Study on the Development level of National Carbon Accounting Information Disclosure based on Topsis Comprehensive Evaluation Method

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Abstract. Enhancing the level of carbon accounting information disclosure is crucial for achieving China;s "dual carbon" goals and promoting a green economic transformation. Based on this, this paper first constructs an evaluation model for the development of carbon accounting information disclosure, which includes 15 indicators across three levels. It then uses the Analytic Hierarchy Process to assign weights to each indicator, followed by the Topsis comprehensive evaluation method to measure and compare the scores of carbon accounting information disclosure at the provincial level, with 31 cities and regions as units. Finally, linear regression is used to predict the scores of carbon accounting information disclosure for each province over the next five years. The conclusions show that Beijing, Shanghai, and Jiangsu have the best levels of carbon accounting information disclosure, while Jilin and Heilongjiang perform poorly. After five years, Beijing will still lead, with Inner Mongolia Autonomous Region and Xinjiang Uygur Autonomous Region steadily improving, while Jilin and Heilongjiang remain at the bottom. In response to these concerns, practical suggestions are proposed from various angles, including optimizing board structures, improving internal environmental concepts and systems within enterprises, expanding pilot programs for carbon emission rights trading, and perfecting regulations on carbon information disclosure. These suggestions aim to enhance the quality of carbon accounting information disclosure by enterprises and provide theoretical references and solutions for achieving the "dual carbon" goals.

Keywords: Carbon Accounting Information Disclosure Level; Topsis Comprehensive Evaluation Method; Analytic Hierarchy Process; Linear Regression.

1. Introduction

At the 75th meeting, President Xi announced that China’s carbon emissions will peak by 2030 and achieve carbon neutrality by 2060. The report of the 20th National Congress of the Communist Party of China proposed a plan for peak carbon emissions and carbon neutrality, with plans to implement and build a new energy system in phases to participate in global climate governance. The United Nations Principles for Responsible Investment promotes ESG concepts, and studies show that ESG significantly enhances corporate performance[1]. During the period from 2020 to 2022, there was a significant increase in the voluntary disclosure of information related to low-carbon activities in corporate social responsibility reports, ESG reports, or sustainability reports, both in terms of coverage and content details. In 2024, the level of environmental responsibility information disclosure by Chinese listed companies increased by 1.7% compared to the previous year, indicating a trend of continuous improvement. Chinese companies still lag behind major global exchange-listed companies in terms of carbon accounting information disclosure, requiring an improvement in the quality and completeness of such disclosures. China’s carbon market consists of mandatory and voluntary markets, but there are significant differences in development across regions, affecting the breadth and depth of disclosures. Regional disparities remain a concern, necessitating balanced market development. Issues such as uneven development between East and West, incomplete disclosures, and lax regulatory oversight regarding whether carbon emissions are related to false accounts, private accounts, or tax evasion persist in disclosures, thus identifying carbon accounting is essential The level of information disclosure is particularly important.

Based on this, the study first clearly defines the connotation of carbon accounting information disclosure. Next, it constructs an indicator system for influencing factors. Then, the Analytic Hierarchy Process is used to assign weights to these indicators. Finally, the Topsis comprehensive

evaluation method is applied to score A-share listed companies nationwide. Scores are given to each province for carbon accounting information disclosure in their respective regions, thereby measuring and analyzing regional differences.

2. Literature Review

2.1 Origin and Development Trend of Carbon Accounting Information Disclosure

Carbon accounting, as a core tool for measuring corporate carbon emissions, has received widespread attention and research from both domestic and international academic circles in recent years. Its development reflects the need to quantify corporate environmental responsibility and the impact of carbon emissions, marking progress in accounting towards climate response and sustainable development. Since the 1990s, environmental scholars have begun using material flow analysis methods to account for carbon stocks and flows, but this was not directly linked to corporate financial accounting systems. After 2002, driven by global climate change and the Kyoto Protocol, the standardization of accounting treatment for CO_2 emissions by companies gradually became a focal point of discussion. Regarding research on carbon disclosure, Kieran[2] points out that insufficient carbon disclosure, ambiguous meanings of carbon emission data, and unreliable supervisory mechanisms make it difficult to interpret carbon emission reports and measure corporate performance. Johnstonetal, Sefeik, Soderstrom[3] studies show that in the United States, CO_2 In the emission trading market, there is a positive correlation between emission quota and company value, which is recognized as an asset. Scholars point out that in order to provide a basis for accounting standards institutions to formulate more perfect carbon accounting standards, it is necessary to identify climate change risks and CO in the trading mechanism CO_2. The value correlation of emission rights should be studied in depth. Ascuietal[4] believes that enterprises should disclose both financial information and non-financial information related to environmental changes, which can help improve the accuracy of carbon accounting information disclosure.

