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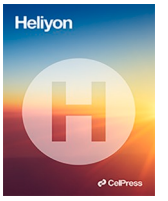

Executives' carbon cognition and corporate carbon performance: The mediating role of corporate low-carbon actions and the moderating role of firm size

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ABSTRACT

Executives' carbon cognition (ECC) is an important driving factor for enterprises to achieve carbon performance (CP) through low-carbon actions, but the existing research has not explored the mechanism between them. Based on the data of 440 Chinese listed companies from 2012 to 2021, we used text mining method to construct the index of ECC, and obtained noteworthy results through regression analysis. The results indicated that ECC has a significant positive impact on corporate low-carbon actions (CLA); CLA has a significant positive impact on CP; CLA plays a mediating role in the relationship between ECC and CP; in addition, firm size negatively moderates the positive impact of ECC on CLA; firm size negatively moderates the mediating effect of CLA on the relationship between ECC and CP. The research conclusions deepen the understanding of the relationship between ECC and CP in the context of carbon neutrality era, and provide theoretical guidance for guiding companies to actively implement low-carbon actions. At the same time, this study introduces the text mining method into the research of ECC, which provides a reference for future research in this field.

1. Introduction

The Paris Agreement's full implementation has made carbon neutrality the center of attention on a global scale. As market players undertaking low-carbon development strategies, enterprises need to correlate low-carbon concepts with their core strategies to form low-carbon core competitive advantages and achieve sustainable and high-quality development. According to the theory of strategic cognition, executive cognition plays a decisive role in organizational behavior and is a direct factor influencing the formulation of corporate strategies. Therefore, the leading role of executives' carbon cognition (ECC) cannot be ignored when studying the influencing factors of enterprises' low-carbon development. ECC is the cognitive structure and cognitive process in which executives interpret and judge carbon-related information and knowledge, and apply them to corporate decision-making, which can support the process of corporate low-carbon development. Because executives can change products, technologies, and processes [1], such enterprises with high ECC are more flexible in terms of carbon reduction [2]. As a performance evaluation of greenhouse gas emissions,

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carbon performance (hereinafter referred to as CP) reflects the degree of fulfillment of corporate environmental responsibility and reveals the benefits of its current carbon input and output activities [3], as well as the results of its internal governance decisions and behaviors. Therefore, it is of great practical significance to explore the action mechanism of ECC on CP through corporate low-carbon actions (CLA) for excavating the path of low-carbon development.

This study attempts to explore the boundary conditions of the above mechanism from the perspective of firm size. Firm size is an important indicator of its resources and represents an objective capability of the enterprise; while ECC dominates the attitude of the whole enterprise towards low-carbon development to a certain extent, which is a manifestation of the subjective cognition of the enterprise, and there is a complex interaction between them. On the one hand, the implementation of CLA is closely related to executives' subjective cognition and strategic preference, and on the other hand, it will also be constrained by their organizational resources. In other words, how a company implements low-carbon actions is influenced by what it "wants to do" and what it "can do." Some studies believe that the larger the enterprise is and the more capital and technology it has, the better the performance of its low-carbon actions will be [4–6]. However, larger firms may also suffer from organizational rigidity and inertia due to excessive procedural costs, may be subject to stricter environmental regulations and choose to passively obey the system, or may lose the competitive advantage of low-carbon innovation by choosing a conservative strategy. Hence, this study believes that the relationship between firm size and CLA may not be a simple linear relationship, and the effect of firm size is interacted with ECC to influence CLA. Therefore, this study introduces the moderating variable of firm size and integrates it with the interaction of ECC, and intends to investigate the mechanism role of firm size in the transformation process between ECC and CLA; meanwhile, a moderated mediation model is constructed for empirical test of large sample data, and the differences in the mediating role of CLA under different firm sizes are discussed.

Our research objectives can be attributed to the following questions: (1) can ECC promote more CLA? (2) can CLA improve the CP of enterprises? (3) can ECC promote the improvement of CP? (4) as one of the important intrinsic characteristics of enterprises, what role does firm size play in the relationship among ECC, CLA and CP? Most of the literature mainly focuses on the impact of demographic variables of executives and heterogeneity of the executive team on corporate performance, such as executives' working experience [7], educational background [8], and work history [9]. Although such indicators are easier to obtain, they are difficult to fully reflect the characteristics of executives' cognitive judgment, analysis and decision-making processes. Because ECC is the beginning of CLA, the lack of such research limits the understanding of ECC in creating corporate value and the mechanism behind them. On the other hand, studies on how to measure CLA mostly focus on its practice scale [10], and few studies have been conducted on CLA from the perspective of capitalization and expensing. In addition, studies on the drivers of CLA are mostly conducted from the perspective of government subsidies and tax incentives [11], the environmental regulations [12–14], the needs of consumers and the public [15,16], regulatory pressure [17], etc. These research perspectives only focus on external factors, ignoring the subjective initiative of enterprises. At the same time, there are differences in knowledge, resources, and capabilities among enterprises of different sizes. Some scholars believe that large enterprises have economies of scale and scope, so they will carry out more innovative behaviors [18,19]. However, some scholars hold different opinions, arguing that the expansion of enterprise-scale will make enterprises dull and rigid in innovation incentive, decision-making and management [20,21]. This literature is still insufficient to discuss the specific moderating mechanism of firm size. Therefore, it is of great practical significance to consider and test the above problems.

