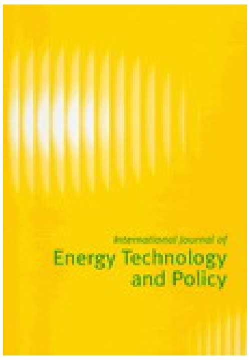

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Evaluation method of enterprise carbon asset value based on analytic hierarchy process and grey correlation method in the context of carbon neutrality

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Abstract: In the context of carbon neutrality, there is a problem of low sensitivity coefficient of carbon asset value in the evaluation of corporate carbon asset value. To this end, a method for evaluating the value of carbon assets in enterprises using the analytic hierarchy process and grey correlation method in the context of carbon neutrality is proposed. Firstly, the construction of an indicator system based on the different forms of corporate carbon assets is completed. Then, through regression calculation of value evaluation indicators, the selection of value evaluation indicators is achieved. Finally, through the analytic hierarchy process – grey correlation method, a carbon asset value evaluation model for enterprises is constructed to achieve value evaluation research. The experimental results indicate that the sensitivity coefficient of using the proposed method to evaluate the value of carbon assets is high, and the evaluation effect is good.

Keywords: carbon neutrality background; analytic hierarchy process; AHP; grey correlation method; regression calculation; information gain; indicator weight; factor set.

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1 Introduction

With the rapid development of the global economy, the global ecological environment and climate are gradually deteriorating, and corporate carbon asset assessment has become an important measure related to ecological environment improvement (Chevalier et al., 2021). Enterprise carbon asset assessment mainly focuses on the statistics of carbon assets owned by entities or organisations to ensure the use and planning of carbon. The valuation of carbon assets estimates the fair value of carbon assets such as corporate carbon emissions, carbon emissions reductions, and carbon financial derivatives based on standards and methods related to carbon assets (Jiang et al., 2021). However, in the actual evaluation process, it is difficult to collect the basic data for carbon asset value evaluation. Due to the fact that the evaluation object of carbon asset value is often a large-scale and complex system, various data needs to be collected, including energy consumption, substance conversion, emission concentration, etc. (Hawari et al., 2021). Due to the wide range of data sources, great difficulty in collecting, and variable data, it has brought considerable difficulties to the actual work, as well as the inconsistency between the area of the evaluation measurement method and the actual evaluation and other problems, which has led to a large deviation and invalidity in the results of the enterprise's carbon asset value evaluation. It seems that there are great challenges in the enterprise's carbon asset evaluation (Gong et al, 2021). The effective evaluation of the carbon asset value of enterprises in the context of carbon neutrality can alleviate the pressure on the entire ecological environment and provide assistance for the sustainable development of human society. For this reason, researchers have designed many evaluation methods for enterprise carbon asset evaluation and gained significant inspiration from them.

Roussanaly et al. (2021) proposed a value evaluation method for improving the acquisition and cost of carbon assets in enterprises from an industrial perspective. Based on previous work in this field, this method establishes improved carbon capture and storage costs from industrial applications as the basis for asset evaluation. Discussed key challenges and factors that have a significant impact on cost assessment results, but are often overlooked or not fully addressed. This includes cost indicators, energy supply, transformation costs, carbon dioxide transportation and storage, and the maturity of capture technologies. If possible, provide examples to illustrate the quantitative impact and complete the assessment of corporate carbon assets, but the scope of the research is small and there are certain limitations. Liu et al. (2021) studied the valuation of options of enterprise carbon assets and its evaluation method in the digital value of carbon assets. The study of this method points out that carbon emission quotas are intended to limit the carbon emissions of enterprises, but some unforeseeable variables may lead to unpredictable demand. With the high volatility of carbon price dynamics, the management of carbon assets is of great significance and difficulty for enterprises with high carbon consumption. In order to address the demand and price uncertainty of carbon emission rights, carbon derivatives provide a feasible solution for these enterprises. The options of carbon assets are evaluated through the Geometric Brownian motion model with state switching. Based on the value estimation and analysis of carbon options, the carbon assets are estimated through the quantitative results of Valuation of options and digital detection during operation. The proposed method is applicable and can optimise the risk control of carbon consuming enterprises. However, the evaluation process of this method is relatively complex, and there is a lack of applicability in the evaluation of carbon assets in general enterprises, which requires further optimisation and improvement. Tao et al. (2021) used the fuzzy matter-element model and entropy weighted TOPSIS method to evaluate the value of corporate carbon assets. This method establishes a TOPSIS evaluation index system based on fuzzy matter element model for the entropy weight of internal control quality of carbon assets in enterprises. Firstly, a composite fuzzy matter-element model was established based on fuzzy matter-element theory. Secondly, the entropy weight method is used to determine the weight of evaluation indicators. Thirdly, the concept of relative closeness was proposed by comparing it with the positive ideal index and the negative ideal index. Finally, the TOPSIS method was used to measure the carbon assets of enterprises. This method is relatively convenient and simple in achieving the evaluation of enterprise carbon assets, and has achieved certain results.