Under the guidance of the "dual carbon" goals, promoting the green transformation of the economy and building low-carbon production methods have become important strategic tasks for Chinas socio-economic development. In recent years, academic circles in our country have been active in research on carbon accounting information disclosure. While addressing issues related to carbon accounting information disclosure, quality, and influencing factors, they mainly focus on the field of carbon accounting or carbon emission rights. Zhifang Zhou and Xu Xiao [5] first proposed the concept of carbon accounting domestically, pointing out that it encompasses multiple aspects including carbon sinks. Haifang Guo [6] emphasized the importance of establishing a corporate low-carbon accounting information disclosure system for a low-carbon economy and sustainable development, and proposed a theoretical framework including disclosure standards, requirements, content, and methods. Dianying Qiang and Guijiang Wen[7] proposed two types of carbon accounting reports: one disclosed in traditional financial statements and notes, and another as an independent report. Yanhua Li[8] found through research on the Carbon Disclosure Project (CDP) reports that while companies in high-pollution industries show relatively low enthusiasm for information disclosure, they tend to provide more qualitative descriptions in their carbon accounting information disclosure, lacking quantitative data.

2.2 Study on the Influencing Factors of Carbon Accounting Information Disclosure

Research on the factors influencing the quality of carbon accounting information disclosure has primarily focused on dimensions such as company size, operating performance, industry characteristics, and debt levels. Taking the studies of Tadros and Magnan as examples, they analyzed environmental-sensitive industries using panel data, finding that companies with superior environmental performance, a greater inclination towards diversified public information methods, and higher quality of disclosure are more likely to succeed. Moreover, in terms of economic and legal incentives, environmental performance plays a significant moderating role in the impact on corporate

environmental information disclosure. Al-Tuwa ij ri and Christensen[9] Research has found that a company's environmental responsibility, environmental disclosure, including carbon accounting disclosure, collectively influence the companys profitability and stock value. Engetal[10] Empirical studies have shown that firm size is positively correlated with the willingness to disclose carbon accounting information; however, Hefinetal[11] research found that firm size does not significantly affect the quality of carbon accounting disclosures.

Domestic scholars such as Yiguang Cui et al. [12] empirically found that the higher a company's debt level, the stronger its willingness to disclose carbon accounting information; while Cui Liu[13] found through research that there is a certain negative relationship between a company's debt level and the level of carbon accounting information disclosure. Taking listed companies in heavily polluting industries as research subjects, HongtaoShen and Feng Jie[14] proved that content involving corporate environmental performance in media reports can significantly improve the quality of corporate environmental information disclosure; at the same time, government inspections not only directly enhance corporate environmental information disclosure but also further strengthen the supervisory effect of public opinion. Ning Gong and Maosheng Duan [15] constructed an evaluation index system for carbon information disclosure to analyze the constituent stocks of China's SSE Corporate Social Responsibility Index, finding a clear positive correlation between corporate carbon emissions and their levels, quality, and quantity of carbon information disclosure, providing a theoretical foundation for the construction of corporate carbon information systems. Yiguang Cui and Xian Ma[16] selected the constituent stocks of the SSE Corporate Social Responsibility Index as samples and concluded that the level of carbon emission information disclosure for domestic companies listed overseas is higher than that of domestic listed companies. Ning Gong and Jin Li [17] found through empirical research that based on data from Chinese high-carbon emission industry listed companies from 2016 to 2020, corporate carbon performance and carbon information disclosure levels exhibit a U-shaped relationship with a decline followed by an increase.

2.3 Review of the Literature

As domestic and international scholars delve deeper into the field of carbon accounting, existing literature has largely clarified the concepts and definitions of carbon accounting and its information disclosure. The literature has conducted in-depth studies on the factors influencing corporate carbon information disclosure and their development trends from various perspectives, providing theoretical support and empirical evidence for policymakers and enterprises. Foreign scholars focus more on building theoretical frameworks and accounting standards in the research of carbon accounting information disclosure, paying attention to the motivations, value, and accounting treatment of carbon emission rights, as well as discussions on the relevance of carbon emission rights value. In contrast, domestic scholars tend to emphasize the introduction of the concept of carbon accounting, the construction of a low-carbon accounting information disclosure system, and the establishment of carbon emission information disclosure systems, along with current situation analysis and improvements. Future research can build upon the work of both domestic and international scholars to further explore the relationship between carbon accounting information disclosure and corporate sustainability, policy formulation, and other aspects. Both sides research has its own focus, collectively contributing to the advancement and improvement of carbon accounting information disclosure.

However, these studies exhibit certain differences in methodology and sample selection, with few scholars evaluating regional disparities in carbon accounting disclosure. Future research can further expand the scope of study, delving deeper into the intrinsic mechanisms of corporate carbon disclosure and the levels of disclosure across provinces. Based on this, the paper first normalizes the data, then assigns weights to indicators using the Analytic Hierarchy Process (AHP), and subsequently evaluates the level of carbon accounting disclosure nationwide at the provincial and municipal levels using the Topsis comprehensive evaluation method. This approach explores how different regions develop differently. Finally, through time series regression, linear regression is used

to predict the development level of carbon accounting disclosure for 31 provinces over the next five years, thereby measuring and evaluating these differences.

