading market (hereinafter carbon market) is an important policy means for the international community to deal with climate change. As an important mechanism for pricing greenhouse gas emissions, the carbon market plays a key role in promoting the transformation to a low-carbon economy and energy framework and has been adopted by more countries and regions over time. Since 2011, China has carried out pilot work on carbon market construction in eight provinces and cities (Beijing, Tianjin, Shanghai, Chongqing, Shenzhen, Hubei, Guangdong, and Fujian), providing valuable experience for the design and construction of the national carbon market. The Fujian province built the Environment and Energy Exchange in 2016 and gradually built a carbon market with local characteristics. This exchange has continuously enriched the exchange varieties and methods, realizing the "double growth" of the total quota and exchange scale. Although Fujian's carbon exchange market has given full play to the important role of the "test field" of the national carbon market. Owing to the independent operation of each carbon market in China and the different system designs [1, 2], the role of the carbon market is not fully understood at present. In 2021, the total carbon emissions exceeded 11.9 billion tons, accounting for about a third of global emissions, making the need for emission reduction urgent [3]. In pursuit of the "double-carbon" goal, the carbon exchange market in Fujian province will face several opportunities and challenges.

Currently, scholars mainly have focused on the general development, mechanism, and impact of the carbon market. In terms of the general development of the carbon market, building the carbon market is essential. Doing this relies on an expanding scale, a rising exchange price, and a strong market liquidity in the future. Huang et al. comprehensively summarized the development trend of China's carbon emissions trading, including trading volume, carbon emissions price, and the effect of carbon emission abatement , and some suggestions have been provided for the operation of the nationwide carbon market [4]. Other scholars have put forward suggestions to improve the market mechanism to support the goal of carbon neutrality, such as the price strategy of carbon emission rights and innovation of the carbon exchange mode [5-7].

For the carbon market mechanism, the emission reduction mechanism is the main entry point. Existing studies have posited that the government needs to establish an emission reduction mechanism based on voluntary emission reduction, which is supplemented by mandatory emission reduction in the early stage [8]. According to industry types and regional characteristics, a detailed carbon market intervention mechanism should be formulated and established to improve the carbon market. As a mechanism for achieving carbon neutrality targets, the pricing mechanism is an essential tool for establishing the carbon market. Existing analysis indicates that the current average carbon price still has room for improvement in China [9, 10]. Li et al. built the carbon asset intrinsic value model based on the general equilibrium analysis of the carbon price, which drives the continuous improvement of the pricing mechanism in the carbon market [11]. Some reports have analyzed the efficiency of the carbon emission rights exchange mechanism and concluded that the imperfect designs of factors such as distribution and flexibility also cause the problem of insufficient efficiency [12]. Furthermore, to formulate carbon emission trading policies, Ding et al. analyzed the classification of carbon emission trading policies in Fujian Province. They concluded that it is essential to form a complete carbon emission trading supervision and management mechanism, which provided a new research direction for the present study [13].

From the perspective of the carbon market impact analysis, scholars have simulated economic growth in each carbon market pilot area using the average equilibrium model. They have found that carbon market will significantly promote the economic development of the heavy industry in midwestern China so as to effectively avoid the carbon trap and promote carbon decoupling. At the same time, the establishment of the carbon market can effectively improve the income of emission control enterprises and promote the target of enterprise and regional economic growth while improving the environment [14, 15]. In addition, the implementation of a carbon exchange pilot has had a technological innovation effect [16], as well as an employment dividend and environmental health effect [17, 18].

In terms of existing research, there has been a lack of effective evaluation of the operation effect in regional carbon markets. Although existing research has examined the actual operation of the carbon market [19, 20], it has lacked a systematic construction of the evaluation index system. The AHP-fuzzy comprehensive evaluation method enhances the reliability of the evaluation results by empowering the fuzzy comprehensive evaluation method through the analytic hierarchy process (AHP). Calculations based on the fuzzy comprehensive evaluation method are helpful for reducing the influence of the subjective factors of AHP, and then make the evaluation results more valuable.

Since the AHP-fuzzy comprehensive evaluation method was created, it has been used widely. To make up for the shortcomings of the above research, this paper applies the fuzzy comprehensive evaluation method to evaluate the operation efficiency of the carbon market in Fujian province.