To fill the above gaps, we explore the relationship among ECC, CLA and CP based on theoretical analysis and empirical analysis, and try to expand the existing research from the following four aspects to make some contributions. (1) The text mining method is used to assign ECC values to sample enterprises, and the relationship between ECC and CLA is investigated. ECC is an abstract concept, and academics generally use questionnaires to measure this kind of concept of executive cognition, but such cross-sectional data are highly subjective, have small sample sizes, and lack the validation of medium- and long-term panel data of listed companies, and the research findings have certain limitations. Therefore, this study seeks objective alternative indicators to quantify ECC, that is, text mining is used to reason out ECC through keyword frequencies in the publicly released reports (social responsibility reports, sustainable development reports and ESG reports) of listed companies. From the perspective of research methods, the measurement method of ECC developed in this study based on text mining can facilitate research on ECC in large samples, across industries and companies, which has certain theoretical contributions. (2) We measure CLA from two dimensions of capitalization and expensing, and test the impact of CLA on CP. For the data of mediating variables, based on the previous research method, the publicly released financial indicators of companies are used as the proxy variables of corporate behaviors [22], and the data of low-carbon related investment expenditures and expenses in the annual reports of listed companies are summed up as the proxy variables of CLA. Compared with the practice scale approach, the approach using financial indicators is more informative and credible, and more verifiable at a later stage [23]. (3) ECC, CLA and CP are included in the same analytical framework, and CLA is used as the mediating variable to study the effect path of ECC on CP. This has enriched the relevant research on the internal drivers of CLA and its consequences, and also provided a reference for enterprises to win market opportunities and improve their CP in the context of carbon neutrality. (4) We explore the moderating effect of firm size, test the influence of ECC on CLA and the mediating effect of CLA under different firm sizes, and reveal the result that the mediating effect of CLA in smaller firms is more significant. In terms of theoretical contribution, this study highlights the interactive mechanisms of organization character on executives' cognition and extends the mechanism among "ECC-CLA-CP".

2. Literature review and hypotheses development

2.1. Executives' carbon cognition and corporate low-carbon actions

The psychological term "cognition" represents the individual's ability to perceive, judge, reason, and construct ideas in response to organizational and environmental stimuli, which serves as the foundation for behavior and decision-making [24]. In this study, ECC is

defined as the cognitive structure and cognitive process of corporate executives in interpreting, judging and reasoning carbon-related information and knowledge, and applying them to corporate decision-making in the face of complex internal and external environments. ECC mainly includes three dimensions: carbon information perception, low-carbon competitive advantage cognition and environmental responsibility awareness. Among them, carbon information perception refers to the acquisition of information and knowledge related to carbon issues, and the knowledge and understanding of carbon related policies; low-carbon competitive advantage cognition refers to the knowledge and understanding of the competitive advantage brought by low-carbon development strategy and the emphasis on carbon reduction and carbon control in the process of enterprise operation and production; environmental responsibility awareness refers to the concern for ecological environment and the willingness to undertake corresponding environmental protection responsibilities.

The strategic cognition theory holds that the antecedent variable of corporate behavior is the subjective cognition of executives [25]. The carbon knowledge and information possessed by executives form their cognitive framework, which is the basis of the cognitive structure [26]. Narayanan et al. [27] pointed out that cognitive structure represents stable characteristics and repeated behavior patterns, and the difference in cognitive structure is an important reason for the difference in decision-making. Based on this, this study believes that different levels of ECC among enterprises will lead to different strategic decisions, which in turn lead to different low-carbon behaviors among enterprises. In addition, Aragon-Correa [28] argued that executives' intentions can influence enterprises' choices of environmental behaviors. Similarly, Liu et al. [29] confirmed that "environmental behavioral intentions have a significant effect on pro-environmental behaviors". Therefore, this study believes that ECC can effectively drive CLA through subjective motivation, that is, the higher the level of ECC is, the more inclined the companies are to take low-carbon actions to promote their own development. Specifically: (1) Based on the perspective of carbon information perception. High quality development driven by carbon neutrality has become the main theme of development at home and abroad. In this context, executives incorporate the acquired, digested and converted low-carbon information into their actual operation, forming the dominant logic and cognitive inertia in enterprise management, serving the company's low-carbon strategy and promoting the implementation of low carbon actions. (2) Based on the perspective of low-carbon competitive advantage cognition. Executives with a higher level of carbon cognition tend to regard low-carbon development as a window of opportunity for enterprises to obtain long-term benefits. The core driver of low-carbon development in enterprises is technological innovation, which can enhance the leading edge of enterprises in the industry. However, low-carbon technology innovation is characterized by high investment and high risk, which makes companies not assign priority allocation to it in terms of resources and capabilities. As the controllers of corporate resources and capabilities, executives' willingness to use corporate resources for low-carbon technology innovation depends on their carbon cognition level. The stronger the ECC is, the more likely they are to achieve original and unique leading advantages through low-carbon technological innovation. Cadez and Czerny [30] conducted case studies on two Slovenian manufacturing enterprises and found that the two enterprises had accumulated a great deal of knowledge about carbon emission reduction prior to the implementation of the Emissions Trading Scheme (EU ETS), implying that the ECC of the case enterprises had increased. Moreover, the carbon management strategies adopted by the two companies gave them a competitive advantage. (3) From the perspective of environmental responsibility awareness. Executives with a higher level of carbon cognition will take the initiative to implement CLA by improving processes, adopting clean energy and environmental protection equipment, and effectively reducing the emissions of "three wastes" and the consumption of corporate resources and energy. At the same time, executives with a higher level of carbon cognition will regard the needs of stakeholders as their own responsibility, improve stakeholders' satisfaction, and thus gain stakeholders' recognition for the fulfillment of corporate environmental responsibility. Therefore, the following hypothesis is proposed.