3. Construction of Analytic Hierarchy Process

3.1 Preliminary Screening of Indicators and Data Sources

The primary indicator is the development level of carbon accounting information disclosure; there are four secondary indicators, namely company background, financial performance, corporate governance, and macro environment; there are fifteen tertiary indicators, including company size, industry characteristics, carbon emissions, debt level, fixed asset ratio, return on net assets, operational capability, development potential, risk level, equity concentration, cross-listing status, board structure, relationship between chairman and CEO, regional economic environment, and pilot carbon emission trading programs. As shown in Table 1.

Table 1. Carbon accounting information level evaluation index system

Primary indicator	Secondary indicators	Level 3 indicators
Development level of carbon accounting information disclosure	Environmental conditions	Company size
		Industry characteristics
		Carbon emission
	Financial performance	Degree of corporate debt
		The proportion of fixed assets
		Return on equity
		Operation capacity
		Development capacity
		Risk level
	Corporate governance	Equity concentration
		Cross-listing situation
		Board structure
		The relationship between the Chairman and the CEO
	Environment	Regional economic environment
		Pilot carbon emission trading

The data sources of this paper are Shanghai Stock Exchange (www.sse.com.cn), ShenzhenSt ock Exchange (www.szse.cn), Tonghuashun Finance (www.10jqka.com.

cn) and Juchao Information Network (cn.bing.com). The data type is panel data, and the relevant carbon accounting information disclosure data from 2019—2023 are selected for analysis.

3.2 Hierarchical Analysis Method Construction

3.2.1 Analytic Hierarchy Process Structure Analysis Model

The structure of the analytic hierarchy process model in this paper is shown in Figure 1:

3.2.2 Constructing Judgment Matrix

The analytic hierarchy process takes the judgment matrix as the core calculation tool. The element value reflects the decision makers judgment on the relative weight of each factor, and is directly related to the accuracy of the final decision. In general, the elements of the judgment matrix are assigned by the scale system from 1 to 9 and its inverse.

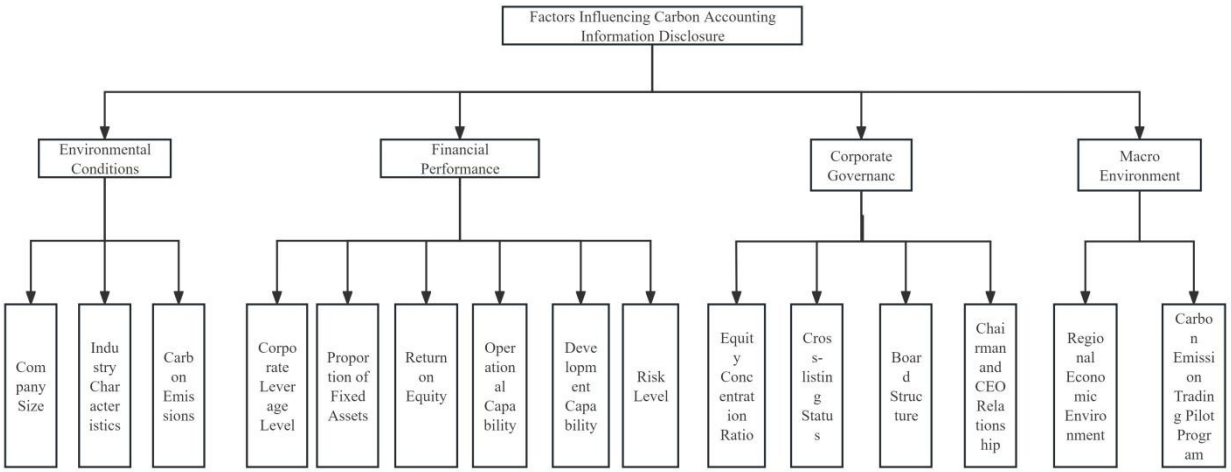

Fig 1. Hierarchical analysis model structure diagram

Table 2. Construct the judgment matrix

scale	meaning
1	The two factors are equally important
3	Of the two factors, one is slightly more important than the other
5	Of the two factors, one is clearly more important than the other
7	Two factors are more important than the other
9	Of the two factors, one is more important than the other
2, 4,6,8	The median of the above two adjacent judgments
Count backwards	If factor i and j are compared to judge B_{ji}That is, the judgment of comparing Factor j with i is B_{ji}=1/ B_{ij}

3.2.3 Hierarchical Single Sorting and Consistency Test

Hierarchical order is used to determine the importance ranking of each factor in a certain level to a factor in the upper level, and its weight is reflected by the eigenvector of the judgment matrix. For example, the characteristic problem of the judgment matrix A is AW= λ_{max} The solution vector W of W, after normalization processing, is the relative weight of each factor at the level to a certain factor at the upper level, which is called hierarchical single sorting. In order to ensure the reliability of the sorting results, it is necessary to conduct consistency test on the judgment matrix, which can be realized by calculating the random consistency ratio.