Compared with the findings of previous studies, the main contributions in this paper are as follows: (1) The construction of an evaluation and analysis framework for the operation effect of the carbon market. According to the characteristics of the regional carbon market, the influencing factors are subdivided in the regional carbon market, and the evaluation model is constructed. Industry experts are invited to discriminate between the weights of factors that affect the operation effect of carbon markets, which provides specific reference experience for regional carbon markets that have not yet established an evaluation system. (2) At present, there is still a large gap in analyzing the influencing factors and operation effect evaluation in the carbon market. In this study, the AHP model is used to determine the evaluation index system of the operation effect, and the fuzzy quantitative evaluation method is applied to conduct a fuzzy comprehensive evaluation in the Fujian carbon market, which makes the evaluation results more credible.

The rest of this paper is structured as follows. In section 2, we introduce data and methods. Section 3 shows the results of the application of AHP-fuzzy comprehensive evaluation in the Environment and Energy Exchange, and section 4 provides conclusions and policy recommendations.

Data and Methods

Data Sources

This paper takes the Environment and Energy Exchange in Fujian province as the research object and makes a comprehensive evaluation through a field investigation, exchange interviews, and expert scoring. Two main types of experts are investigated in this paper: 1) staff of the Environment and Energy Exchange in Fujian province, including the staff and managers of carbon exchange services (10 people); 2) experts and scholars (6 people) familiar with the Environment and Energy Exchange in Fujian province. The content of the expert questionnaire mainly involves the service function and index weight evaluation of the carbon emission exchange platform. The study conducts a one-on-one questionnaire interview for field research in 2021. A total of 16 expert questionnaires are obtained. Excluding the missing data questionnaire, a total of 15 effective questionnaires are obtained, and the efficiency of the questionnaire is as high as 93.75%.

Construction of the Evaluation System

To effectively construct the evaluation index system in the Environment and Energy Exchange in Fujian province, we refer to the research results of various experts and scholars on the evaluation of the platform's effectiveness. In this paper, the evaluation index system is designed using the ladder hierarchical structure and is constructed according to the principles of scientificity, comparability, and feasibility.

The criterion layer indicators should be able to reflect the degree of the role of the carbon market from different aspects. Based on the SWOT model, this paper selects four criteria: Strength (S), Weakness (W), Opportunity (O), and Threat (T). In terms of specific indicator selection, specific indicators that can reflect the exchange situation of the carbon market are selected based on literature review, referencing existing research results, expert consultation, and field research. Each evaluation factor is stratified according to the hierarchical model, and key indicators are selected to build a multifaceted index system. The final evaluation index system includes one objective, four criteria, and 15 indicators, as shown in Table 1.

Research Methods

SWOT-AHP Model

The SWOT-AHP model involves carrying out quantitative analysis, determining the weight of each index, decomposing the complex decision-making problem into several relatively simple influencing factors,and obtaining the influence weight of each factor on the problem. This model effectively makes up for the deficiency that SWOT can only conduct qualitative analysis but not quantitative analysis. The specific operation process is as follows.

First, it is necessary to build the structural model of multilevel analysis. According to the results of SWOT analysis, the order of the evaluation indicators is reasonably determined. By means of a field investigation and expert interviews, the advantages, disadvantages, external opportunities, and threats of the Environment and Energy Exchange in Fujian province are taken as the criterion layer, and the specific indicators corresponding to advantages, disadvantages, opportunities, and threats are taken as the indicator layer.

Second, we construct the matrix of pairwise comparison. By comparing and scoring indicators of the same level by different experts, we construct a judgment matrix. The matrix judgment scale (1-9 scale method) is often cited, as shown in Table 2.

Third, we perform a single ranking of the AHP. The weight matrix of a specific index is obtained by determining the influence of low-level factors on high-level factors. The judgment matrix A is

Table 1. Evaluation system of the Environment and Energy Exchange in Fujian province.

