

A Comparative Regional Study of Carbon Accounting Disclosure Based on the Fuzzy Comprehensive Evaluation Method--Taking the Eastern, Western, Southern, Northern and Central Regions as an Example

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Abstract. With the gradual development of corporate ESG investment concepts, it is becoming increasingly clear that exploring carbon accounting disclosure can contribute to the promotion of low-carbon economic development. In view of this, this study divides the country into five regions: east, west, south, north and central, firstly constructs three-level indicators affecting the disclosure of carbon accounting information, then assigns weights to the indicators using hierarchical analysis, and finally uses the fuzzy comprehensive evaluation method to score the overall level of disclosure in the five regions, and identifies that the central region has the highest scores, the western region, the southern region, and the northern region have medium scores, and the eastern region has the lowest scores. It also identified that the central region has the highest score, the western region, the southern region and the northern region have the middle score, and the eastern region has the lowest score, and that factors such as enterprise size and annual carbon emissions of cities are important factors affecting carbon accounting information disclosure.

Keywords: Carbon accounting disclosure, Fuzzy comprehensive evaluation method, Hierarchical analysis, Influencing factors, Low carbon economy.

1. Introduction

President Xi Jinping 2022 pointed out during the two sessions that "achieving the 'dual carbon' goal is a broad and profound change, as well as a long-term task", and since the 18th CPC National Congress China has made remarkable achievements in the construction of ecological civilization, but China's ecological environmental protection China has made remarkable achievements in the construction of ecological civilization since the 18th CPC National Congress, but China's ecological environmental protection is still facing serious problems, and there is a long way to go to achieve the goal of carbon peak carbon neutral. China's enterprises as a whole still lack the importance of carbon accounting information disclosure, 2022 only 80 listed companies in the annual report mentioned the environmental information disclosure content, while only 7 formed an independent environmental report, the level of information disclosure between enterprises varies greatly. In addition to voluntary disclosure by enterprises, the number of enterprises disclosing through participation in the environmental information questionnaire issued by the non-profit organization CDP (Carbon Disclosure Project) has increased significantly, with 2,723 companies answering the CDP's climate change questionnaire in 2022, an increase of 75% compared to 2020, but overall, the number of voluntary or mandatory carbon-accounting information However, overall, the number of listed companies that voluntarily or mandatorily disclose carbon accounting information still reaches less than 50%. The contradiction between the high demand of the government and the market on the level of carbon accounting disclosure and the incomplete and insufficient disclosure by enterprises needs to be solved urgently, so the research on carbon accounting disclosure is of great significance in promoting the sustainable development of enterprises and helping the government to supervise.

Based on this current contradiction, focusing on the current situation of carbon accounting information disclosure of listed companies in the Chinese market, the country was divided into five regions: east, west, south, north and central, and the data of carbon accounting information disclosure

of listed companies within the region from 2015 to 2022 were dimensionless, and 17 indicators such as enterprise scale, marketization degree, and shareholding concentration were constructed, and the hierarchical analysis was used to construct the weighting model of factors influencing the level of carbon accounting information disclosure level using hierarchical analysis to construct the weighting model of the factors influencing the level of carbon accounting information disclosure. And the fuzzy comprehensive evaluation method was used to quantitatively score the carbon accounting information disclosure level in five regions of China, with a view to providing differentiated and referable path revelation for listed companies.

2. Literature Review

2.1. Exploring the relationship between carbon accounting disclosure and corporate performance

Overseas research on carbon accounting information disclosure started relatively early, and in-depth investigations have been carried out in terms of disclosure methods, influencing factors, and the relationship with corporate performance, etc. Based on the perspective of resource-based enterprises, Alsaifi·K and Elnahass·M et al. (2020) have confirmed the positive correlation between voluntary carbon disclosure and corporate financial performance [1], while Abubakar·S and Akhtaruzzaman·M (2021) have conducted empirical analyses in different institutional contexts and obtained the conclusion that carbon disclosure has a positive impact on carbon performance [2]. Fereshteh·Mahmoudian et al. (2023) explored the impact of the details of the carbon disclosure process of firms on the cost of debt using a sample of North American firms in the report of the CDP project. The results show that firms help to reduce the cost of debt by providing detailed reports on carbon emission projects, while the reduction in the cost of debt facilitates firms to expand their investments in GHG emission reduction projects [3].