Table 3. Random consistency index

Determine the order n of the matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Consistency ratio:

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

When CR (consistency ratio) is less than 0.1, the result of hierarchical single sorting is considered to be acceptable; otherwise, the value of elements in the judgment matrix needs to be adjusted.

3.2.4 Hierarchical Total Sorting and Consistency Test

In the analytic hierarchy process, not only does each judgment matrix need to be checked for consistency, but also the combination consistency test needs to be carried out layer by layer. Among them, the combination consistency ratio of the p-th layer relative to the first layer can be calculated in the following ways:

$$CR^{(p)} = CR^{(p-1)} + \frac{CI^{(p)}}{RI^{(p)}}, p = 3,4,\cdots,s \tag{2}$$

For the analysis of the index, CR=0.071646<0.1 was calculated, so the decision result was credible and the hierarchical analysis method was completed.

3.3 Indicator Weight Table

After the above hierarchical analysis method is constructed, the weight table of the three-level indicators of carbon accounting information disclosure development level is obtained, as shown in Table 4 below.

Table 4. Carbon accounting information disclosure development level weight table

Primary indicator	Secondary indicators	Level 3 indicators	Level 3 indicator weight
Development level of carbon accounting information disclosure	Environmental conditions	Company size	0.0365
		Industry characteristics	0.0850
		Carbon emission	0.3296
	Financial performance	The degree of corporate debt	0.0120
		The proportion of fixed assets	0.0019
		Return on equity	0.0428
		Operation capacity	0.0042
		Development capacity	0.0250
		Risk level	0.0126
	Corporate governance	Equity concentration	0.0100
		Cross-listing	0.0012
		Board structure	0.0048
		The relationship between the chairman and the CEO	0.0197
	Environment	Regional economic Environment	0.3456
		Pilot trading of carbon emission rights	0.0691

4. Topsis Comprehensive Evaluation Method

4.1 Construct Decision Matrix

Construct decision matrix A= $(a_{ij})_{m\times n}$, Each column is an evaluation index, and each row is a scheme to be evaluated; in order to eliminate the influence of dimensions and facilitate comparison, the data are normalized by the range transformation method to get B= $(b_{ij})_{m\times n}$, among:

If X is a very large attribute:

$$b_{ij} = \frac{a_{ij} - a_j^{\min}}{a_j^{\max} - a_j^{\min}} \tag{3}$$

If X is a very small attribute:

$$b_{ij} = \frac{a_j^{\max} - a_{ij}}{a_j^{\max} - a_j^{\min}} \tag{4}$$

4.2 Assigning Weights

According to the impact of each evaluation index on the final result, it is assigned a corresponding weight. W=[w_1,w_2,w_3,w_4,w_5,w_6,w_7,w_8,w_9,w_{10},w_{11},w_{12},w_{13},w_{14},w_{15}], Multiply column j of B by its weight W_j, Get the weighted norm matrix C= $(c_{ij})_{m\times n}$

4.3 Determine the Ideal Solution C+ and the Negative Ideal Value C-

Positive ideal solution:

$$c_j^{+}=\left\{\frac{\max\limits_i c_{ij}, j \text{ is the } Maximum\ Property}{\min\limits_i c_{ij}, j \text{ is the } Minimum\ Property} j=1,2,...,n\right\} \tag{5}$$

Negative ideal solution:

$$c_j^{-}=\left\{\frac{\min\limits_i c_{ij}, j \text{ is the } Maximum\ Property}{\max\limits_i c_{ij}, j \text{ is the } Minimum\ Property} j=1,2,...,n\right\} \tag{6}$$

4.4 Calculate the Relative Progress of the Project

Calculate the distance between each evaluation scheme and the positive ideal solution and the negative ideal solution:

Alternative a_i Distance to the ideal solution:

$$d_i^{*}=\sqrt{\sum_{j=1}^{n}\left(c_{ij}-c_j^{+}\right)^2}, i=1,2,...,m; \tag{7}$$

Alternative a_i Distance to the negative ideal solution:

$$d_i^{0}=\sqrt{\sum_{j=1}^{n}\left(c_{ij}-c_j^{-}\right)^2}, i=1,2,...,m; \tag{8}$$

Calculate the relative progress of each evaluation scheme (evaluation reference value):

$$f_i=\frac{d_i^0}{d_i^0+d_i^*}, \quad i=1,...,m \tag{9}$$

And then well take the f_i Arrange the options from largest to smallest to get a priority order for each option.