Target layer	Criterion layer	Index layer	Reference literature
Environment and Energy Exchange in Fujian province	Strength (S)	Conducive to protecting the legitimate rights and interests of all parties to the transaction (S_1)	Wang and Liu [21]
		Forms a complete carbon emission exchange system (S_2)	Wang and Liu [21]
		Beneficial to realize information symmetry (S_3)	Li [22]
		Forms a bidding price mechanism (S_4)	Jiang [23]
	Weakness (W)	Excessive complexity of exchange rules and measurement (W_1)	Li [22]
		Less influence of local carbon exchange platforms (W_2)	Cheng [24]
		Unbalanced structure of transaction items (W_3)	Chen and Zhang [25]
		Lack of professional management talents (W_4)	Cheng [24]
	Opportunity (O)	Sound policy environment (O_1)	Zhang and Meng [26]
		Broad market space (O_2)	Zhang and Meng [26]
		Combined development of property rights transaction and green financing (O_3)	Lu et al. [27]
	Threat (T)	Fuzzy nature of exchange platform (T_1)	Li [22]
		Imperfect market supervision system (T_2)	Wang [12]
		Lack of dominance in carbon exchange pricing power (T_3)	Yang [28]
		Competition from other exchange platforms (T_4)	Tan et al. [29]

Table 2. AHP evaluation scale.

Scale	Definition
1	Equal importance
3	Slight importance
5	Obvious importance
7	Strong importance
9	Very strong importance
2, 4, 6, 8	Intermediate values

normalized, $\overline{A_{ij}} = \frac{A_{ij}}{\sum_{i=1}^{n} A_{ij}}$, $\overline{A_{ij}}$ is summed, $\overline{W_i} = \sum_{i=1}^{n} \overline{A_{ij}} (j = 1..n)$, and $\overline{W} = \left[\overline{W_i}\right]^T$ can be obtained, where i = 1, 2, ...n. On this basis, the vector set of evaluation factors is obtained through normalization. The element is the de-weighted value in the single order of the corresponding element.

Fourth, we perform consistency test. The index and ratio of consistency are used to conduct a reasonable test for the weight set. The formula of consistency test is $CR = CI/RI$ When the consistency test is below 0.1, the weight value of the indicator meets the setting requirements.

Fuzzy Comprehensive Evaluation Method

The fuzzy comprehensive evaluation method refers to the process of quantifying the importance of relevant factors through a fuzzy transformation and realizes the comprehensive evaluation of indicators at different levels. To overcome the randomness of the AHP and to reduce the lack of valuable information to evaluate the effect of the Fujian Environment and Energy Exchange, this paper uses the fuzzy evaluation method with a weighted average and establishes the score function of the evaluation standard. The specific steps are as follows:

(1) Establish the set of factors.

The 15 indexes in the evaluation system are the elements of the factor set $U = \{U_1, U_2, ..., U_n\}(n = 15)$.

(2) Establish fuzzy evaluation terms.

The evaluation results of each evaluation index have their corresponding evaluation levels and an evaluation set. According to the principle of spacing equal division, the cross-evaluation set is defined as V = {excellent, good, average, poor, very poor}. The false evaluation values are set as 100, 80, 60, 40 and 20 points, respectively, and the evaluation standard score function is established.

(3) Construct the membership matrix and determine a comprehensive evaluation in the fuzzy operator.

The membership degree of each index is expressed by the proportion of the number of an evaluation index to the total number of this index in the questionnaire (i.e., index normalization), as follows:

$$R_{ij} = \frac{V_{ij}}{\sum_{j=5}^{5} V_{ij}}$$

where i = 1, 2... 15. R_{ij} is the fuzzy membership degree of the JTH comment value of the ith index, and V_{ij} is the number of valid samples that answers the JTH comment of the ith index. On this basis, the single factor fuzzy relation matrix is obtained as follows:

$$R = \begin{bmatrix} r_{11} \cdots r_{1m} \\ \dots \cdots \dots \\ r_{n1} \dots r_{nm} \end{bmatrix} \quad 0 \le r_{nm} \le 1$$

When the fuzzy relation matrix and weight vector are determined, a fuzzy comprehensive evaluation should be carried out. Thus, the first-order fuzzy transformation is as follows:

$$D = W_i * R_i (i = 1, 2, ..., n)$$

In the above formula, W_i is the weight vector of the evaluation index at the index layer. R_i is the membership matrix of evaluation index. D is the first-order fuzzy transformation matrix.

In the second level, the formula of fuzzy transformation is as follows:

$$A = W * D$$

In the above formula, A is the second-level fuzzy transformation matrix and W is the weight set of the criterion layer. The evaluation score is calculated as follows:

$$M = A_1V_1 + A_2V_2 + A_3V_3 + A_4V_4 + A_5V_5$$

Result

AHP Method to Determine the Weight of the Evaluation Index

In this paper, the AHP method is used to calculate the weight coefficient of each index. According to the scoring results, the judgment matrix is constructed and the consistency is tested to determine the weight vector value of the index. The importance of indicators is generally expressed on a scale of 1 to 9, and the weight is determined by pairwise comparison of indicators. The inspection is carried out layer by layer from a high level to a low level. The *CR* values of evaluation indexes at all levels are below 0.1. At this time, the results satisfy the condition of matrix consistency. As shown in Table 3, it is known that the consistency ratio is less than 0.1; that is, it meets the requirements of the basic settings.