On the basis of existing methods, in order to enhance the effectiveness of evaluation, this article proposes the design of an enterprise carbon asset value evaluation method based on the analytic hierarchy process (AHP) and grey correlation method in the context of carbon neutrality. This method mainly carries out double screening of indicators to clarify the relative importance of indicators, speed up the evaluation efficiency, and avoid the evaluation results caused by too many indicators. Moreover, dimensionless processing is carried out on the set of influencing factors to eliminate the dimensional difference between the indicators and improve the comparability of the evaluation results. Grey correlation method is used to determine the correlation coefficient and correlation degree of enterprise carbon asset value evaluation indicators. In order to ensure the accuracy of evaluation results, the AHP is introduced to improve the grey correlation method, and the correlation degree is used as the weight measure to conduct consistency test, so as to make the evaluation results more credible. After that, the importance of the weight coefficients were sorted, and an evaluation model of AHP – grey correlation method was constructed to achieve accurate assessment of the value of corporate carbon assets. The specific implementation steps of the method are described as follows:

Step 1 Based on the different forms of enterprise carbon assets, determine the intangible asset evaluation indicators in the enterprise carbon asset value evaluation indicators, and determine the tangible asset evaluation indicators in the enterprise carbon asset value evaluation indicators according to the different sources of enterprise carbon assets. Complete the construction of the enterprise carbon asset value evaluation indicator system under the background of carbon neutrality.

Step 2 Based on the index system constructed above, in order to avoid the impact of invalid indicators on the evaluation results, ensure the effectiveness of the evaluation results, and reduce the difficulty of enterprise carbon asset value evaluation under the background of carbon neutrality, regression calculation is used to screen the key evaluation indicators. Then, in order to ensure the objectivity of the subsequent evaluation results, the information gain of each indicator is calculated, the information content of different indicators is determined, the weight of indicators is calculated, and the quantitative processing of each key indicator is complete.

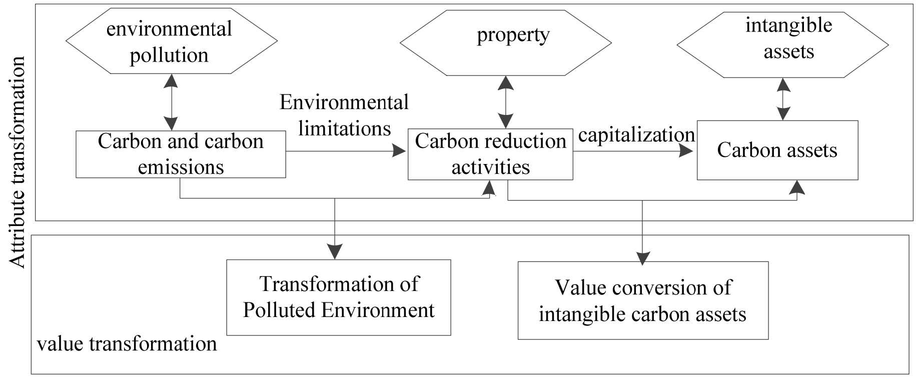
Step 3 In order to further improve the effectiveness of the subsequent evaluation results and speed up the evaluation efficiency, the key indicators that have the most influence on the value of carbon assets of enterprises are determined based on the calculated weight results to clarify the relative importance of the indicators. Then dimensionless processing is carried out on the set of influencing factors to eliminate the dimensional difference between the indicators. Then, grey correlation method is used to determine the correlation coefficient and correlation degree of enterprise carbon asset value evaluation index, so as to provide an important basis for subsequent evaluation. In order to ensure the accuracy of the evaluation results, the AHP is introduced to improve the grey correlation method, and the correlation degree is used as the weight measure to carry out the consistency test, so as to make the evaluation results more credible. After that, the importance of the weight coefficient is sorted, and the evaluation model of AHP and grey correlation method is constructed to realise the value evaluation of enterprise carbon assets.

2 Design of analytic hierarchy process and grey correlation method for evaluating the value of carbon assets in enterprises under the background of carbon neutrality

2.1 Construction of an evaluation index system for carbon asset value of enterprises under the background of carbon neutrality

In order to reflect the real value of carbon assets, the design of evaluation index system should fully consider the characteristics and sources of carbon assets of enterprises, and determine the evaluation index of different types of assets. The characteristics and sources of corporate carbon assets are as follows: carbon assets include intangible assets (such as carbon emission rights, carbon emission reduction project income, etc.) and tangible assets (such as energy equipment, emission control devices, etc.). Therefore, based on this, the evaluation indexes of carbon assets are mainly divided into intangible assets and tangible assets, and the two categories of assets are classified and studied to build an enterprise carbon asset value evaluation index system. The intangible assets in the evaluation indicators of enterprise carbon asset value mainly include: value conversion from carbon to carbon emission reduction activities under environmental constraints, capitalisation of carbon emission reduction activities, and intangible carbon assets (Liu et al., 2022a). The specific intangible asset evaluation indicators are shown in Figure 1.

Figure 1 Schematic diagram of intangible asset indicators for enterprise carbon asset value evaluation



Among them, the value conversion from carbon to carbon reduction activities under environmental requirements is achieved through the exchange of carbon generated by products and carbon in intermediate links (Zhu et al., 2022). The capitalisation of carbon emission reduction activities is to analyse the reasons for the capitalisation of carbon emission reduction activities and study how it occurs during this process, as shown in Figure 2.