Domestic scholars are also concerned about the relationship between carbon accounting disclosure and corporate performance, Yang Xiaoshu (2022) selected the key industry of low-carbon transition, the electric power industry, through the construction of an empirical model to prove the positive relationship between carbon disclosure and financial performance [4]. Xu Wenjing et al. (2022) selected the heavy pollution industry through empirical research and found that the higher the quality of carbon information disclosure, the more obvious the enhancement of financial performance, and is positively affected by the marketization process [5]. Pang Jingyu (2023) selected iron and steel industry for empirical analysis and verified that improving the level of carbon disclosure quality helps to improve corporate performance, while the degree of environmental regulation plays a positive moderating role [6].

2.2. Analysis of factors affecting disclosure of carbon accounting information

Scholars at home and abroad have done a lot of empirical research on the influencing factors of carbon accounting disclosure, although the perspectives are different, foreign scholars pay more attention to the impact of audit level and policy environment on carbon accounting disclosure. Two scholars, Qian·W and Horisch·J (2018), through an empirical analysis of 114 large enterprises around the world, get the conclusion that auditing and bench-marking tools as well as control tools have a significant impact on carbon management and disclosure [7]. Chariri·A, Januarti·I et al. (2018) explore the impact of audit characteristics on carbon disclosure, and get the conclusion that several characteristics of audit committee are positively related to carbon accounting disclosure [8]. Mardini·GH and Lahyani·FE (2022) selected 67 non-financial listed companies in France and got the conclusion that foreign directors have a significant positive impact on both performance and disclosure level of carbon emissions [9].

Domestic scholars, on the other hand, are more likely to choose specific factors of internal management of enterprises in a certain industry to explore. Liu Yiping et al. (2018) innovatively introduced industry category in addition to traditional factors, confirming the positive correlation

between industry category, enterprise size and proportion of independent directors and carbon accounting disclosure level as well as the negative correlation between degree of indebtedness and carbon accounting disclosure level [10]. Yang Ruolin (2022) used a variety of statistical methods to obtain the positive correlation between the level of carbon accounting disclosure and the size of the company's auditing organization and earnings per share, and the negative correlation with the profitability of net assets [11]. Wang Yanlin et al. (2023) selected listed companies in the iron and steel sector as samples, and used a fixed effects model to obtain the positive correlation between the size of the company, the corporate governance structure, whether it is a pilot city for carbon trading, the economic level of the region to which it belongs and the level of carbon accounting disclosure, as well as the negative correlation between the gearing ratio and the level of carbon accounting disclosure [12].

2.3. Literature Review Commentary

The relationship between carbon accounting disclosure and corporate performance has been thoroughly studied by both domestic and foreign scholars. Foreign scholars mainly focus on the relationship between carbon disclosure and internal management factors such as corporate financial performance and debt cost. At the same time, they also focus on analyzing the impact of external factors such as audit level and policy environment on carbon accounting disclosure. In contrast, domestic scholars are more likely to choose specific factors of internal management of enterprises in a certain industry for research, such as industry category, enterprise scale, corporate governance structure, etc. Through the empirical study of specific industry samples, they obtained the positive and negative correlations between these factors and the level of carbon accounting disclosure, and verified the importance of the influencing factors on carbon accounting information disclosure.

However, there are several deficiencies in the research on carbon accounting disclosure: 2014-2015 is the peak year of carbon accounting research, and the existing research on influencing factors mostly adopts the data before 2015, which has lost its timeliness with the change of policies and the development of enterprises; most of the research on enterprises focuses on certain factors of corporate governance, and the model is relatively simple, and it only makes correlation research without judging the degree of influence of each factor; the analysis of the current situation is too general, mostly evaluating the disclosure level from the whole, while the classification focuses on the generality of an industry without evaluating from the geographical division. The research on enterprises mostly focuses on certain factors of corporate governance, the model is simple, and only makes correlation research without judging the degree of influence of each factor; the analysis of the current situation is too general, mostly evaluates the disclosure level as a whole, and the classification focuses on the general situation of an industry without evaluating the evaluation from the geographical division. In this paper, we select the data of listed companies other than those in the financial industry from 2015 to 2022 as samples, construct a model with 18 indicators and use hierarchical analysis to evaluate and assign weights to the influencing factors, and innovatively quantitatively rate the level of disclosure of carbon accounting information of national enterprises based on geographical divisions.

3. Construction of indicator weights

3.1. Initial screening of indicators and data sources

Through reviewing the existing domestic and foreign related literature, this paper summarizes the impact factors of carbon accounting disclosure studied by current scholars and introduces new variables, and constructs a total of 5 secondary indicators and 17 tertiary indicators, the construction of each indicator and the explanation of the indicators are shown in Table 1 below:

All of the above data are from the National Bureau of Statistics (data.stats.gov.cn), Cathay Pacific database (data.csmar.com), China Carbon Accounting Database (www.ceads.net.cn), City Statistical Annual Reports, Enterprise Annual Reports, and the years spanning January 1, 2015 to December 31, 2021 for the data.