5. Multiple Linear Regression

5.1 Regression Model Construction

Taking the development level of carbon accounting information disclosure from 2024 to 2028 as the dependent variable y and the occurrence year as the independent variable x, the relationship between the development level of carbon accounting information disclosure and the occurrence year can be expressed by a linear regression model:

$$y=a+bx+e \tag{10}$$

Where: a is the constant of regression model; b is the coefficient of regression model; e is the residual term.

From 2019 to 2023, the development level of carbon accounting information disclosure in 31 provinces and the occurrence year all meet the following linear relationship:

$$y_i=a+bx_i+e_i \tag{11}$$

In linear regression prediction, the residual term is eiIt is inevitably difficult to estimate accurately, and the prediction value y is usually calculated by a+ bxiThen the parameters a and b are determined. The relationship between y and x can be expressed as:

$$y=a+bx \tag{12}$$

Table 5. The development score of carbon accounting information disclosure in 31 provinces

Province	2019	2020	2021	2022	2023	Ranking 2023
Anhui Province	0.196751	0.197337	0.185576	0.172508	0.166921	20
Beijing City	0.845913	0.842624	0.846290	0.845672	0.845859	1
Fujian Province	0.362982	0.365799	0.363676	0.370633	0.364896	5
Gansu Province	0.137468	0.145124	0.142097	0.149164	0.151478	23
Guangdong Province	0.294375	0.293890	0.284030	0.287227	0.294466	7
The Guangxi Zhuang Autonomous Region	0.117630	0.157555	0.164566	0.154604	0.178071	19
Guizhou Province	0.124778	0.127563	0.130492	0.128841	0.131699	29
Hainan Province	0.150896	0.140621	0.150369	0.141581	0.141316	26
Hebei Province	0.172909	0.169453	0.155576	0.158797	0.150132	24
Henan Province	0.161963	0.156992	0.148859	0.147511	0.13728	28
Heilongjiang Province	0.102137	0.063949	0.091568	0.096117	0.073667	31
Hubei province	0.268668	0.249549	0.255376	0.257668	0.251024	11
Hunan Province	0.167895	0.171179	0.160040	0.165465	0.149554	25
Jilin Province	0.124371	0.101938	0.088544	0.112300	0.112004	30
Jiangsu Province	0.383661	0.391045	0.390786	0.398499	0.410274	3
Jiangxi Province	0.187877	0.230897	0.225264	0.216606	0.158787	22
Liaoning Province	0.222729	0.253652	0.230931	0.217197	0.221297	13
The Nei Monggol Autonomous Region	0.304226	0.338831	0.339280	0.360399	0.279277	8
The Ningxia Hui Autonomous Region	0.192468	0.195833	0.196473	0.215799	0.205783	14
Qinghai Province	0.183011	0.151026	0.172684	0.172230	0.160122	21
Shandong Province	0.224986	0.231784	0.222393	0.230805	0.238121	12
Shanxi Province	0.218843	0.236080	0.249904	0.264803	0.200775	15
Shanxi Province	0.189661	0.190287	0.186013	0.200220	0.198394	16
Shanghai City	0.525480	0.533111	0.519262	0.517612	0.532736	2
Sichuan Province	0.149380	0.132571	0.142008	0.146493	0.13905	27
Tianjin City	0.343948	0.338469	0.337703	0.339351	0.386255	4
Xizang Autonomous Region	0.168041	0.166045	0.168228	0.172388	0.194843	17
the Xinjiang Uygur Autonomous Region	0.186200	0.208026	0.226111	0.238398	0.258354	9
Yunnan Province	0.204104	0.257274	0.238877	0.235154	0.192645	18
Zhejiang Province	0.321934	0.320798	0.319419	0.327939	0.326684	6
Chongqing City	0.254876	0.263455	0.259900	0.250159	0.257912	10

In regression analysis, ordinary least squares (OLS) is a common method to estimate the parameters of linear model.

$$b = \frac{\sum x_i y_i - \overline{x}\sum y_i}{\sum x^2 - \overline{x}\sum x_i} \tag{13}$$

$$a = \overline{y} - b\overline{x} \tag{14}$$

In the formula: x_i is the actual value of the independent variable, y_i is the actual value of the dependent variable The average of the independent and dependent variables.

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{15}$$

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} \tag{16}$$

Where: n is the number of samples.

For each actual value of the independent variable, there is a fitted value:

$$y_i^{'} = a + bx_i \tag{17}$$

The difference between y_i and the actual value is the residual term:

$$e_i = y_i - y_i^{'} \tag{18}$$

5.2 Empirical Analysis of Linear Regression

After the comprehensive evaluation of Topsis mentioned above, a total score for the development level of carbon accounting information disclosure nationwide was obtained. Taking the development levels of carbon accounting information disclosure in 31 provinces as dependent variables and the years they occurred as independent variables, a linear regression model for the entire country was constructed to obtain model parameters. The calculation results are shown in Table 6.