Figure 2 Schematic diagram of the capitalisation process of carbon reduction activities

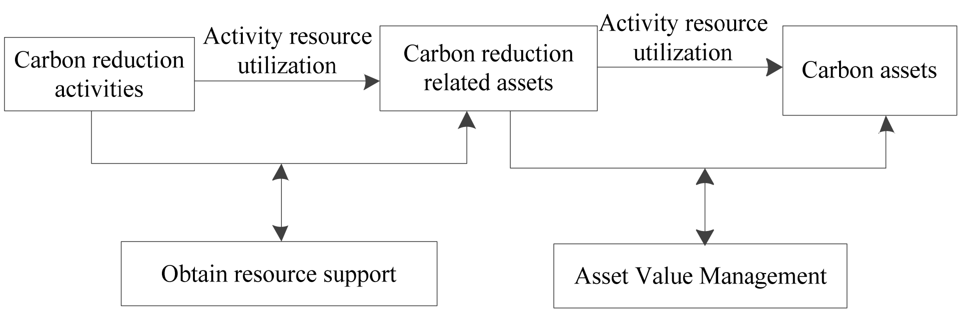


Table 1 Evaluation index system for tangible assets of enterprise carbon asset value

Classification criteria	*Index*
Revenue channels	Carbon emission trading basic products
Source channel	Carbon finance products
Classification criteria	Social effect carbon products
Revenue channels	Government issued carbon assets
	Carbon assets related to emission reduction projects
	Financial market carbon assets

Based on the above analysis of the intangible assets of the enterprise's carbon asset value, the tangible assets of the asset value are further determined. Tangible assets are the asset value reflected based on physical assets (Liu et al., 2021), and the specific physical asset values are shown in Table 1.

As shown in Table 1, it can be seen that tangible asset evaluation indicators for carbon asset value are divided according to different income channels and sources (Niu et al., 2021), completing the construction of an enterprise carbon asset value evaluation indicator system under the background of carbon neutrality.

2.2 Selection of evaluation indicators for carbon asset value of enterprises under the background of carbon neutrality

Due to the large amount of value evaluation index data in the carbon neutral background of enterprise carbon asset value evaluation index system constructed above, it is not possible to evaluate all indicators of this scale, which will render the evaluation results invalid and affect the evaluation efficiency of the evaluation algorithm (Hong and Lin, 2022). Therefore, in order to reduce the difficulty of evaluating the carbon asset value of enterprises in the context of carbon neutrality, this article screens key evaluation indicators in this chapter to improve the performance of enterprise carbon asset value evaluation in the context of carbon neutrality (Blay-Armah et al., 2022). In the screening of carbon asset value evaluation indicators for enterprises in the context of carbon neutrality, these indicators are all from the indicator system constructed above.

The indicators for evaluating the value of carbon assets in enterprises include the following:

1 Carbon emission right price indicator: this indicator is regarded as an explanatory variable through its impact on the price of corporate carbon emissions trading, and as a proxy variable of carbon asset value. The indicator is expressed in the form of:

$$c_i = \sum_{i=1}^{n} (c_0 + c_1 - c_3) / h \tag{1}$$

In equation (1), c_i represents the price of carbon emissions rights, c_0 represents the initial capital of carbon emissions rights, c_1 represents the changing capital during the issuance process of carbon emissions rights, and c_3 represents the interference term in the conversion of carbon emissions rights.

2 Carbon quota total indicator: At present, the estimation of carbon emissions in the value of corporate carbon assets is crucial, and the estimation of this indicator can effectively carry out subsequent estimates. The expression of this indicator is:

$$E_t = q_f E_f + q_m E_m + q_n E_n \tag{2}$$

In equation (2), E_t represents the carbon emissions of the enterprise, q_f represents the required amount of coal consumption, E_f represents the conversion coefficient of coal consumption, E_m represents the required amount of natural gas consumption, q_m represents the conversion coefficient of oil consumption, q_n represents the standard amount of other fuel consumption, and E_n represents the general conversion coefficient of other fuel consumption.

3 Environmental climate indicators: in the enterprise carbon asset value indicators, the current environment is measured by the environmental Air quality index, and the AQI index (Li et al., 2021) is introduced as the expression of this indicator. The expression formula of this index is:

$$AQI(x) = \frac{1}{m}\sqrt{(s - s_i)^2} \Big/ s_i \tag{3}$$

In equation (3), m represents the number of air quality measurements, s represents the gas concentration value in air quality, and s_i represents the impurity content in air.

4 Carbon asset industrial structure indicator: This indicator is generally analysed based on the industrial structure of the enterprise, and the proportion of this asset indicator in the industrial structure reflects the criticality of the enterprise's carbon assets. To some extent, it reflects the demand for carbon assets in terms of corporate carbon emissions and can be evaluated from the overall impact of the quota (Fu, 2021). The manifestation of this indicator is:

$$\delta i = \prod_{i=1}^{n} di \Big/ c_i \sum E_t \tag{4}$$

In equation (4), δ_i represents the carbon asset quota of the enterprise's industrial structure, and d_i represents the proportion of carbon assets in the entire industrial structure.