H1. ECC has a positive effect on CLA.

2.2. Corporate low-carbon actions and carbon performance

In this study, we regard CP as the corresponding economic benefits of output per unit of CO2 emissions caused by enterprises in the production process, and use it to measure the input-output effect of CO2-related activities. To a certain extent, the level of CP can reflect the effectiveness of carbon emission reduction of enterprises. CLA is a behavior of sustainable development of enterprises and an effective means for enterprises to assume the responsibility of carbon emission reduction. Enterprises integrate various resources and improve CP through resource interaction. Specifically, enterprises' low-carbon process innovation can reduce pollutant emissions in the production process and improve the resource utilization efficiency of the process [31]; enterprises can reduce their external losses and environmental costs through clean technologies such as carbon capture and carbon storage. Wang et al. [32] studied the influencing factors of carbon dioxide emissions in China and found that low-carbon technology progress inhibited carbon dioxide emissions. Cole et al. [33] have studied Japanese companies and found that investment in research and development can significantly curb their carbon emissions. Yin et al. [34] used the ratio of R&D investment to GDP as a proxy variable for technological progress, and found that technological progress is conducive to CO2 emission reduction. Cadez et al. [2] took 247 European GHG intensive enterprises as samples and found that more implementation of GHG emission reduction strategies by enterprises could not only reduce GHG emissions, but also reduce GHG-related costs. Zheng et al. [35] focused their research on green agriculture and found that "the carbon emission per unit area of green agricultural products was significantly lower than that of ordinary agricultural products". Based on the above literature analysis, we propose the following hypotheses.

H2. CLA has a positive effect on CP.

2.3. The mediation role of corporate low-carbon actions

Based on the logic of "cognition-strategic behaviors-performance," Nadkarni and Narayanan [36] studied the data of 225 sample enterprises and confirmed that executives' cognition would affect corporate performance through its impact on effective strategic behaviors. Under the trend of carbon neutrality, the level of executives' discrimination and processing of decision-making information depends on their cognitive ability. At the same time, based on the premise of limited rationality of executives, the limited information processing capacity of executives causes changes in the allocation of executive attention resulting in a screening mechanism [37]. Therefore, differences in carbon cognition among executives can lead to differences in low-carbon actions among firms. Cadez et al. [2] conducted a study of European carbon-intensive enterprises participating in the EU Emissions Trading System, with respondents including CEOs, chief environmental executives, or CFOs. The data collected through these executives' cognition of corporate environmental strategy confirmed that enterprises with a high awareness of environmental factors in the strategic planning process will have a higher degree of implementation of their GHG reduction strategy. Furthermore, the use of green products and processes by enterprises for the purpose of protecting ecology is not only the embodiment of CLA, but also the key to improving CP of enterprises. Specifically, enterprises will make comprehensive use of resources, develop low-carbon or zero-carbon technologies through new processes, achieve energy conservation, reduce the output of carbon emissions, and ultimately improve CP. To sum up, the stronger the carbon cognition of executives, the more they can drive enterprises to actively take low-carbon actions, and the more conducive it is to the improvement of corporate CP. Therefore, the following hypothesis is proposed.

H3. ECC is positively related to CP indirectly via CLA.

2.4. The moderating role of firm size

Firm size is an important attribute that reflects enterprise resources. When faced with the external environment, companies behave differently depending on the amount of resources they have. Enterprises of different sizes have different behavioral logics and pursue different value creation goals in low-carbon development. Therefore, the relationship among ECC, CLA and CP in enterprises of different sizes is heterogeneous.

First of all, this study proposes that the effect of ECC on CLA may be affected by firm size. Guagnano et al. [38] developed the "Attitude-Context-Behavior" theory, which suggests that behavior variable is the result of the interaction between attitudinal variable and contextual factor, and validates the moderating role of the contextual factor in the relationship between environmental attitude and environmental behavior. According to the "Attitude-Context-Behavior" theory, ECC (attitude) is the antecedent variable of CLA (behavior), and firm size (context) plays a moderating role in the relationship between the two (attitude-behavior). On the one hand, from the perspective of organizational structure, when an enterprise is large, its organizational structure tends to be complex and perfect. CLA requires coordination and cooperation involving multiple departments, but too many procedures and norms often lead to organizational rigidity and inertia, making it difficult to respond to the current mega-trend of low-carbon development with rapid and effective action. For small enterprises, the flexibility of their organization is a key characteristic to stimulate innovation [39], which allows executives to use their carbon cognition to achieve business model innovation in low-carbon trends. ECC can quickly identify the niche market that larger enterprises have not yet occupied, grasp the new opportunities in the low-carbon product market, promote the efficient low-carbon actions, and then achieve the goal of low-carbon development of enterprises. On the other hand, from the perspective of environmental regulation, the larger the size of an enterprise is, the larger its emissions are, and the stricter the environmental regulation by the government is. In this case, the low-carbon actions of enterprises may not be the active behavior choice of executives according to their own cognition, but may be the passive obedience to the system. Therefore, in larger enterprises, the impact of ECC on CLA may be weakened. Therefore, the following hypothesis is proposed.

H4a. Firm size negatively moderates the positive effect of ECC on CLA, such that when the level of firm size is low, the positive effect of ECC on CLA is enhanced, and when the level of firm size is high, this relationship is weakened.