The weight results in the judgment matrix of the secondary index B_i-C_i are shown in Tables 4-7. Similarly, the consistency ratios are 0.0678 and 0.0375, respectively, both of which are less than 0.1. That is, they meet the requirements of basic settings.

It can be seen from the above table that the maximum eigenvalue of matrix S is 4.18, and that the normalized eigenvector corresponding to the maximum eigenvalue is $(0.3823, 0.2918, 0.2236, 0.1023)^T$.

It can be seen from the above table that the maximum eigenvalue of matrix W is 4.0996, and that the normalized eigenvector corresponding to the maximum eigenvalue is $(0.4211, 0.2455, 0.1545, 0.1789)^T$.

Table 3. Weight in the judgment matrix of evaluation index B.

B	S	W	O	T	ω
S	1	1.3299	1.0556	1.3715	0.2888
W	0.7519	1	0.7584	1.0079	0.2134
O	0.9474	1.3185	1	1.8459	0.3032
T	0.7291	0.9922	0.5417	1	0.1946

CR = 0.0055

Table 4. Weight in the second-level index S judgment matrix.

C	S_1	S_2	S_3	S_4	ω
S_1	1	2.0213	1.6353	2.5468	0.3823
S_2	0.4947	1	2.0572	2.7241	0.2918
S_3	0.6115	0.4861	1	3.2772	0.2236
S_4	0.3926	0.3671	0.3051	1	0.1023

CR = 0.0678

Table 5. Weight in the W judgment matrix of the second-level index disadvantage.

C	W_1	W_2	W_3	W_4	ω
W_1	1	2.4956	1.8750	2.2514	0.4211
W_2	0.4007	1	1.9134	1.6585	0.2455
W_3	0.5333	0.5226	1	0.7038	0.1545
W_4	0.4442	0.6030	1.42	1	0.1789

$CR = 0.0375$

Table 6. Weight and test of the second-level index chance O judgment matrix.

C	O_1	O_2	O_3	ω
O_1	1	2.4134	2.0158	0.5244
O_2	0.4144	1	1.0556	0.2349
O_3	0.4961	0.9474	1	0.2406

$CR = 0.0059$

Table 7. Weight and test of the second-level index threat T judgment matrix.

C	T_1	T_2	T_3	T_4	ω
T_1	1	1.1159	1.7323	0.9246	0.2933
T_2	0.8628	1	0.5323	1.6888	0.2217
T_3	0.5773	1.8785	1	2.2436	0.3050
T_4	1.0815	0.5921	0.4457	1	0.1801

$CR = 0.0923$

It can be seen from the above that the maximum eigenvalue of matrix O is 3.0061 and that the normalized eigenvector corresponding to the maximum eigenvalue is $(0.5244, 0.2349, 0.2406)^T$.

It can be seen from the above that the maximum eigenvalue of matrix T is 4.2454 and that the normalized eigenvector corresponding to the maximum eigenvalue is $(0.2933, 0.2217, 0.3050, 0.1801)^T$.

According to the consistency test results of the above judgment matrix, the values of all evaluation indexes are less than 0.1. Therefore, the matrix consistency conforms to the condition requirements .

Fuzzy Comprehensive Evaluation Analysis

Based on the evaluation results of experts on each indicator, this paper obtains the membership degree of each indicator to the rating of comments, as shown in Table 8.

On this basis, the single factor of the fuzzy comprehensive evaluation matrix is established. In addition, the calculation process of the SWOT comprehensive evaluation is obtained as follows.