Table 1. Indicators of factors influencing carbon accounting disclosure

First indicators	Secondary indicators	Tertiary indicators	Interpretation of indicators
Quality of carbon accounting disclosure	Company size	Total Assets (TA)	Total of each item of assets at the end of the year (RMB)
		Lerner Index (LI)	(Operating income - operating costs - selling expenses - administrative expenses) / Operating Income (%)
		Top Ten Holders Rate (THR)	Sum of shareholdings of the top ten largest shareholders of the Company (%)
	Company structure	Independent Director Ratio (IDR)	Number of independent directors / Size of directors (%)
		Board Size(BS)	Number of directors on the board of directors (persons)
		Management Shareholding (MS)	Number of shares held by directors and supervisors to total number of shares (%)
	Corporate performance	Nature Of Controlling Shareholders (NATURE)	Dummy variable 0: Non-state-owned enterprises 1: State-owned enterprises
		Earnings Per Share (EPS)	Net profit for the period / Paid-in capital at the end of the period (RMB)
		Return On Equity (ROE)	Average of net profit/Shareholders' equity (%)
	Status of assets	Operating Revenue Growth (ORG)	Operating income of the current year - operating income of the previous year / Operating income of the previous year (%)
		Tobin's Q-value (TQ)	Market capitalization / Total assets (%)
		Asset Liability Ratio (ALR)	Total liabilities / Total assets (%)
	Urban area	Fixed Assets Proportion (FAP)	Fixed Assets / Total Assets (%)
		Total Assets Turnover (TAT)	Operating Income / Total Assets (%)
		Gross Regional Product Of City (GDP)	Annual regional GDP (billion RMB)
	Urban area	Whether It Is A Carbon Trading Pilot City (PC)	Dummy variable 0: No 1: Yes
		Carbon Emission (CE)	Total annual carbon emissions of the city where the enterprise is located (tons)

3.2. Hierarchical analysis method to construct indicator weights

Hierarchical analysis is a quantitative method of analyzing complex multi-criteria decision-making problems by comparing the relative importance of different criteria through quantitative means. By

using hierarchical analysis, researchers can make accurate assessments and decisions for a systematic decision-making process. This method improves the science and rationality of research decisions and is of great help in complex research problems.

In this paper, hierarchical analysis is used to assess the weights of different influencing factors on the quality of carbon accounting disclosure, transforming qualitative subjective judgments into quantitative quantitative assessments, and determining the relative importance of each influencing factor on the quality of carbon accounting disclosure. Through the use of hierarchical analysis, this paper decomposes the decision-making problem into multiple sub-problems, and assesses and compares multiple tertiary indicators included under the secondary indicators layer by layer, so as to derive the influence of different factors, which makes the analysis process more systematic.

3.2.1. Establishment of a hierarchical analysis model

As shown in Figure 1.below, this paper constructs a hierarchical structural analysis model containing five secondary indicators: company size, company structure, company performance, asset status, and city geography; and seventeen tertiary indicators: total assets, degree of marketization, shareholding concentration, percentage of independent directors, size of the board of directors, percentage of shares held by the management, whether or not the company is a state-owned enterprise, rate of return on earnings per share, rate of return on net assets, rate of growth of operating income, value of investment, asset-liability ratio, percentage of fixed assets, turnover rate of total assets, regional GDP, whether or not it is a pilot city for carbon trading, and the annual carbon emissions of the city.

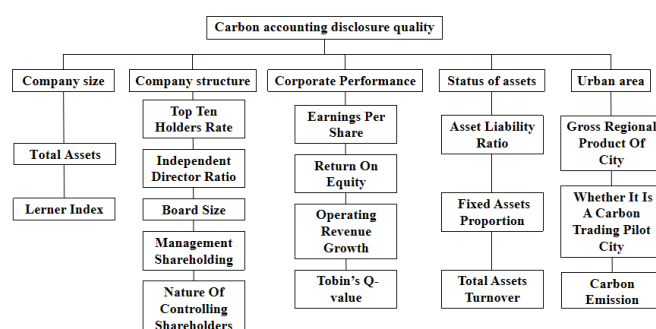


Figure 1. Hierarchical analysis model of carbon accounting disclosure quality

3.2.2. Constructing judgment matrices

When using the hierarchical analysis method, it is necessary to compare the elements in each layer two by two, this process needs to construct a judgment matrix to realize, the value of the judgment matrix represents the value of the relative importance between the factors in the matrix, this paper adopts the 9 score method to evaluate the elements of each level. The scale and meaning of the judgment matrix are shown in Table 2 below:

Table 2. Comparison of 9-point evaluation criteria scales and their meanings

Scale	Meaning
1	Indicates that the two factors are of equal importance compared to each other
3	Indicates that one factor is slightly more important than the other when compared to two factors
5	Indicates that one is significantly more important than the other when comparing two factors
7	Indicates that one factor is more strongly important than the other when compared to two factors
9	Indicates the extreme importance of two factors compared to one over the other
2, 4, 6, 8	denotes the median of the above two neighboring judgments
From the bottom	If factor i is compared with j to get the judgment B_{ij} , then factor j is compared with i to get the judgment $B_{ji}=1/B_{ij}$

3.2.3. Hierarchical single ordering and consistency test

Hierarchical ordering is an important step in hierarchical analysis, and hierarchical ordering refers to the ranking of the relative importance of different factors within each level. By comparing each factor two by two on a 9-point scale and then normalizing, the relative importance weights of the factors at this level can be obtained with respect to the factors at the previous level.

In order to eliminate the influence of subjectivity and uncertainty on the comparison results, a consistency test of the judgment matrices is required to ensure the credibility of the data. This process is usually realized by calculating the consistency index and comparing the consistency ratios. The formula for calculating the consistency index CI and consistency ratio CR is shown below:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

$$CR = \frac{CI}{RI} = \frac{\lambda_{\max} - n}{RI(n - 1)} \quad (2)$$

Where $\lambda_{\max}$ is the maximum eigenvalue of the judgment matrix.

The relationship between the stochastic consistency index RI used in the calculation and the judgment matrix order n is shown in Table 3 below.

Table 3. Relationship between judgment matrix order and stochastic consistency indicators

Determine the matrix order	1	2	3	4	5	6	7	8	9	10
Randomized consistency indicator	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The results of the hierarchical single sort are considered plausible only if the consistency ratio $CR < 0.1$, otherwise the values of the matrix elements need to be re-judged.

3.2.4. Hierarchical total ordering and consistency test

The hierarchical total ranking is based on the hierarchical single ranking, the relative importance of all factors at each level is compared to the top factor, and the weights of all factors at each level are determined from the highest level to the lowest level.

In addition to the consistency test for each judgment matrix in the hierarchical single sort, a combined consistency test needs to be performed on a level-by-level basis, again by calculating the combined consistency ratio for the plausibility test, and the results of the hierarchical total sort are considered to have a satisfactory consistency only if the combined consistency ratio, CR, is < 0.1 .

The formula for calculating the combined consistency ratio of layer p to layer 1 is shown below:

$$CR^{(p)} = CR^{(p-1)} + \frac{CI^{(p)}}{RI^{(p)}}, p = 3, 4, \dots, s \quad (3)$$

In this paper, $CR = 0.0038 < 0.1$ is calculated, so the result of the judgment is credible and the construction of hierarchical analysis is completed.

3.3. Indicator weighting table

Based on the construction of the above hierarchical analysis method indicator weights, this paper obtains the indicator weight scores as shown in Table 4 below:

Table 4. Weights of carbon accounting disclosure quality indicators obtained from hierarchical analysis method

First indicators	Secondary indicators	Weighting of secondary indicators	Tertiary indicators	Weighting of tertiary indicators
Quality of carbon accounting disclosure	Company size	0.1612	TA	0.1343
			LI	0.0269
			THR	0.0101
	Company structure	0.1612	IDR	0.0458
			BS	0.0138
			MS	0.0458
			NATURE	0.0458
	Corporate performance	0.0565	EPS	0.0294
			ROE	0.0044
			ORG	0.0114
			TQ	0.0114
			ALR	0.0691
	Status of assets	0.1612	FAP	0.023
			TAT	0.0691
			GDP	0.0657
	Urban area	0.4599	PC	0.1971
			CE	0.1971

3.4. Multiple linear regression to construct indicator weights

Multiple linear regression can analyze the relationship between multiple independent variables and a dependent variable, and regression coefficients and their significance can be obtained for each indicator through regression analysis. The regression coefficients reflect the degree of contribution of the independent variables to the dependent variable, and are used to assign corresponding weights to each indicator.