Secondly, firm size will affect the relationship among "ECC–CLA–CP". Firm size will affect organizational strategic decision-making, resulting in different results in the integration and allocation of enterprise resources [40]. From the perspective of market competition, larger firms have a favorable position in their industry and executives can maintain an advantage by conducting the firm in a prudent manner. Therefore, such enterprises may prefer a conservative strategic style that is prudent. In addition, although it is easier for larger enterprises to obtain scarce resources, it will also affect their innovation motivation and innovation efficiency [41], thus weakening their profitability [42]. In addition, it should not be ignored that the larger the firm size, the greater the emissions and the more serious the pollution to the environment. Therefore, the larger the firm size, the more costs it needs to pay to improve its CP. However, for smaller enterprises, due to their limited internal and external resources, and the need to continuously expand market share and improve business performance, it is difficult to solve the development problem only by relying on the strategy of following the rules. Therefore, in the current external environment advocating low-carbon development, smaller enterprises may prefer to take aggressive low-carbon actions to gain competitive advantages [43], rapidly gather innovation resources in a short period of time, and thus significantly improve CP. To sum up, combined with the elaboration of H3 and H4a, this study puts forward a moderated mediating effect hypothesis.

H4b. Firm size negatively moderates the indirect effect of ECC on CP via CLA, such that the positive indirect effect becomes stronger when the level of firm size is low than when firm size is high.

Our arguments culminate into a conceptual model (Fig. 1), which aims to reveal the intrinsic mechanism through which ECC

enhances CP. On the one hand, this study analyzes relationship among ECC, CLA and CP. On the other hand, this study takes firm size into account and analyzes its moderating effect on the relationship of "ECC–CLA–CP".

3. Research methodology

3.1. Data collection

There are two stock markets in Mainland China, the Shanghai Stock Exchange and the Shenzhen Stock Exchange, in which the stocks traded are A-shares and B-shares. Since B-shares are traded in foreign currencies and in smaller quantities, this study only covers A-shares in the Shanghai and Shenzhen Stock Exchanges. A-shares refer to ordinary RMB shares circulating in the Chinese market and are one of the main investment targets in the Chinese stock market. The A-share market is also the largest, most liquid and most traded stock market in China. In 2007, the China Securities Regulatory Commission (CSRC) issued the *Measures for the Management of Information Disclosure of Listed Companies*, which stipulated that listed companies should regularly disclose annual, interim and quarterly reports. According to the provisions of the CSRC, the contents disclosed in the periodic report include the basic situation of the company and the main accounting data and financial indicators. The information regularly disclosed by these listed companies is released after auditing, which is an important basis for reflecting the company's operating conditions. Therefore, the selection of Shanghai and Shenzhen A-share listed companies as research samples can ensure the availability and accuracy of data.

In addition, we limited the industry types of sample companies to take into account carbon reliance. According to Cadez and Czerny [44], "carbon reliance refers to the degree to which the existing business processes of firms are dependent on the usage of carbon resources". They claim that a company's climate change mitigation strategy depends on its carbon reliance. Moreover, an important determinant of which carbon-based resources a firm uses and its relative carbon efficiency is its type of industry [44]. Therefore, it would be more practical for us to limit our sample to carbon-intensive industries.

The sample companies in this study are limited to five types of industries: energy industry, manufacturing industry, agriculture industry, construction industry and transportation industry. The reasons for selecting these industries are as follows. (1) Energy industry. According to the *BP Statistical Review of World Energy 2019*, carbon emissions from China's power sector account for about 40 % of the country's total emissions. Thermal power enterprises rely heavily on fossil fuels, which have a significant impact on climate change. However, enterprises in the energy sector are expected to achieve significant carbon efficiency gains and reduce CO2 emissions through energy conversion progress [45]. (2) Manufacturing industry. The two main types of CO2 emissions from carbon-intensive enterprises are combustion and process emissions, with process emissions occurring almost exclusively in the manufacturing industry [44]. Steel enterprises, for example, are the single largest source of carbon emissions in the industrial system, using fossil fuels at every step, from heating semi-finished products to rolling steel into plates. Cadez and Guilding [45] pointed out that enterprises in the manufacturing industry can improve the carbon efficiency of combustion by reducing the combustion emissions per unit of positive output. (3) Agriculture is an important source of greenhouse gas emissions [46]. Nitrogen-rich fertilizers used in agriculture produce large amounts of greenhouse gas emissions, and the use of chemicals such as pesticides and herbicides affects the soil's ability to sequester carbon. (4) The construction industry has significant characteristics such as high energy consumption, high emission and low efficiency. Significant amounts of greenhouse gases are generated during the production and transportation of building materials, construction, demolition and operation of buildings. According to the *Series Research Report on Carbon Emissions in China's Urban and Rural Construction in 2022*, the total energy consumption of buildings and construction accounted for 45.5 % of China's total energy consumption in 2020; its total carbon emissions and operational carbon emissions accounted for 50.9 % and 21.7 % of the country's total carbon emissions, respectively. (5) Transportation industry. The inherent components in gasoline and diesel produce greenhouse gases when burned. A large amount of automobile exhaust has caused the waste of fossil fuel resources and the pollution of the ecological environment.