Table 6. Model parameter calculation results

Metric	*a*	*b*	Metric	*a*	*b*
Anhui Province	-0.00845	0.20917	Liaoning Province	-0.00393	0.24096
Beijing City	0.00029	0.84439	The Nei Monggol Autonomous Region	-0.00283	0.33290
Fujian Province	0.00087	0.36300	The Ningxia Hui Autonomous Region	0.00466	0.18729
Gansu Province	0.00320	0.13545	Qinghai Province	-0.00246	0.17519
Guangdong Province	-0.00065	0.29274	Shandong Province	0.00253	0.22203
The Guangxi Zhuang Autonomous Region	0.01179	0.11911	Shanxi Province	-0.00074	0.23631
Guizhou Province	0.00151	0.12414	Shanxi Province	0.00274	0.18469
Hainan Province	-0.00182	0.15042	Shanghai City	-0.00375	0.53323
Hebei Province	-0.00562	0.17824	Sichuan Province	-0.00067	0.14392
Henan Province	-0.00589	0.16818	Tianjin City	0.00855	0.32350
Heilongjiang Province	-0.00248	0.09292	Xizang Autonomous Region	0.00600	0.15593
Hubei province	-0.00272	0.26461	the Xinjiang Uygur Autonomous Region	0.01747	0.17101
Hunan Province	-0.00424	0.17555	Yunnan Province	-0.00450	0.23912
Jilin Province	-0.00144	0.11214	Zhejiang Province	0.00166	0.31836
Jiangsu Province	0.00443	0.37993	Chongqing City	-0.00072	0.25943
Jiangxi Province	-0.00725	0.22563			

5.3 Visualization of Result Prediction

The total score of carbon accounting information disclosure development in China from 2024 to 2029 is calculated by linear regression model as shown in the following table.

The heat map of the carbon accounting information disclosure level in 2023 and 2028 is drawn by using the prediction results of the existing regression model, as shown in the figure 2 below.

6. Conclusion

(1) First, the regions with the most prominent development levels in carbon accounting information disclosure include Beijing, Shanghai, Jiangsu Province, Tianjin, and Fujian Province, scoring between 0.3649 and 0.8459. Although Shanghai's development level slightly declined over

the next five years, from 0.5328 to 0.4956, it still ranks second, maintaining an "optimal" development level. The other four provinces have seen their development levels continue to rise, staying at high levels.

Table 7. The development score of carbon accounting information disclosure in 31 provinces

Province	2024	2025	2026	2027	2028	Ranking 2028
Anhui Province	0.1585	0.1500	0.1416	0.1331	0.1247	27
Beijing City	0.8462	0.8464	0.8467	0.8470	0.8473	1
Fujian Province	0.3682	0.3691	0.3699	0.3708	0.3717	5
Gansu Province	0.1547	0.1579	0.1611	0.1643	0.1675	20
Guangdong Province	0.2889	0.2882	0.2876	0.2869	0.2863	9
The Guangxi Zhuang Autonomous Region	0.1899	0.2017	0.2135	0.2252	0.2370	13
Guizhou Province	0.1332	0.1347	0.1362	0.1377	0.1393	23
Hainan Province	0.1395	0.1377	0.1359	0.1340	0.1322	26
Hebei Province	0.1445	0.1389	0.1333	0.1276	0.1220	28
Henan Province	0.1329	0.1270	0.1211	0.1152	0.1093	29
Heilongjiang Province	0.0781	0.0756	0.0731	0.0706	0.0681	31
Hubei province	0.2483	0.2456	0.2429	0.2402	0.2374	12
Hunan Province	0.1501	0.1459	0.1416	0.1374	0.1331	25
Jilin Province	0.1035	0.1021	0.1006	0.0992	0.0978	30
Jiangsu Province	0.4065	0.4109	0.4153	0.4198	0.4242	3
Jiangxi Province	0.1821	0.1749	0.1677	0.1604	0.1532	21
Liaoning Province	0.2174	0.2134	0.2095	0.2056	0.2016	18
The Nei Monggol Autonomous Region	0.3159	0.3131	0.3102	0.3074	0.3046	8
The Ningxia Hui Autonomous Region	0.2153	0.2199	0.2246	0.2292	0.2339	14
Qinghai Province	0.1604	0.1580	0.1555	0.1531	0.1506	22
Shandong Province	0.2372	0.2397	0.2423	0.2448	0.2473	11
Shanxi Province	0.2319	0.2311	0.2304	0.2296	0.2289	15
Shanxi Province	0.2011	0.2039	0.2066	0.2094	0.2121	17
Shanghai City	0.5108	0.5070	0.5033	0.4995	0.4958	2
Sichuan Province	0.1399	0.1392	0.1385	0.1379	0.1372	24
Tianjin City	0.3748	0.3833	0.3919	0.4004	0.4090	4
Xizang Autonomous Region	0.1919	0.1979	0.2039	0.2099	0.2159	16
the Xinjiang Uygur Autonomous Region	0.2758	0.2933	0.3108	0.3282	0.3457	6
Yunnan Province	0.2121	0.2076	0.2031	0.1986	0.1941	19
Zhejiang Province	0.3283	0.3300	0.3317	0.3333	0.3350	7
Chongqing City	0.2551	0.2544	0.2537	0.2529	0.2522	10