In this paper, we use Stata17.0, after doing Z-standardized treatment for each variable, we input the REGRESS statement to construct the overall value of the multiple linear regression, and get the output of Stata as shown in Table 5 below, and the weights of the carbon accounting disclosure quality indicators obtained are shown in Table 6:

Table 5. Multiple linear regression results

ZSCORE	Coefficient	Std.err.	t	P> t	Beta
PC	0.1667825	0.0393786	4.24	0.000	0.0831932
NATURE	0.0031735	0.0428776	2.56	0.041	0.0010069
ZGDP	0.1073788	0.026959	3.98	0.000	0.1073788
ZCE	-0.1193783	0.023501	-5.08	0.000	-0.1193783
ZTQ	-0.0159097	0.0146107	-2.09	0.076	-0.0159097
ZTHR	0.01451724	0.0139506	10.41	0.000	0.1451724
ZTA	0.2341326	0.0147976	15.82	0.000	0.2341326
ZEPS	0.0542422	0.0152656	3.55	0.025	0.0542422
ZROE	-0.0040037	0.0154204	-3.26	0.000	-0.0040037
ZIDR	0.0173034	0.0150269	2.15	0.004	0.0173034
ZLI	-0.0133742	0.0158936	-2.84	0.000	-0.0133742
ZMS	-0.0837916	0.0141487	-5.92	0.000	-0.0837916
ZORG	0.0056761	0.0130905	3.43	0.000	0.0056761
ZALR	0.0367751	0.0152249	2.42	0.016	0.0367751
ZBS	0.0507563	0.0153453	3.31	0.001	0.0507563
ZFAP	0.1636399	0.0141923	11.53	0.000	0.1636399
ZTAT	0.046663	0.0143146	3.12	0.002	0.0446663
_cons	-0.0778857	0.0229186	-3.40	0.001	.

The overall equation was obtained by multiple linear regression as shown below, with results retained to four decimal places:

$$Y=0.1668X_1+0.0032X_2+0.1074X_3-0.1194X_4-0.0159X_5+0.1452X_6+0.2341X_7+0.0542X_8-0.0040X_9+0.0173X_{10}-0.0134X_{11}-0.0838X_{12}+0.0057X_{13}+0.0368X_{14}+0.0508X_{15}+0.1636X_{16}+0.0447X_{17}-0.0779 \quad (4)$$

The indicator weight values are calculated by the following formula:

$$W_x = \frac{a_x}{\sum_{a_1}^{a_n} a_x} \quad (5)$$

Table 6. Table of weights of carbon accounting disclosure quality indicators obtained from multiple linear regression

First indicators	Secondary indicators	Tertiary indicators	Weighting of indicators
Quality of carbon accounting disclosure	Company size	TA	0.1742
		LI	0.0010
		THR	0.1080
	Company structure	IDR	0.0129
		BS	0.0378
		MS	0.0623
	Corporate Performance	NATURE	0.0024
		EPS	0.0404
		ROE	0.0030
		ORG	0.0042
		TQ	0.0118
		ALR	0.0274
	Status of assets	FAP	0.1218
		TAT	0.0332
		GDP	0.0799
	Urban area	PC	0.1241
		CE	0.0888

3.5. Arithmetic average method of constructing indicator weights

The final weight system can be obtained by arithmetic averaging the weights of the indicators obtained by comprehensive hierarchical analysis and multiple linear regression, and the final weights of the indicators obtained are shown in Table 7 below.

The formula for calculating the average indicator weights is shown below:

$$W_x = \frac{W_1 + W_2}{2} \quad (6)$$

Table 7. Table of weights of carbon accounting disclosure quality indicators obtained by arithmetic averaging method

First indicators	Secondary indicators	Tertiary indicators	Weighting of indicators	Arrange in order
Quality of carbon accounting disclosure	Company size	TA	0.1543	2
		LI	0.0140	14
		THR	0.0591	6
	Company structure	IDR	0.0294	11
		BS	0.0258	12
		MS	0.0541	7
	Corporate performance	NATURE	0.0241	13
		EPS	0.0349	10
		ROE	0.0037	17
		ORG	0.0078	16
		TQ	0.0116	15
		ALR	0.0483	9
	Status of assets	FAP	0.0724	5
		TAT	0.0512	8
		GDP	0.0728	4
	Urban area	PC	0.1606	1
		CE	0.1430	3

4. Fuzzy comprehensive evaluation method

4.1. Principles of Fuzzy Comprehensive Evaluation Method

4.1.1. Factor theory domains that define the object of the evaluation

In this paper, we first determine the factors of the carbon accounting disclosure evaluation object, there are seventeen indicators, denoted by u . The constructed factor thesis is shown below:

$$U = \{u_1, u_2, \dots, u_{17}\} \quad (7)$$

4.1.2. Determining the rubric level thesis field

This paper makes an evaluation of carbon accounting disclosure based on a number of metrics, the results of which are denoted by v . The resulting combination of evaluations becomes the set of rubrics V .

$$V = \{v_1, v_2, \dots, v_{17}\} \quad (8)$$

As described in 3.2.2 this paper uses a 9-point scale to compare the relative importance of the factors.