In this study, A-share listed enterprises in Shanghai and Shenzhen during 2012–2021 are selected as research samples. In 2012, the Chinese government made the strategic decision of "vigorously promoting the construction of ecological civilization", and companies started to focus on low-carbon development from that year onward. In addition, as some enterprises have not released the financial data related to low-carbon actions in 2022, the research sample ends in 2021. The data of ECC come from the publicly released social responsibility reports, corporate sustainable development reports and ESG reports of the sample enterprises. The data of CLA come

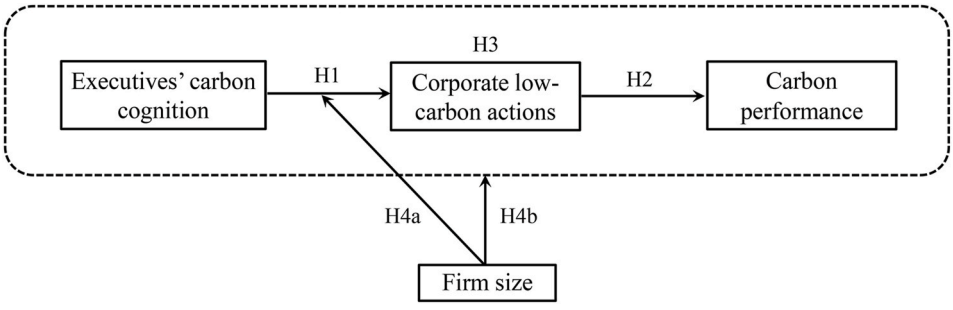

Fig. 1. Conceptual model.

from corporate annual reports. Industry energy consumption is derived from the *China Energy Statistical Yearbook*. The reference coefficients for energy carbon emissions are derived from the Emissions Trading Network. Additional data are obtained from Wind database and CSMAR database. In this study, the original samples are processed as follows: (1) eliminating enterprises with missing data; (2) excluding ST, *ST and PT enterprises Finally, 1545 observations of 440 listed companies are obtained, which are mainly concentrated in the manufacturing industry (accounting for 83 %). To avoid the effect of sample outliers, we winsorize all continuous variables by 1 %.

3.2. Measurement instruments

3.2.1. Executives' carbon cognition

Executive cognition is an abstract concept derived from psychology, which is difficult to measure. Scholars have generally used interviews or questionnaires to measure the cognitive level of subjects. However, the questionnaire approach usually suffers from low response rates and subjective bias in response results [47]. Therefore, this study will seek objective alternative indicators to quantify ECC, that is, through text mining of social responsibility reports, ESG reports and corporate sustainable development reports issued by listed companies. Text mining is "the process of extracting interesting, implicit and non-trivial patterns or knowledge from text documents" [48]. Many studies have used text mining methods to conduct research in the financial field, such as the discussion on the correlation between the readability of accounting text information and enterprise performance [49,50], discussion on the correlation between executive tone and future corporate performance [51,52]. In addition, some scholars have constructed word lists specifically for sentiment or tone analysis of financial texts based on specific financial texts [53,54], and they have been widely used. Using text mining method to construct ECC has the following advantages. Features such as corporate values, governance structure and self-expectations are mapped to some extent into the text [55–57]. Such information on corporate low-carbon development strategies is more probably to be reflected in corporate social responsibility reports, ESG reports, and sustainability reports. The publicly released reports of enterprises are approved by executives, and the information conveyed in the reports is recognized by executives and communicated to the public. Moreover, the vocabulary usage in the reports can reflect the business philosophy promoted by executives. Hence, it is viable and reasonable to utilize the text mining method to transform the non-quantitative information of ECC hidden in the report into quantifiable data, and conduct meaningful data classification and analysis.

The specific construction of ECC indicators in this study is as follows: (1) Collect and screen social responsibility reports, corporate sustainable development reports and ESG reports from 2012 to 2021 for a sample of Chinese A-share listed companies. (2) Build a lexicon of ECC. A certain number of enterprise samples with high ECC are selected by means of manual judgment. The judgment criterion comes from the theoretical analysis. That is, whether executives have a grasp of carbon-related information (carbon information perception), whether they attach importance to carbon reduction and carbon control in the process of enterprise operation and production, and to low-carbon technological innovation (low-carbon competitive advantage cognition), and whether they pay attention to the external ecological environment (environmental responsibility awareness). Then, the Jieba Chinese word splitting function based on Python is used to split the selected samples into words and conduct word frequency statistics to filter out the high-frequency words related to ECC and form the initial seed word set. After that, the seed word set needs to be expanded with similar words, because expressors often use multiple words with similar semantics to describe the same concept. Word2Vec machine learning technology developed by Mikolov et al. [58] is based on the word embedding method. This method represents words into multi-dimensional vectors according to contextual semantic information and obtains the semantic similarity between words by calculating the similarity between the vectors. Therefore, Word2Vec machine learning technology is used to train the total sample based on the seed word set, and the similar words of the seed words are obtained to form the final ECC keyword lexicon, with a total of 101 keywords. (3) Based on the above keyword lexicon, the disclosure times of ECC keywords in the sample reports are counted. Social psychology believes that language can reflect people's cognition [59], and the type and frequency of words used in subjects' language can be used to analyze people's characteristics [60,61]. Thus, the frequency of word occurrence represents the degree of attention that executives pay to information related to it, i.e., the higher the word frequency, the more attention executives allocate to that information. (4) Finally, considering the typical "right-biased" nature of this type of data, this study logarithmizes the keyword frequency to obtain the indicators to characterize ECC. In the robustness test, the ratio of the keyword frequency of the sample companies to the mean value of the total keyword frequency of all samples in the same industry in the same year is used as a proxy indicator, and the regression test is conducted again.