The evaluation vector of strength (S) is

$$B_1 = W_1 * C_1 = [0.3259\ 0.5272\ 0.0803\ 0.0667\ 0] \quad (1)$$

The evaluation vector of weakness (W) is

$$B_2 = W_2 * C_2 = [0\ 0.1567\ 0.2633\ 0.3760\ 0.2040] \quad (2)$$

The evaluation vector of opportunity (O) is

$$B_3 = W_3 * C_3 = [0.3120\ 0.3800\ 0.2633\ 0.0347\ 0] \quad (3)$$

The evaluation vector of threat (T) is

$$B_4 = W_4 * C_4 = [0.0480\ 0.2147\ 0.4887\ 0.2060\ 0.0320] \quad (4)$$

Then, the comprehensive evaluation vector is obtained as follows:

$$A = W_A * R_A = [0.1980\ 0.3427\ 0.2543\ 0.1501\ 0.0498] \quad (5)$$

Furthermore, the comprehensive evaluation value of the Environment and Energy Exchange in Fujian province is obtained as follows:

Table 8. The second-level index membership of the Environment and Energy Exchange in Fujian province.

Target layer	Criterion layer (B)	Index layer (C)	Excellent	Good	Average	Poor	Very poor
Environment and Energy Exchange in Fujian province	S	S_1	10	3	1	1	0
		S_2	1	12	1	1	0
		S_3	3	10	1	1	0
		S_4	1	10	3	1	0
	W	W_1	0	0	1	11	3
		W_2	0	6	3	3	3
		W_3	0	3	10	1	1
		W_4	0	1	4	5	5
	O	O_1	5	6	3	1	0
		O_2	8	6	1	0	0
		O_3	1	5	9	0	0
	T	T_1	3	5	6	1	0
		T_2	0	4	6	5	0
		T_3	0	1	10	4	0
		T_4	0	4	9	2	0

$$M = A*V = 100*0.1980 + 80*0.3427 + 60*0.2543 + 40*0.1501 + 20*0.0498 = 69.4766$$

Analysis of Research Results

The Operation Effect Level of the Exchange Platform

The comprehensive evaluation score of the exchange platform is 69.4766, indicating that the construction level of the exchange platform is still at the average level. According to the above research, the Environment and Energy Exchange in Fujian province is at the level of excellent in terms of advantages, while the opportunities and the threats are at the average level. Meanwhile, the disadvantages are at the less excellent level. From the perspective of the first-level index, the advantages and opportunities are important indicators to increase the comprehensive level in the exchange platform, while the disadvantages and threats effectively reduce the comprehensive level in the exchange platform. It is necessary for us to expand to a higher level to promote the development of the carbon market as shown in Table 9.

Table 9. Statistical table of various levels of platforms.

Type	Score
S	82.252
W	47.454
O	78.786
T	60.178
Total score	69.477

The Development Level of Each Index in Exchange Platform

At present, the development levels of exchange platforms are significantly different. In particular, the evaluation index value of advantages reaches a good grade. The exchange platform provides a complete carbon emission exchange system, which helps to protect the legitimate rights and interests of exchange parties in the carbon market.

Firstly, the development level of opportunity is at the upper limit of the average level. Among them, carbon policy is the basic guarantee for the construction of the carbon market. Relevant carbon exchange policies should be further implemented. The performance of the property rights transaction and green financing is poor, with the maximum membership being 0.6000.

Secondly, the disadvantages are mainly reflected in two important aspects: excessively complicated carbon exchange rules and measurement work, and the insufficient cultivation of professional talents. The performance of these indicators is unsatisfactory. The maximum memberships are 0.7333 and 0.3333, respectively, which are the key aspects to be improved. Therefore, it is necessary to simplify carbon exchange procedures and pay attention to the cultivation of professional talents in the carbon exchange, which is consistent with the results of the field investigation.

Table 10. The result of the fuzzy comprehensive evaluation of the index layer.

Index layer	Maximum membership	Evaluation result	Index layer	Maximum membership	Evaluation result
S_1	0.6667	Excellent	O_1	0.4000	Good
S_2	0.8000	Good	O_2	0.5333	Excellent
S_3	0.6667	Good	O_3	0.6000	Average
S_4	0.6667	Good	T_1	0.4000	Average
W_1	0.7333	Poor	T_2	0.4000	Average
W_2	0.4000	Good	T_3	0.6667	Average
W_3	0.6667	Average	T_4	0.6000	Average
W_4	0.3333	Poor			

Moreover, the evaluation results of other indicators are at the good level or higher, such as protecting the legitimate rights and interests of all exchange parties, realizing the symmetry of exchange information, and forming a bidding price mechanism as shown in Table 10.