4.1.3. Determining the fuzzy relationship matrix

Determination of the fuzzy relationship matrix first needs to evaluate the single factor, single factor fuzzy evaluation is used to determine the degree of affiliation of each evaluation object to the evaluation set V . After constructing the hierarchical fuzzy subsets need to quantify carbon accounting disclosure from each factor one by one to determine the degree of affiliation of carbon accounting disclosure to each subset v from each factor u , to form a single-factor evaluation matrix r representing the fuzzy relationship between the factor set U and the evaluation set V , and then get the fuzzy relationship matrix R :

$$R = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{117} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{171} & r_{m2} & \cdots & r_{1717} \end{pmatrix} \quad (9)$$

Where r_{ij} ($i=1, 2, \dots, 17; j=1, 2, \dots, 17$) denotes the degree of affiliation of a certain evaluated object U_i to the fuzzy subset of V_j rank from the factor point of view.

4.1.4. Determination of fuzzy weight vectors for evaluation factors

In order to determine the importance of each factor in the evaluation system, it is necessary to assign the corresponding weights a_i ($i=1, 2, \dots, 17$) to each factor u to represent the weight of the factor, and the fuzzy set A , which the weights are combined into, is called the weight set, as shown in Table 6 above.

4.1.5. Multi-factor fuzzy evaluation

By synthesizing the fuzzy relationship matrix R with the weight vector A through the appropriate synthesis operator, the fuzzy comprehensive evaluation result vector of each evaluated object is obtained B . In the matrix R , the different rows reflect the degree of affiliation of each evaluated object to each fuzzy subset rank from the perspective of multiple single factors. By synthesizing the different rows using the fuzzy weight vector A , the degree of affiliation of each evaluated object to each fuzzy subset level from the overall perspective can be derived, and the fuzzy comprehensive evaluation result vector B is obtained:

$$B = A \bullet R = (a_1, a_2, \dots, a_m) \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} = (b_1, b_2, \dots, b_n) \quad (10)$$

Where b_j ($j=1, 2, \dots, 17$) is obtained from the j column operation of A and R , and represents the degree of affiliation of the rated object to the fuzzy subset of the V_j rating from the overall point of view.

4.2. Empirical analysis of fuzzy comprehensive evaluation method

Firstly, the whole country is divided into five regions: East, South, West, North and Central, and the data of all listed companies in the region, such as BYD, Rainbow Mall, Chang'an Automobile, etc., are collected for a total of 848 companies for the period from 2015 to 2021. After that, the data are grouped by year and region for normalization, for the positive impact indicators affecting the quality of carbon accounting information disclosure, such as total assets, earnings per share, etc., take the maximum value of the group for normalization, and for the negative indicators, such as the city's annual carbon emissions, return on net assets, etc., take the minimum value of the group for normalization, and the formula used for normalization is shown as follows:

For the positive indicators, we use Equation (11) for the treatment:

$$X' = \frac{X}{X_{MAX}} \quad (11)$$

For negative indicators, we use Equation (12) for this:

$$X' = \frac{X_{MIN}}{X} \quad (12)$$

After the data are normalized, due to the different relative importance of each factor to the level of carbon accounting information disclosure, the principle of weighted average is used for processing, and the weight w is obtained by the hierarchical analysis method, as shown in Table 6 above. The weight vector A is obtained by weighted average of the fuzzy comprehensive evaluation results b . The formula for calculating the weight vector A is shown below:

$$A = \frac{\sum_{w=1}^n b_w^k \cdot w}{\sum_{w=1}^n b_w^k} \quad (13)$$

Due to the uneven geographical distribution of the collected data, after obtaining the fuzzy weight vector A , the arithmetic average method was used to do the arithmetic average of the carbon accounting disclosure level of the enterprises in the region, and the overall level of carbon accounting disclosure of the five parts of the country was obtained as shown in Table 8 below:

Table 8. Fuzzy Comprehensive Evaluation of the Overall Level of Carbon Accounting Disclosure in the Five Parts of the Country