In order to determine whether the above determined evaluation index data can be used as the content of this evaluation, regression analysis was conducted on the above indicators to determine the data optimality (Huang et al., 2021). The macro evaluation index screening results after regression were expressed as:

$$v_i = (\beta_0) \Big/ \sum_{i=1}^{n} (c_i, E_t, AQI(x)) \int \beta_i \tag{5}$$

In equation (5), v_i represents the screening results of the macro evaluation indicators after regression, β_0 represents the minimum square error of the macro evaluation indicators, and β_i represents the minimum regression coefficient of the macro evaluation indicators.

According to the above screening of enterprise carbon asset value evaluation indicators, the information content dimension included in different indicators also varies in measuring the key degree of the indicator (Sun et al., 2022). Therefore, this article determines the amount of information in different indicators by calculating the information gain of the evaluation value indicators. The information gain result of the evaluation indicators is:

$$INTO(X) = \sum_{X=1}^{N} U_i log_2 U_i \tag{6}$$

In equation (6), $S(X)$ represents the information gain value of different value evaluation indicators, and U_i represents the proportion of information content in ii the first evaluation indicator.

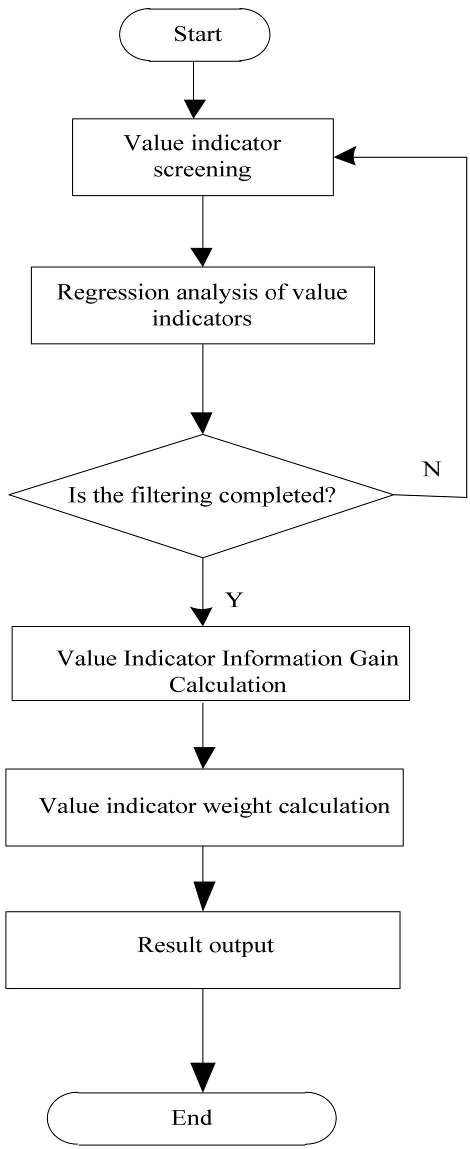
Based on the amount of information contained in the enterprise carbon asset value evaluation indicators, further weight calculation can be carried out to determine the order of evaluation indicators in the evaluation (Li, 2021), reducing the complexity of the evaluation. The weight calculation result is:

$$H_i = m \sum_{i=1}^{n} U_i \left(\frac{R_i}{R_j} \right) \tag{7}$$

In equation (7), H_i represents the weight result of the indicator, m represents the number of indicators, R_i represents the key information value of the indicator, and R_j represents the key degree factor of the indicator.

The screening process of enterprise carbon asset value evaluation indicators under the background of carbon neutrality is shown in Figure 3.

Figure 3 Schematic diagram of the screening process for enterprise carbon asset value evaluation indicators under the background of carbon neutrality



In the screening of carbon asset value evaluation indicators for enterprises under the background of carbon neutrality, regression calculation of value evaluation indicators is used to determine the carbon emission rights price, total carbon quota, environmental climate, and carbon asset industry structure indicators. The information gain is calculated to determine the information content of different indicators, and the index weight is calculated. The asset value evaluation indicator screening process is designed to achieve the screening of carbon asset value evaluation indicators for enterprises under the background of carbon neutrality.

2.3 Implementation of analytic hierarchy process and grey correlation method for evaluating the value of carbon assets in enterprises under the background of carbon neutrality

Based on the selected enterprise carbon asset value evaluation indicators mentioned above, this article adopts the AHP grey correlation method to design an evaluation algorithm. The essence of this algorithm is an algorithm that determines the geometric relationships between research objects based on time series (Xu et al., 2021). This algorithm describes the significant correlation between the grey correlation factor and the curve of the research object over time. It can describe the trend of future development and changes, avoid the influence of human subjective factors, and reduce evaluation errors. However, Gray correlation method may not accurately capture the complex relationship between indicators when evaluating correlation. Therefore, in order to ensure the accuracy of evaluation results, the AHP is introduced to improve the gray correlation method, and the correlation degree obtained by it is used as a weight measure to conduct consistency test on it, so as to make the evaluation results more credible and effectively improve the reliability of evaluation results. The general steps for the implementation of this algorithm are: first, the determination of the influencing factor set, which is the time series data of the relevant factors that affect the evaluation objectives determined when using the algorithm. Then, it involves dimensionless processing of research data to eliminate differences between research objects. Then, the correlation coefficient and correlation degree are determined, the AHP is introduced to improve the grey correlation method, and the correlation degree obtained by it is used as the weight measure to carry out the consistency test, so as to ensure the reasonable consistency and reliability of the weights and improve the reliability of the evaluation results. Finally, the importance of the tested weight coefficients is sorted, and the evaluation model of AHP and grey correlation method is constructed to realise the value evaluation of enterprise carbon assets (Zhu et al., 2021). Based on this principle, this article designs an enterprise carbon asset value evaluation algorithm using AHP and grey correlation method in the context of carbon neutrality. The specific implementation process is as follows:

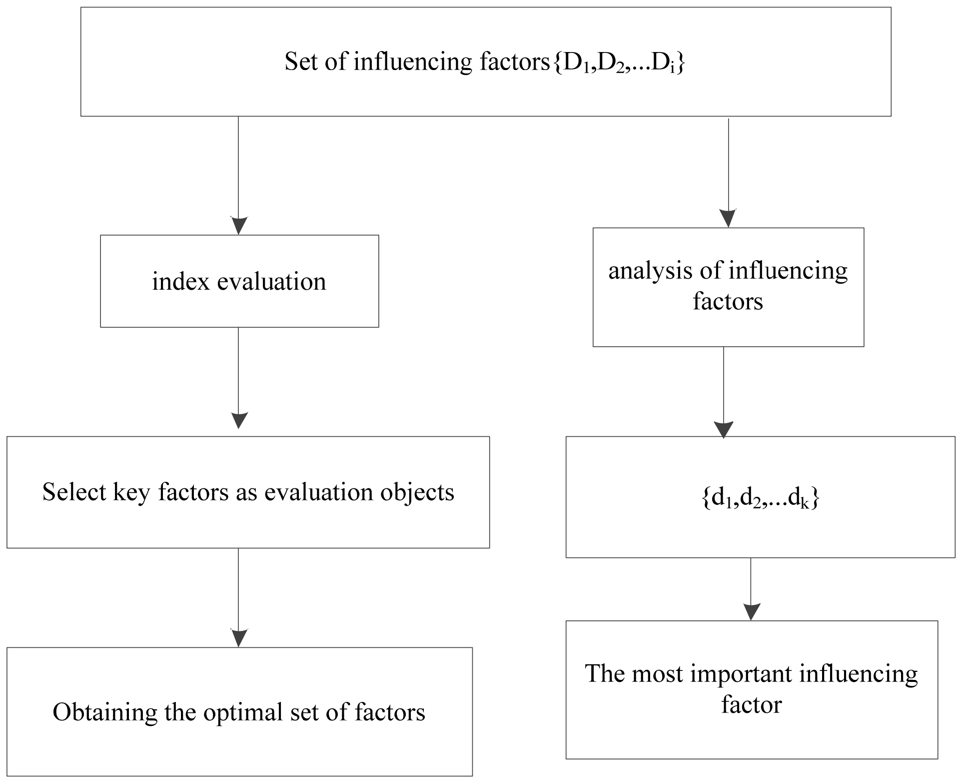
Firstly, the determination of the influencing factor set. On the basis of the above content, in order to further improve the effectiveness of the subsequent evaluation results and speed up the evaluation efficiency, the key indicators that have the most influence on the value of carbon assets of enterprises are determined based on the weight results of the calculation, so as to clarify the relative importance of indicators and avoid excessive indicators leading to miscellaneous and inaccurate evaluation results. Therefore, according to this process, the key indicators for evaluating the value of carbon assets in enterprises are selected as the research object, and the evaluation model of this indicator can be expressed as:

There are n key indicators $\{D_1, D_2, \ldots D_i\}(i = 1, 2, \ldots n)$ for evaluating the value of carbon assets, with each indicator D_i containing:

$$D_i = \{d_1, d_2, ...d_k\} \quad (8)$$

In equation (8), d_k represents k key evaluation indicator data. Select certain key indicators from D_i to form a rating set, and select data from multiple indicator systems to determine the influencing factor set. The process is shown in Figure 4.

Figure 4 Process for determining the set of influencing factors for evaluating the value of carbon assets in enterprises



Considering the correlation and lag effect between the influencing factors and the carbon assets of enterprises, the long-time series data will be more helpful to provide comprehensive and accurate assessment results. Therefore, based on the above analysis, the determined set of influencing factors for evaluating the value of corporate carbon assets can assume a reference data sequence, namely:

$$\{X_i\} = \{X_i(1), \ldots X_i(n) i = 1, 2, ..m\} \quad (9)$$

In equation (9), $\{X_i\}$ represents the determined set of influencing factors for the evaluation of carbon asset value of enterprises, and m represents the number of data comparison sequences.

Then, dimensionless processing is carried out on the set of influencing factors for enterprise carbon asset value assessment to unify the units and orders of magnitude of different indicators, eliminate the dimensional differences between indicators, and enable them to be compared and weighed on the same scale. In this process, in order to reduce the impact of different indicators on carbon asset value evaluation for different enterprises, the above-mentioned set of influencing factors is studied in different dimensions of data, which can avoid the impact of data with greatly different magnitudes. Implement using positive indicator dimensions. The sequence of setting the evaluation indicators for carbon asset value of enterprises is:

$$\begin{cases} X_1 = \left(x_1(1), x_1(2), \ldots x_1(n)\right) \\ X_m = \left(x_m(1), x_m(2), \ldots x_m(n)\right) \end{cases} \tag{10}$$

According to the above determined sequence, obtain the difference sequence of the dimensioned indicator set, namely:

$$\Delta(k) = \left| x_0'(k) - x_m(k) \right|, k = 1, 2, \ldots n \tag{11}$$

In equation (11), $\Delta(k)$ represents the difference sequence of the dimensioned index set, $x_0'(k)$ represents the initial range value, and $x_m(k)$ represents the maximum range value.