3.2.2. Corporate low-carbon actions

CLA can be regarded as a series of corporate behaviors related to low energy consumption, low pollution and low emissions in the process of production and operation. There is no mature measurement index system for CLA in existing studies. Some scholars measured corporate carbon emission reduction behavior from the aspects of KLD index [62] and corporate pollution emissions [63]. However, such indicators cannot reflect the intensity of CLA. Plumlee et al. [23] pointed out that corporate low-carbon behaviors could be measured by the financial data disclosed by enterprises, as they are more informative and credible, and can be more verifiable at a later stage. Thus, this study divides CLA into two dimensions: capitalized and expensed. Capitalized CLA includes investments in developing cleaner production technologies, researching environment-friendly products, and improving environmental management capabilities; expensed CLA includes the increased operating costs to combat pollution, improve environmental quality, and meet environmental standards. Based on this, this study sums up the expenditure items related to low emissions, low pollution and low energy consumption in the schedule of notes on construction in progress, statement of general and administrative expenses, and schedule of other payables of the annual report of the enterprise, such as desulfurization and denitrification, sewage treatment, energy

saving, dust removal, waste gas and waste residue treatment, environmental treatment, ecological restoration and clean production project data. It is divided by total assets at year-end for standardization to obtain the final measurement index of CLA.

3.2.3. Carbon performance

At present, there are two main methods for evaluating CP. One is the single-factor CP evaluation index. For example, Clarkson et al. [64] measured CP of enterprises by using the operating income obtained per unit of carbon emission. Busch and Hoffmann [65] used the ratio between total greenhouse gas emissions and corporate sales to measure. The second method is to build a CP evaluation index system. For example, Ozawa-Meida et al. [66] used LCA life cycle method to construct CP evaluation index system. Dong et al. [67] adopted the input-output analysis method to construct CP index system. Given the performance and applicability of the indicators, we choose a single indicator to measure CP. According to the method proposed by Clarkson et al. [64], we define CP as: CP = operating income/corporate carbon emission. The higher the value, the better the CP of the enterprise.

Because there is no mandatory disclosure of corporate carbon emissions in China, few companies voluntarily disclose their annual carbon emissions in their social responsibility reports. Therefore, we use industry carbon emissions to estimate corporate carbon emissions. Industry carbon emission is equal to industry energy consumption multiplied by the corresponding energy carbon emission coefficient. Corporate carbon emissions are defined as: corporate carbon emissions = (industry carbon emissions/industry operation costs) x corporate operating costs. Finally, CP value is obtained: corporate CP = Ln (operating income/corporate carbon emissions).

3.2.4. Firm size

Firm size reflects the concentration of its labor force and means of production, and is an important indicator depicting the abundance of resources of an enterprise, which is generally measured by total assets in empirical studies. With reference to previous studies, the natural logarithm of year-end total assets is used as a measure of firm size in this study.

3.2.5. Control variables

In this study, total asset turnover (ATO), inventory ratio (INV), independent director ratio (Indep), ownership concentration ratio (OC), number of directors (Board), management expense ratio (Mfee), and Debt to asset ratio (Lev) are selected as control variables. Furthermore, this study adds year (Year) and industry (Industry) control variables to the model to control the impact of industry factors and macroeconomic environment in different years. The industries of listed enterprises are classified in accordance with the industry classification standards promulgated by China Securities Regulatory Commission in 2012, and the manufacturing industry is sub-divided according to the first two codes. The specific definitions of variables are listed in Table 1.

4. Results

4.1. Descriptive statistics of the measurement scales and correlation analysis

Firstly, we conducted a descriptive statistical analysis of each variable to be studied (see Table 2). ECC, CLA and CP in the sample enterprises all have large differences, which shows certain research significance. Secondly, before doing the regression analysis, we conducted correlation analysis and multicollinearity analysis. The results of Pearson correlation test (see Table 3) show that ECC and CLA are significantly positively correlated at the level of 1 % level, and CLA and CP are significantly positively correlated at the level of 5 %, which has initially verified the research hypothesis proposed above. Additionally, the correlation between the control variables and the main variables is also certain, and the correlation coefficients between the variables are all below 0.6 and most of them are less than 0.2. In order to further test whether there is multicollinearity among the variables in the research model, we conducted the

Table 1
Variable definitions.

Type of variables	Variables	Code of variables	Description
Variable explained	Carbon performance	*CP*	Ln (Operating income/corporate carbon emission)
Explanatory variable	Executives' carbon cognition	*ECC*	Calculated by text mining method
Mediating variable	Corporate low-carbon actions	*CLA*	Total low-carbon related expenditures in the annual report/total assets at the end of the year
Moderating variable	Firm size	*Size*	Natural logarithm of total assets at the end of the period
Control variables	Total assets turnover	*ATO*	Operating income/average total assets
	Inventory ratio	*INV*	Net inventory/total assets
	Independent director ratio	*Indep*	Number of independent directors/directors
	Ownership concentration ratio	*OC*	Shares held by the top five shareholders/total shares
	Number of directors	*Board*	Natural logarithm of the number of board members
	Management expense ratio	*Mfee*	Management expense/operating income
	Debt to asset ratio	*Lev*	Total liabilities/total assets
	Year	*Year*	Year dummy variable
	Industry	*Industry*	Industry dummy variable

Table 2
The statistical description of the variables.

	N	Mean	SD	Min	Max
ECC	1545	1.813	0.365	0.778	2.603
CLA	1545	0.007	0.014	0.001	0.089
CP	1545	7.555	0.742	5.339	9.800
Size	1545	23.306	1.323	20.578	26.574
ATO	1545	0.726	0.446	0.129	2.467
INV	1545	0.134	0.106	0.004	0.524
Indep	1545	0.372	0.054	0.333	0.571
OC	1545	0.558	0.163	0.203	0.895
Board	1545	2.214	0.209	1.609	2.708
Mfee	1545	0.069	0.049	0.007	0.271
Lev	1545	0.493	0.181	0.082	0.896

variance inflation factor (VIF) test for all the variables in the model (see Table 4). The VIF values among the variables are lower than 4, the threshold suggested by Hair et al. [68], indicating that there is no serious multicollinearity problem in the model estimations.