Among them, the main reason for the higher development level of carbon accounting information disclosure is that provinces and cities have been listed as pilot regions for carbon emission trading. In 2013, seven provinces and cities, including Beijing, Shanghai, and Shenzhen, were designated as pilot regions for carbon emission trading. Among these five provinces, all but Jiangsu are national carbon emission pilot areas. The quality of carbon accounting information disclosure is positively correlated with the carbon emission trading pilots. Within the pilot regions, there are differences in corporate carbon emission allowances; companies that exceed their limits must purchase additional carbon emission rights, while those with surplus allowances can sell their excess. This mechanism

effectively enhances companies enthusiasm for energy conservation and emissions reduction, encouraging them to proactively calculate the value of their carbon emission rights and disclose this information in their financial statements.

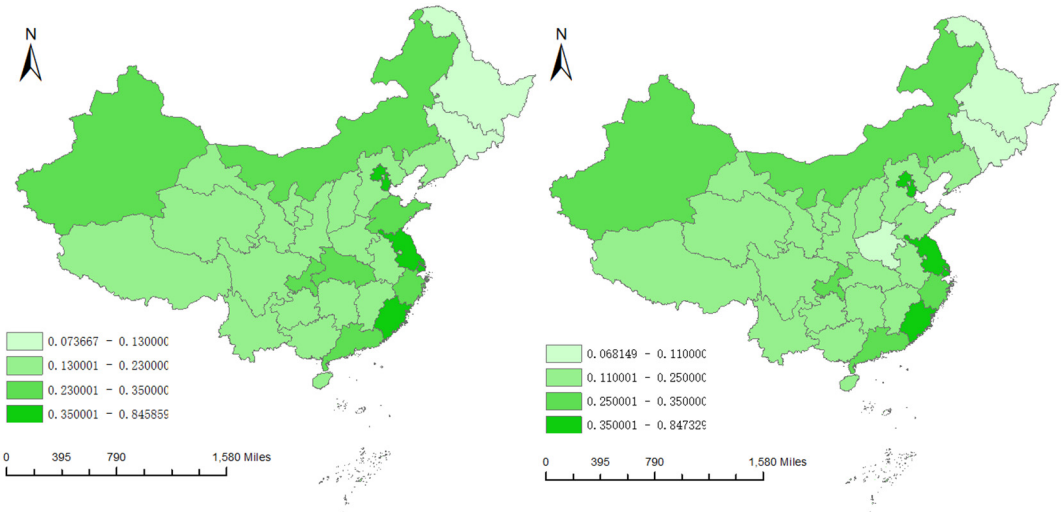

Fig 2. Thermal map of carbon accounting information disclosure level in China in 2023 and 2028

(2) Secondly, regions with "good" levels of carbon accounting information disclosure include Zhejiang Province, Guangdong Province, Inner Mongolia Autonomous Region, Xinjiang Uyghur Autonomous Region, Chongqing Municipality, Hubei Province, and Shandong Province, with scores of 0.3267,0.2945,0.2793,0.258 4,0.2579,0.2511, and 0.2381, respectively. Over the next five years, the scores for Zhejiang Province, Chongqing City, and Hubei Province are expected to decline, with Hubei Province experiencing a significant drop to an "average" level. The other four provinces will see steady or slightly improving development levels.

Chongqing's score decline is mainly due to its relatively low return on net assets, while corporate profitability is positively correlated with carbon disclosure levels. An increase in the return on net assets reflects enhanced corporate profitability, which in turn encourages companies to disclose carbon information more proactively. This not only helps companies secure more funds and resources but also attracts investment and shapes an image of a "green and environmentally friendly enterprise." The main reason for Hubei Province's score decline lies in its smaller scale of enterprises and lower levels of cross-listing. Generally, the larger the enterprise, the more social resources it occupies, and the higher its carbon emissions. According to social responsibility theory, large enterprises should bear greater environmental and social responsibilities. Moreover, cross-listing is positively correlated with the quality of carbon accounting disclosures, as cross-listed companies face regulatory pressures from multiple regions and tend to strengthen carbon disclosures to reduce operational risks.