Then, the grey correlation method is used to determine the correlation coefficient and correlation degree of the enterprise carbon asset value evaluation index, which provides an important basis for the subsequent evaluation. The correlation coefficient of the enterprise carbon asset value evaluation index using the grey correlation method in the context of carbon neutrality is expressed as:

$$G_i(k) = \frac{\Delta x_0'(k) + \vartheta \Delta x_m(k)}{\Delta(k) + \vartheta \Delta x_m(k)} \tag{12}$$

In equation (12), $G_i(k)$ represents the correlation coefficient of the enterprise's carbon asset value evaluation index, and ϑ represents the resolution coefficient.

According to the correlation coefficient of enterprise carbon asset value evaluation indicators, the calculation of correlation degree is obtained as follows:

$$\gamma(x) = \frac{1}{n} \sum_{i=1}^{n} G_i(k) \tag{13}$$

In equation (13), $\gamma(x)$ represents the correlation between asset value evaluation indicators.

Because the grey correlation method mainly calculates the correlation degree between the indicators according to the data difference and development trend, its calculation method does not take into account the internal correlation and causality between the indicators. As a result, it may not be possible to accurately capture the complex relationships between indicators when evaluating correlations. AHP can divide a complex decision problem into a multi-level structure, and order and summarise the influencing factors. In this way, the problem can be more clearly decomposed into different levels of factors, and the relationship, weight and influence degree of factors can be established step by step. Through the hierarchical way of thinking, the relationship and importance between various factors can be considered and compared more comprehensively, so as to accurately capture the complex relationship between indicators and improve the effectiveness and credibility of the evaluation results. Therefore, in this regard, the AHP is selected to improve the grey correlation method, conduct consistency test on it, and assist the grey correlation method to solve the situation of sparse or incomplete data, so as to make the evaluation results more credible, so as to realise the value assessment of enterprise carbon assets.

Next, the correlation degree $\gamma(x)$ of the above enterprise carbon asset value evaluation indicators as a measure of weight. Indicators with higher correlation can be considered as more important indicators, while indicators with lower correlation may have smaller weights. Using the method of numerical transformation, convert the correlation coefficient into weight values within the range of [0, 1], and the expression is as follows:

$$Wi = \frac{\gamma(x)_i}{\max(\gamma(x) - \min(\gamma(x)))} \tag{14}$$

In equation (14), W_i represents the weight of indicator i, $\gamma(x)_i$ represents the correlation degree of indicator i, $\max(\gamma(x))$ represents the maximum value of the correlation coefficient, and $\min(\gamma(x))$ represents the minimum value of the correlation coefficient.

Based on the weight values obtained above, construct a weight matrix with the following expression:

$$W = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1j} \\ w_{21} & w_{22} & \cdots & w_{2j} \\ \vdots & \vdots & \cdots & \vdots \\ w_{i1} & w_{i2} & \cdots & w_{ij} \end{bmatrix} \tag{15}$$

In equation (15), w_{ij} represents the weight value of indicator i relative to indicator j.

To ensure that the weights have reasonable consistency and credibility, consistency ratio (CR) is calculated for weight consistency testing. CR evaluates the consistency of the weight matrix by comparing the actual consistency index with the random consistency index. If CR is less than a predetermined threshold (usually taken as 0.1), then the weight matrix is considered to have reasonable consistency, expressed as:

$$CR = CI / RI \tag{16}$$

$$CI = (\lambda \max - n) / (n - 1) \tag{17}$$

In equation (17), λmax represents the value of the maximum feature root, and n represents the dimension of the weight matrix.

Rank the importance of the obtained weight coefficients, and the enterprise carbon asset value evaluation model based on AHP grey correlation method is represented as:

$$v_i(k) = \sigma \sum \frac{\max W_i - W_i}{\max W_i - \min W_i} / \gamma(x) \tag{18}$$

In equation (18), $v_i(k)$ represents the output of the enterprise's carbon asset value evaluation, and σ represents the descending factor of indicator correlation.