4.2. Case analysis

To more intuitively demonstrate the effect of the ECC and CLA measurement methods used in this study, we select one company in the sample for case analysis. Zhongjin Lingnan Nonferrous Metals Co., LTD. (hereinafter referred to as NONFEMET) is an international multi-metal resource company with lead, zinc and copper as its main business. To make the observation of NONFEMET's ECC clearer, the following analysis does not treat the word frequency logarithmically, which does not affect the trend of the data. NONFEMET's ECC is little different between 2013 and 2018 (minimum 21; maximum 41). This is followed by a sharp rise to 131 in 2019 and 134 in 2020. According to the executive personnel change data in the authoritative Chinese database CSMAR, NONFEMET changed its president in 2019. The personnel change in the company's top important positions has caused huge fluctuations in the ECC of the enterprise.

According to the analysis of NONFEMET's ECC, in 2019 and 2020, NONFEMET mentioned a large number of keywords such as "green upgrading", "green manufacturing", "green development", "recycling", "energy conservation" and "reduction of waste gas pollutants" in its social responsibility report compared to 2018. This indicates that after the change of the position of president with decision-making power, NONFEMET attaches great importance to the low-carbon transition. In 2020, NONFEMET's environmental investment was approximately 700 million yuan. The environmental protection projects carried out or put into operation include the technical transformation of low nitrogen capacity of boilers, the energy-saving environmental protection technology transformation of fuming furnaces, and the use of natural gas instead of gas, etc. In the same year, NONFEMET's CLA value of 0.0287 was the highest in its CLA data, and it also ranked at the top of the CLA score for manufacturing companies in the same year.

4.3. Testing the research hypotheses

Stata 16.0 was applied to test our proposed hypotheses, and Table 5 shows the results of the regression analysis of direct and mediating effects. The results in column (1) show that the coefficient of ECC and CLA is significantly positive at the level of 1 %, indicating that the higher the level of ECC, the better the performance of CLA. Therefore, H1 is validated. Column (2) shows that CLA has a significant positive impact on corporate CP ($\beta = 0.994$, $p < 0.05$). Therefore, H2 has been verified, that is, CLA can improve the CP of enterprises.

We refer to the mediation test procedure proposed by Baron and Kenny [69] to test the mediating role of CLA between ECC and CP. The first step is to test whether the regression coefficient of the independent variable (ECC) to the dependent variable (CP) is statistically significant. The results in column (3) of Table 5 show that ECC has a significant positive effect on CP ($\beta = 0.04$, $p < 0.05$), indicating that the next test can be carried out. The second step is to test whether the regression coefficient of the independent variable (ECC) to the intermediate variable (CLA) and the regression coefficient of the intermediate variable (CLA) to the dependent variable (CP) are statistically significant. The results in columns (1) and (2) of Table 5 are statistically significant, and then the third step analysis can be carried out. The third step is the regression of the independent variable (ECC) and intermediate variable (CLA) with the dependent variable (CP) simultaneously. The results in column (4) of Table 5 show that the coefficients of ECC and CLA are significantly positive at the level of 5 %, which means that CLA plays an intermediary role between ECC and CP. H3 is verified.

In order to further verify whether CLA has a mediating effect between ECC and CP, we learn from Hayes' method [70] and apply Bootstrap method to test the mediating effect, and also adopt Sobel method as a reference test. The results are shown in Table 6. The 95 % confidence interval of indirect effect based on 5000 bootstrap samples does not contain 0 (0.004–0.038), indicating that CLA is a valid mediating variable. In addition, we also use the sgmediation test command to conduct the Sobel test, and the Z-value is 2.675, corresponding to $P = 0.007 < 0.01$, indicating that the Z-value is significant, which supports CLA as a mediator variable for the influence of ECC on CP. Moreover, after accounting for the impact of CLA, the impact of ECC on CP is reduced by about 22.7 %. H3 is again verified.

We use SPSS hierarchical regression analysis to test the moderating effect of firm size on the relationship between ECC and CLA. In order to eliminate collinearity, we centralize the independent and moderating variables. First, the independent variable (ECC) and the

Table 3
Correlation coefficients of variables.

	1	2	3	4	5	6	7	8	9	10	11
1.CP	1.000										
2.ECC	−0.103***	1.000									
3.CLA	0.054**	0.155***	1.000								
4.Size	−0.052**	0.352***	−0.005	1.000							
5.ATO	0.071***	−0.026	−0.080***	0.082***	1.000						
6.INV	0.087***	−0.089***	−0.128***	−0.156***	0.139***	1.000					
7.Indep	0.035	0.022	−0.056**	0.070***	0.041	−0.021	1.000				
8.OC	−0.064**	0.142***	−0.017	0.298***	0.140***	−0.147***	0.064**	1.000			
9.Board	−0.124***	0.092***	−0.013	0.222***	−0.019	−0.024	−0.351***	0.076***	1.000		
10.Mfee	0.051**	−0.147***	−0.026	−0.393***	−0.474***	0.008	−0.029	−0.126***	−0.069***	1.000	
11.Lev	−0.210***	0.136***	−0.032	0.517***	0.012	0.029	−0.013	0.021	0.176***	−0.195***	1.000

Notes: Significance at the 10 %, 5 %, and 1 % levels is indicated by *, **, and ***, respectively.