Year Area	East	South	West	North	Central area
2015	0.2293	0.0172	0.2553	0.4200	0.3703
2016	0.2254	-0.2384	0.3222	0.1736	0.3008
2017	0.2484	1.2249	0.2922	0.3272	0.0909
2018	0.1559	0.2709	0.4365	0.2788	0.5034
2019	0.0494	0.1845	0.2097	0.3060	0.3657
2020	0.2280	0.2372	0.2418	0.2526	0.3132
2021	-0.1186	0.2862	0.2617	0.2601	0.2493

5. Conclusion

(1) The overall level of carbon accounting disclosure in the Eastern region shows an overall decreasing trend, with the highest value in 2017, when the overall level of carbon accounting disclosure is 0.2484, and the lowest value in 2021, when the overall level of carbon accounting disclosure is -0.1186.

The main reasons for the declining trend in the level of carbon accounting disclosure in the eastern region are the increase in urban carbon emissions, corporate NAV and corporate Lerner index. The eastern region has an open and flexible market environment and economic development support policies, the rapid development of the economic level, and plays an important role in trade and import and export, so the urban carbon emissions increase year by year. At the same time, the rapid development of innovative industries and the gathering of enterprises in the eastern region have formed an industrial cluster effect, and the development of enterprises has been rapid.

The unusual increase in the level of carbon accounting disclosure in the Eastern region in 2020 may be related to the hindered development of enterprises and the slowdown of economic growth during the epidemic. Enterprises affected by the epidemic suffered from declining performance, shrinking assets, and slow development, which affected the level of carbon accounting disclosure significantly.

(2) The overall level of carbon accounting disclosure in the southern region shows an overall fluctuating upward trend, with the highest value in 2017, when the overall level of carbon accounting disclosure was 1.2249; and the lowest value in 2016, when the overall level of carbon accounting disclosure was -0.2384.

The reasons for the fluctuation and increase in the level of carbon accounting information disclosure in the southern region are mainly related to the level of economic development and changes in the policy environment. The overall economic development in the southern region has been relatively rapid, but the growth rate has slowed down due to the impact of the epidemic, and the governance structure and financial situation of enterprises have therefore experienced major changes, which has affected the fluctuation of the level of carbon accounting disclosure in the southern region.

The significant decline in the level of carbon accounting information disclosure in the southern region in 2016 was mainly affected by the carbon market policy changes and economic downward pressure, the carbon trading policy has been gradually promoted but the specific implementation details are still undetermined, so enterprises are more cautious about carbon accounting information disclosure, and the deterioration of the business situation has also led to the decline in the level of disclosure.

The significant increase in the level of carbon accounting disclosure in the southern region in 2017 was due to the introduction of policies such as the Several Opinions on Drawing and Strictly Abiding by the Red Line of Ecological Protection, the Regulations on the Implementation of the Environmental Protection Tax Law (Draft for Public Comments), the entry into force of the International Climate Change Agreement, and the signing of the Paris Climate Accord the previous year, which has heightened the international community's attention to energy saving and emission reduction and talk about disclosure, and has incentivized companies to be more proactive in their disclosure.

(3) The overall level of carbon accounting disclosure in the Western region has not changed much as a whole, with the highest value in 2018, when the overall level of carbon accounting disclosure is 0.4365, and the lowest value in 2021, when the overall level of carbon accounting disclosure is 0.2097.

The overall carbon accounting disclosure level in the Western region has not changed much, mainly affected by the level of economic development, the low level of corporate governance, the slow improvement of corporate performance, and the low level of corporate equity concentration, the percentage of independent directors, and other indicators, so the level of carbon accounting disclosure is relatively stable.

In 2018, the level of carbon accounting information disclosure in the western region has significantly increased due to the influence of environmental protection and ecological restoration

work, and the governance work carried out to address the problems of land sanding and water scarcity in the western region may have prompted enterprises to pay attention to environmental protection work, thus increasing the disclosure of carbon accounting information.

(4) The overall level of carbon accounting disclosure in the northern region shows a fluctuating downward trend as a whole, with the highest value in 2015, when the overall level of carbon accounting disclosure was 0.4200; and the lowest value in 2016, when the overall level of carbon accounting disclosure was 0.1736.

The reason for the overall decline in carbon accounting disclosure levels in the northern region may be due to the remediation actions carried out for heavy industrial enterprises in the north, where the government has vigorously promoted the de-capacitation of the steel and electric power industries, strengthened environmental supervision, and promoted energy-saving and clean technologies to reduce enterprise resource and energy consumption, which has both reduced the overall carbon emissions in the region and promoted the enhancement of enterprises' awareness of environmental protection.