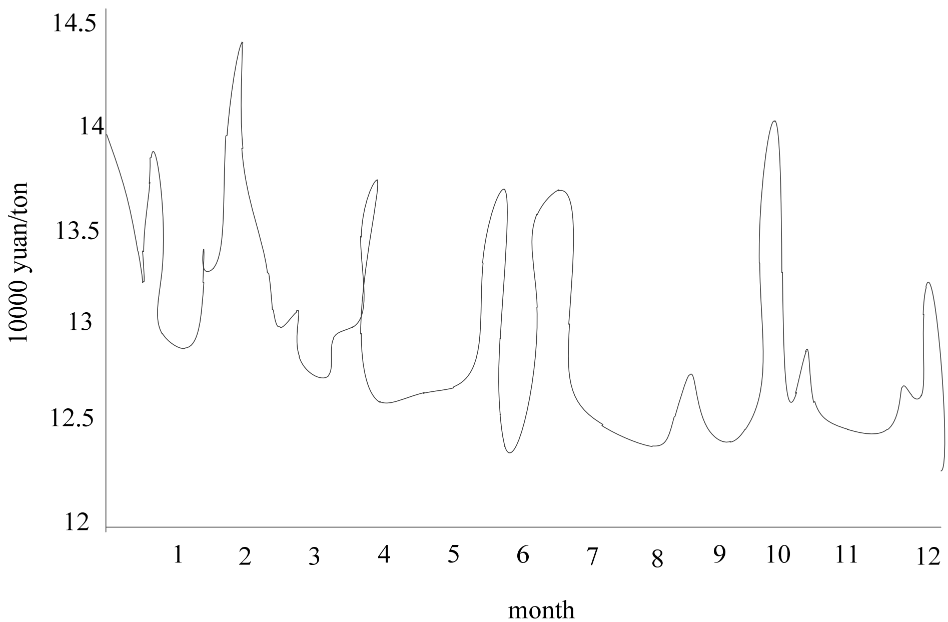
Based on the above steps, complete the hierarchical analysis grey correlation method for evaluating the value of corporate carbon assets in the context of carbon neutrality.

3 Experiment

3.1 Experimental plan design

In order to verify the feasibility of the proposed evaluation algorithm, this experimental analysis was designed. In this experiment, a local power company was selected as the research object, and the carbon asset value of the power company was used as the research object. The enterprise trades assets on a certain carbon emission exchange and has filed a project for two years. Its carbon reduction emissions meet the standards. The company adheres to low-carbon consumption and continuously develops carbon development and emission reduction projects, and conducts value evaluation based on historical and real-time data as the research object. The agreed price for the carbon assets of the enterprise is 125,000 Yuan/ton, with a transaction volume of approximately 10,000 tons. The risk-free rate of the enterprise's carbon assets selects the yield of treasury bond of the past two years, and collects five treasury bond overdue for nearly two years. The price change of the carbon assets within one year is shown in Figure 5.

Figure 5 Schematic diagram of price changes in carbon assets of sample enterprises within one year



Evaluate the asset value based on the price changes of carbon assets of the sample enterprise within one year, mainly evaluating the sensitivity coefficient of the volatility of carbon asset value of the sample enterprise. When the volatility of carbon asset price of the sample enterprise is large, analyse the sensitivity coefficient of the volatility of carbon asset value of the enterprise. The closer the sensitivity coefficient is to 1, the better the representative effect. On the basis of this analysis, in order to highlight the feasibility of the proposed method, it is necessary to further analyse the evaluation error of the enterprise carbon asset value evaluation using the AHP grey correlation method in the context of carbon neutrality. The smaller the error value, the better the feasibility of the method.

The experimental analysis in this article adopts a comparative approach, and the three methods for comparison are: method in this paper, method of Roussanaly et al. (2021), and method of Liu et al. (2021). In order to ensure the feasibility of the experimental data, the data obtained from the experiment was statistically analysed using SPSS 10.0, and the consistency of the experimental environment and background was ensured.

3.2 Experimental results

The experiment used method in this paper, method of Roussanaly et al. (2021) and method of Liu et al. (2021) to analyse the sensitivity coefficients of the volatility of carbon asset values in sample enterprises. Three methods were used to observe the changes in the sensitivity coefficients of the volatility within the [–50% –50%] range of sample carbon asset prices during the observation period. The results are shown in Table 2.

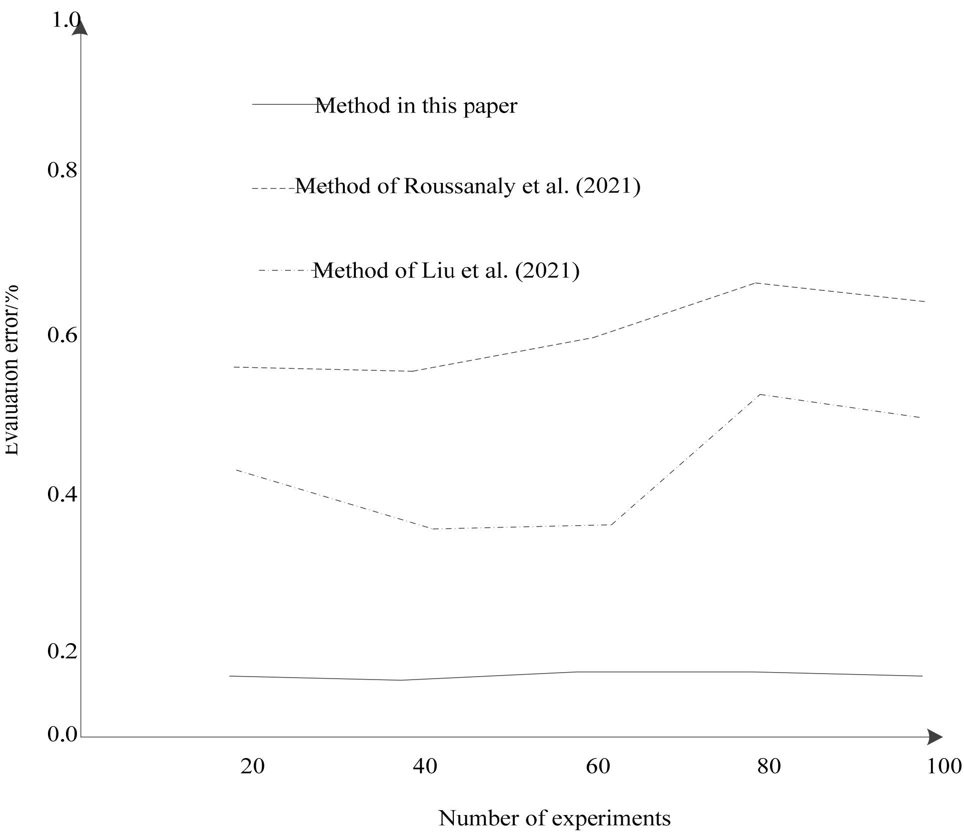
Table 2 Sensitivity coefficient of volatility of enterprise carbon asset value