Conclusions and Policy Recommendations

Currently, assessing the operation effects of the carbon market is fundamental to its implementation nationwide. Taking the Environmental and Energy Exchange in Fujian province as a case study, this paper uses the AHP–fuzzy comprehensive evaluation method to assess the effects of the carbon market on achieving "30·60" goal.. The evaluation results showed that the carbon market is still in the preliminary stage of development. The major conclusions and policy recommendations of this paper are as follows.

(1) Significant differences exist in the level of internal indicators in the carbon market. Among them, the evaluation effect of advantages is the best, which reaches the good grade. The evaluation results of opportunities and threats are at the average level. However, the development level of the threat is at the lower limit of the average level and the disadvantage rating is at a lower level. Therefore, multi-dimensional efforts should be made to promote the operation effect of the carbon market. First, the SWOT-AHP analysis confirmed the fundamental role played by opportunity in the carbon exchange market. Hence, the exchange platform should exploit the opportunity of the platform to compensate for internal deficiencies. Specifically, it is urgent to make full use the favorable policy in the publicity of the platform to enhance the influence of platform and encourage the involvement of market users.

Secondly, the platform also actively uses its advantages to respond to external threats. Owing to the dual nature of the economy and public welfare in the carbon exchange, the carbon exchange platform should take advantage of the government at an early stage to expand business volume and improve the trust of the exchange platform. In the later stage of development, profitable businesses should be actively explored by the platform. Furthermore, the platform can achieve a service enterprise through a carbon emission exchange, a carbon derivatives exchange, and carbon gold.

(2) The evaluation results of indicators are at a poor level, such as exchange rules, measurement work, performance of the property rights transactions and green financing, and professional management personnel, which are the key paths through which the carbon exchange market can take effect. Firstly, from the results, exchange rules and measurement work have a more significant effect on the carbon market, so it is necessary to set convenient exchange rules for all stakeholders and enrich the market players involved in the exchange, which may contribute to improve the efficiency of the market operation.

Secondly, given the poor performance of property rights exchange and green financing, it is essential to establish a standardized and effective carbon financial system to guarantee the reasonable profits of the exchange platform and set rules for all stakeholders. In addition, a series of carbon financial products should be developed, such as by focusing on the carbon swap exchange, carbon futures, carbon options, carbon funds, and other financial innovations [4]. This is in line with the criteria of national carbon exchange system.

Thirdly, it is crucial to expand the local carbon exchange market so that more professional personnel are included. Hence, a further important issue that arose within this study was the necessity of establishing an effective mechanism to improve the skills of professional personnel, such as by increasing policy support for existing employees, introducing carbon talents in a reasonable and timely manner, and encouraging wide-ranging cooperation between universities, enterprises, and government departments to cultivate a community of professionals in the carbon market. Previous studies have drawn similar conclusions [13, 22].

Although the carbon market has good development, the operation effect evaluation is still in the preliminary stage overall. There are some research limitations that need to be improved in future research. The evaluation of the carbon market is a type of systematic engineering, and accurately grasping its index layer is very important and a key direction for future research.

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Data Availability Statement

The data generated and analyzed in this manuscript are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

All authors have read and approved the final manuscript. Junjie Lin is the first author in this paper. Yuanzhu Wei is the corresponding author in this paper.