(3) Regions with "average" levels of carbon accounting information disclosure include Hebei Province, Shanxi Province, Anhui Province, Liaoning Province, Central China (excluding Hubei Province), Guangxi Zhuang Autonomous Region, Hainan Province, Southwest China (excluding Chongqing Municipality), and Northwest China, with scores ranging from 0.131699 to 0.221297. Predictive assessments for the next five years show that the scores and rankings of Central China, Liaoning Province, and Qinghai Province have all declined, with Henan Province falling to a "poor" level by 2028.

Provinces with a significant decline in scores have lower proportions of independent directors. The size of the board and the proportion of independent directors are positively correlated with the level of corporate carbon disclosure. Independent directors generally focus more on their own interests and will require management to enhance carbon disclosure to improve the company's reputation and performance, thereby enhancing their own prestige. Therefore, independent directors typically

constrain decisions made by the shareholders meeting and the board of directors, promoting stronger information disclosure.

Finally, the regions with the "worst" performance in the development of carbon accounting information disclosure are Jilin Province and Heilongjiang Province, with scores of 0.112004 and 0.073667 respectively. In the next five years, the level of carbon accounting information disclosure in these two provinces will continue to decline.

Among the main reasons for low development levels are poor performance in return on net assets, development level, and economic environment. Data from the past five years show that the development levels of the two provinces are relatively backward, even showing negative growth. The ability of enterprises to develop is positively correlated with their level of carbon information disclosure; companies with strong development capabilities tend to proactively disclose carbon accounting information. To maintain sustainable development capabilities, companies should formulate targeted strategies at different stages, increase investment in low-carbon technology research and development, enhance corporate image to boost investor confidence. From an economic environment perspective, the per capita GDP level of the region where a company is located is positively correlated with the quality of carbon accounting information disclosure. Economically underdeveloped regions find it relatively difficult to attract management talent and introduce advanced energy-saving and emission reduction technologies, while economically developed regions have higher public environmental awareness, stricter government and environmental department regulations on carbon emission governance and supervision, and clearer requirements for corporate carbon information disclosure.

7. Recommendations

7.1 Attach Importance to the Role of Independent Directors and Optimize the Structure of Directors

To improve the development level of carbon accounting information disclosure, it is essential to optimize the board structure and emphasize the role of independent directors. First, pay attention to the proportion of independent directors. The overall ratio of independent directors in Chinese companies is between 0.36 and 0.38. Therefore, it is recommended to set this ratio higher to encourage companies to proactively disclose carbon accounting information. Second, recognize the importance of independent directors and fully leverage their functional advantages. Independent directors should effectively oversee the company’s carbon reduction and carbon disclosure efforts, guiding high-quality carbon accounting information disclosure. Finally, encourage companies to optimize their board structures, diversify demographic composition, and enhance the development level of carbon accounting information disclosure through measures such as introducing fresh young talent into the board.

7.2 Improve Environmental Protection Concept and Implement Environmental Awareness

Environmental awareness determines environmental behavior, integrating environmental concepts into corporate culture and establishing a green development perspective. In specific measures, on one hand, environmental concepts are incorporated into the core values of the company, with ideas such as environmental protection and sustainable development written into the corporate charter, and enhancing the environmental awareness of senior management, integrating environmental concepts into strategic decision-making. On the other hand, a sound environmental management system is established to implement environmental concepts; comprehensive environmental management systems are formulated, environmental information disclosure is strengthened, social supervision is accepted, and it is ensured that these systems are effectively enforced.

7.3 Expand the Pilot Trading of Carbon Emission Rights and Strengthen the Demonstration Effect of the Pilot

Pilot carbon emission trading programs significantly enhance the quality of corporate carbon accounting information disclosure. First, the scope of carbon emission pilots should be expanded to include more high-energy-consuming and high-emission industries such as building materials, non-ferrous metals, and chemicals, and encourage more regions to participate, forming a multi-level and multi-sector pilot system. Second, differentiated pilot models should be explored based on the characteristics of different industries and regions. Finally, it is necessary to timely summarize pilot experiences to develop replicable and scalable models, providing reference for the construction of a national carbon market and the improvement of carbon accounting information disclosure systems.

7.4 Improve Laws and Regulations to Facilitate Information Disclosure

To achieve the "dual carbon" goals, China needs to accelerate the improvement of its carbon accounting information disclosure system. Currently, corporate carbon accounting disclosures mainly rely on voluntary principles, leading to issues such as incomplete content and inconsistent standards. To address this, the government can establish unified standards for carbon accounting information disclosure, specifying the content and quality requirements; secondly, strengthen supervision by environmental protection departments to effectively manage non-compliant companies; finally, improve relevant laws and regulations on carbon accounting information disclosure, establish incentive and constraint mechanisms, and enhance companies enthusiasm for disclosure. At the same time, the government should guide the development of a green and low-carbon development system, encourage companies to increase research and development in clean technologies, and promote low-carbon transformation. By combining policy guidance with regulatory measures, the quality of corporate carbon information disclosure can be improved, providing institutional support for achieving the "peak carbon emissions and carbon neutrality" goals.

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