Asset value volatility/%	*Method in this paper*	*Method of Roussanaly et al. (2021)*	*Method of Liu et al. (2021)*
–50	0.95	0.91	0.91
–45	0.94	0.91	0.89
–35	0.96	0.90	0.89
–30	0.95	0.91	0.87
–25	0.95	0.91	0.85
–20	0.97	0.90	0.89
–15	0.95	0.91	0.89
–10	0.95	0.89	0.89
–5	0.98	0.89	0.89
5	0.99	0.91	0.85
10	0.99	0.90	0.86
15	0.96	0.91	0.84
20	0.98	0.87	0.86
25	0.96	0.87	0.86
30	0.98	0.85	0.85
35	0.96	0.91	0.84
40	0.98	0.89	0.86
45	0.95	0.91	0.86
50	0.97	0.88	0.85

According to the analysis of the test results in Table 2, it can be seen that the sensitivity coefficients for the volatility of carbon asset values of the sample enterprises were maintained at a high level using Method in this paper, method of Roussany et al. (2021) and method of Liu et al. (2021). Although the sensitivity coefficients of method of Roussany et al. (2021) and method of Liu et al. (2021) are relatively high, compared to method in this paper, it can be seen that the sensitivity coefficient of method in this paper is higher, with a maximum of 0.99, indicating that changes in the price of carbon assets in enterprise valuation are more sensitive to them, verifying the feasibility of this method. This is because the proposed method adopts regression calculation to screen the key evaluation indicators and further determine the key indicators that have the most influence on the value of carbon assets of enterprises to clarify the relative importance of the indicators, thus improving the sensitivity of the proposed method to price changes and making it have a high sensitivity coefficient of the volatility of the value of carbon assets of enterprises.

The experiment further used Method in this paper, method of Roussanaly et al. (2021) and method of Liu et al. (2021) to analyse the error values of carbon asset value evaluation of sample enterprises. The lower the value, the more ideal the evaluation results are. The results obtained are shown in Figure 6.

Figure 6 Error results of enterprise carbon asset value evaluation



Analysing the test results in Figure 6, it can be seen that there are certain differences in the error values of the carbon asset valuation of the sample enterprises analysed by method in this paper, method of Roussany et al. (2021) and method of Liu et al. (2021). From the curve trend analysis in the figure, it can be seen that the error of method in this paper in evaluating the carbon asset value of sample enterprises has always been less than 0.2%, while the error values of the other two methods have significant fluctuations and are consistently higher than the proposed method. This is because the method in this paper screens key indicators before evaluation, identifies the key indicators that have the most influence on the value of carbon assets of enterprises, and carries out dimensionless processing on them to eliminate dimensional differences between indicators. In addition, grey correlation method is used to determine the correlation coefficient and correlation degree of the enterprise carbon asset value evaluation index. In order to ensure the accuracy of the evaluation results, the AHP is introduced to improve the grey correlation method, and the correlation degree is used as the weight measure to conduct consistency test, so as to make the evaluation results more credible. Therefore, the performance of this method is improved, the evaluation result is more accurate, and the evaluation error is reduced.

4 Conclusions

The evaluation of the carbon asset value of enterprises in the context of carbon neutrality plays a crucial guiding role in the sustainable development of the entire society. Therefore, this article proposes an AHP grey correlation method for evaluating the value of corporate carbon assets in the context of carbon neutrality. By determining the intangible asset evaluation indicators and tangible asset evaluation indicators in the enterprise carbon asset value evaluation indicators, the indicator system construction is completed. And through regression calculation of value evaluation indicators, determine the price of carbon emissions rights, total carbon quota, environmental climate, and carbon asset industry structure indicators, calculate information gain to determine the information content of different indicators, calculate indicator weights, and design a process for screening asset value evaluation indicators to achieve value evaluation indicator screening. Based on this, the correlation coefficient and magnitude of the indicators are determined, the asset value evaluation indicators are arranged in descending order, and a corporate carbon asset value evaluation model based on AHP grey correlation method is constructed to achieve value evaluation research. The feasibility of this evaluation method was verified through experiments.

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