The reason for the significant decrease in the level of carbon accounting disclosure in the northern region in 2016 may be similar to that of the southern region, which is also affected by the introduction of the "13th Five-Year" Environmental Impact Assessment Reform Program, the Environmental Protection Tax Law and other policies, and the enterprises carry out the disclosure of carbon accounting information has not formed a unified standard, and at the same time by the economic pressure of the enterprises to slow down the pace of development.

(5) The overall level of carbon accounting disclosure in the central region shows a decreasing trend as a whole, with the highest value in 2018, when the overall level of carbon accounting disclosure was 0.5034, and the lowest value in 2017, when the overall level of carbon accounting disclosure was 0.0909.

The overall downward trend in the level of carbon accounting disclosure in the central region may be due to the rapid economic development of the region, on the one hand, the rapid growth of enterprise performance and optimization of the governance structure, on the other hand, the residents' consumption ability is improved, the market demand is increased, and the quantity of consumer carbon emissions is therefore increased, leading to an overall decrease in the level of carbon accounting disclosure.

The reason for the significant decline in the overall level of carbon accounting disclosure in the central region in 2017 is mainly due to the rapid development of enterprises and the rapid growth of market share and return on net assets, both of which adversely affect carbon accounting disclosure.

6. Recommendation

6.1. Improve policies and regulations and strengthen regulatory efforts

As the organizer and manager of economic development, the government can play the roles of both policy maker and regulator in promoting the development of carbon accounting information disclosure. As a policy maker, the government can improve the carbon accounting information disclosure related policies and regulations, introduce binding regulations on the content and mode of carbon accounting information disclosure of enterprises, and can change voluntary disclosure to mandatory disclosure mainly through the first easy to be followed by the difficult and gradual implementation [13]; and as a regulator, the government should introduce incentive and punishment policies, combining the encouraging policies and strict and transparent punishment system in order to promote enterprises to consciously and actively participate in the carbon accounting information disclosure work, and enhance the overall environmental protection of the enterprises. This will promote the enterprises to consciously and actively participate in carbon accounting information disclosure, and enhance the overall environmental protection level of enterprises.

6.2. Harmonization of calculation methods and establishment of a measurement system

Due to the lack of uniformity and comparability in the disclosure of carbon accounting information, the data collection standards and carbon emission calculation methods are different, and the disclosure by enterprises is arbitrary and scattered [14]. In this regard, the government should draw on the experience of developed countries to develop a unified data collection and accounting system in line with China's national conditions [15], and clarify the scope of carbon accounting information disclosure, disclosure of indicators and their data collection and accounting methods, auditing requirements, reporting cycles and time limits and other standards. To ensure the comparability and accuracy of data. The organization establishes a scientific and perfect carbon emission measurement system, provides technical support and guidance to enterprises, and helps them accurately obtain and report carbon emission data, so as to improve the credibility and authority of carbon accounting information disclosure.

6.3. Raise environmental awareness and fulfill ESG responsibilities

Enterprises should fulfill their environmental, social and governance responsibilities based on the goal of sustainable development, strengthen their social commitment and take the initiative to make objective disclosure of carbon accounting information [16]. Enterprises also need to fully recognize the necessity and importance of carbon accounting information disclosure, integrate the concept of environmental protection into the corporate culture, strengthen the training of employees' environmental awareness, encourage low-carbon innovation practices within the enterprise, and carry out energy-efficiency management through energy-saving measures and upgraded equipment to promote the enterprise to reduce carbon emissions by reducing carbon emissions from the source. In addition, enterprises need to actively cooperate with government regulators and auditing departments, and at the same time strengthen communication and cooperation with investors and customers to jointly promote the in-depth development of carbon accounting disclosure.

6.4. Broaden disclosure methods and expand disclosure content

At present, the main carbon accounting information disclosure methods are non-independent reports and independent reports, and with the increasing importance of carbon information disclosure, independent reports will become a more important disclosure method. At present, the number of enterprises forming independent reports is still very small, in terms of channels, enterprises can broaden the way of carbon accounting information disclosure, not only can disclose the relevant data in the annual report, but also can prepare independent reports, and take the initiative to disclose information through a variety of channels such as corporate websites, social media, and so on. And in the form can break through the traditional accounting report form [17], expand the disclosure content, in addition to carbon emissions, emission reduction measures, environmental performance, but also can disclose carbon performance, carbon assets, carbon rights and interests and other aspects of the content, so that the disclosure of information is more comprehensive and transparent.

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