References

1. ZHAO X., WU L., LI. A. Research on the efficiency of carbon exchange market in China. Renew able and Sustainable Energy Reviews, **79**, 1, **2017**.
2. ZHU B., ZHOU X., LIU X., WANG H., HE K., WANG P. Exploring the risk spillover effects among China's pilot carbon markets: A regular vine copula-CoES approach. Journal of Cleaner Production, **242** (5), 118455, **2020**.
3. BP INTERNATIONAL LIMITED. Statistical review of world energy 2021 (70th edition). https://www.bp.com/content/dam/bp/businesssites/en/global/corporate/pdfs/energy-economics/statistical-review/ bp-stats-review-2021-full-report.pdf. **2021**.
4. HUANG W., WANG Q., LI H., et al. Review of recent progress of emission trading policy in China. Journal of Cleaner Production, **349**, 131480, **2022**.
5. WENG Z., MA Z., LIU T. Current situation, challenges and Countermeasures of China's carbon market under the goal of carbon neutrality. Environmental Protection. **49** (16), 18, **2021** [In Chinese].
6. GENG W., FAN Y. Did carbon exchange policies contribute to the decline in energy intensity? - Based on the pilot carbon market in Hubei Province. China Population, Resources and Environment, **31** (09), 104, **2021** [In Chinese].
7. ZHANG R., CHEN D., LIN Y. The path and countermeasure design of establishing regional carbon exchange market: Based on the "carbon ticket" exchange model of Chongqing. China Science and Technology Forum, **5**, 57, **2012** [In Chinese].
8. ZHU F., LI T.Q. An empirical study on the emission reduction performance of China's carbon exchange market. Taxation and Economics, **3**, 54, **2021** [In Chinese].
9. JIANG J., YE B. A comparative analysis of Chinese regional climate regulation policy: ETS as an example. Environmental Geochemistry and Health, **2019**.
10. SHEN W., WANG Y. Adaptive policy innovations and the construction of emission exchange schemes in China: Taking stock and looking forward. Environmental Innovation and Societal Transitons, **30**, 59, **2019** [In Chinese].
11. LI J., YAO H., MEI D. Research on Pricing Mechanism of Chinese Carbon Market under the goal of Carbon Neutralization. Environmental Protection, **49** (14), 24, **2021** [In Chinese].
12. WANG J., DOU X., JI R. Research on the effectiveness of carbon emission exchange scheme for global climate governance: Advances in the academic frontier of low-carbon economy. Journal of Shandong University (Philosophy and Social Sciences), **2**, 174, **2019** [In Chinese].
13. DING G., DENG Y., LIN S. A study on the classification of China's provincial carbon emissions trading policy instruments: Taking Fujian province as an example. Energy Reports, **5**, 1543, **2019**.
14. JIA Z., LIN B. Rethinking the choice of carbon tax and carbon exchange in China. Technological Forecasting and Social Change, **159**, 120187, **2020**.
15. YANG L., YAO Y., ZHANG J., et al. A CGE analysis of carbon market impact on CO2 emission reduction in China: a technology-led approach. Natural Hazards, **81** (2), 1107, **2016**.
16. FAN D., WANG W., LIANG P. Analysis of the performance of carbon emissions exchange right in China--the evaluation based on the difference-in-difference model. China Environmental Science, **37** (6), 2383, **2017** [In Chinese].
17. YAMG X., JIANG P., PAN Y. Does China's carbon emission exchange policy have an employment double dividend and a porter effect. Energy Policy, **142**, 111492, **2020**.
18. ZHANG W., LI J., LI G., et al. Emission reduction effect and carbon market efficiency of carbon emissions exchange policy in China. Energy, **196**, 117, **2020**.
19. ABRELL J., NDOYE F. A., ZACHMANN G. Assessing the impact of the EU ETS using firm level data. Bruegel Working Paper, **2011**.
20. YIN Y., WU Z., MA H. Study on the Impact of China's carbon emission exchange Pilot Policy on regional carbon decoupling. Shanghai Finance, **5**, 70, **2022** [In Chinese].
21. WANG K., LIU Y. Review and Prospect of China's carbon market in 2020. Transactions of Beijing Institute of Technology (Social Sciences Edition), **22** (02), 10, **2020** [In Chinese].

22. LI Y. Current situation, problems and suggestions of carbon emission exchange pilot in Fujian Province. Macroeconomic Management, **2**, 66, **2018** [In Chinese].
23. JIANG J. The latest progress of carbon pricing mechanism and suggestions for the development of China's carbon market. Price Theory and Practice, **2**, 26, **2022** [In Chinese].
24. CHENG W. Existing problems and countermeasures of China's carbon exchange service platform. Social Science Front, **6**, 58, **2014** [In Chinese].
25. CHEN X., ZHANG M. Carbon emission exchange market: International experience, Chinese characteristics and policy recommendations. Shanghai Finance, **9**, 22, **2022** [In Chinese].
26. ZHANG H., MENG J. Carbon emission reduction effects of China's carbon market from the perspective of incentives and constraints. Resources Science, **44** (09), 1759, **2022** [In Chinese].
27. LU Z., YE X., QIAN L., FANG Q. Research on China's carbon market and carbon finance development under the vision of "carbon neutrality". Southwest Finance, **12**, 3, **2021** [In Chinese].
28. YANG J.Q. Development status, problems and countermeasures of Chinese carbon exchange market. Enterprise Economics, **37** (10), 29, **2018** [In Chinese].
29. TAN X.,WANG B., HUANG J. Price stability mechanism, evaluation and implications of carbon exchange pilot in Hubei Province. Advances in Climate Change Research, **14** (03), 310, **2018**.