Table 4
Results of multicollinearity test.

Variable	VIF	1/VIF
ECC	1.18	0.844
CLA	1.06	0.944
Size	2.01	0.498
ATO	1.39	0.719
INV	1.10	0.910
Indep	1.18	0.847
OC	1.17	0.857
Board	1.23	0.810
Mfee	1.56	0.642
Lev	1.44	0.696

Table 5
Regression results of the direct and mediating effects.

	(1)	(2)	(3)	(4)
	CLA	CP	CP	CP
ECC	0.005***		0.040**	0.036**
	(4.95)		(2.33)	(2.07)
CLA		0.994**		0.879**
		(2.26)		(1.98)
ATO	−0.002**	−0.106***	−0.106***	−0.105***
	(-2.25)	(-6.44)	(-6.50)	(-6.38)
INV	−0.012***	0.104*	0.090	0.100
	(-3.21)	(1.65)	(1.44)	(1.60)
Indep	−0.019***	0.044	0.017	0.034
	(-2.74)	(0.37)	(0.15)	(0.29)
OC	−0.002	0.072*	0.062	0.064*
	(-1.05)	(1.89)	(1.62)	(1.67)
Board	−0.003	−0.001	−0.006	−0.004
	(-1.42)	(-0.01)	(-0.20)	(-0.13)
Mfee	−0.003	0.692***	0.713***	0.716***
	(-0.36)	(4.62)	(4.74)	(4.77)
Lev	−0.003	−0.349***	−0.359***	−0.357***
	(-1.40)	(-10.10)	(-10.35)	(-10.28)
Constant	0.010	6.841***	6.811***	6.802***
	(1.53)	(61.28)	(60.17)	(60.11)
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Observations	1545	1545	1545	1545
R^2	0.101	0.905	0.905	0.905
Adj. R^2	0.088	0.904	0.904	0.904
F	7.74***	657.75***	657.91***	630.69***

Notes: (1) T statistics are reported in parentheses; (2) Significance at the 10 %, 5 %, and 1 % levels is indicated by *, **, and ***, respectively.

Table 6
Results of mediation effect test.

Variables			Bootstrap	Sobel
Variable explained	Explanatory variable	Mediating variable	95%CI	Z-value
CP	ECC	CLA	[0.004, 0.038]	2.675***

Notes: N = 1545; CI = confidence interval; Bootstrap samples = 5000.

moderating variable (firm size) are put into the regression equation of the first layer as predictors. Then, the independent variable (ECC), the moderating variable (firm size) and the interaction term (the product of the two decentralized variables) are put into the second layer regression equation to test whether the influence of ECC, Size and their interaction on CLA is significant. The results in Column (2) of Table 7 show that the interaction term between ECC and firm size has a significantly negative correlation with CLA. This shows that the larger the firm size is, the weaker the positive relationship between ECC and CLA is, thus verifying H4a. To more intuitively observe the moderating effect of firm size, we plot according to the method recommended by Aiken et al. [71]. Fig. 2 plots the effect of ECC on CLA at a high level of firm size (one standard deviation above the mean) and a low level of firm size (one standard deviation below the mean). As can be seen from Fig. 2, ECC has a steeper positive impact on CLA when the firm size is small, and H4a is empirically supported.

Furthermore, firm size is posited to moderate the mediating role of CLA between ECC and CP. We used the Model 8 in the PROCESS macro compiled by Hayes [70] to test the moderated intermediary model with the addition of control variables. The results in Table 8 show that when the firm size is small, the indirect effect of ECC on CP through CLA is 0.033 (CI = [0.0087, 0.0609]) ; when the firm size is large, the indirect effect of ECC on CP through CLA is 0.020 (CI = [0.0057, 0.0343]) . The results indicate that the indirect effect of ECC on CP through CLA is significant regardless of whether the firm size is large or small; and the effect coefficient is higher when the firm size takes a low value. In addition, the Index value of −0.005 in Table 8 with a confidence interval of [-0.0116, −0.0001] (excluding 0) also confirms that the indirect effect of ECC on CP via CLA varies at levels of firm size. Hence, H4b is supported.

4.4. Robustness tests

In this study, robustness tests were conducted by replacing the core variables and the results are presented in Table 9. First of all, considering that ECC may be correlated with the competitive and uncertain market environment, the measurement method of independent variable was replaced by "keyword frequency/mean value of total keyword frequency in the same industry in the current year" (variable code is ECC1). The regression results of module (1) in Table 9 indicate that ECC1 has a significantly positive effect on CLA ($\beta = 0.002$, $p < 0.01$); CLA plays a fully mediating role between ECC1 and CP ($\beta = 0.913$, $p < 0.05$); the interaction term between ECC1 and firm size has a significantly negative impact on CLA ($\beta = -0.001$, $p < 0.5$), thus H1, H3 and H4a are verified.

Finally, considering that national low-carbon development policies or public low-carbon awareness may have an impact on ECC and CLA, as well as that there may be omitted corporate governance factors in the control variables, H1 and H2 may have endogeneity problems. To this end, we used the one-year lagged data of ECC (variable code is LagECC) as the instrumental variable of ECC. We also used the one-year lagged data of CLA (variable code is LagCLA) as the instrumental variable of CLA. It can be seen from module (2) of Table 9 that LagECC has a significant positive effect on CLA ($\beta = 0.002$, $p < 0.1$); LagCLA has a significantly positive impact on CP ($\beta = 1.020$, $p < 0.05$), which is consistent with the previous conclusions. To sum up, the test results of this study have good robustness.

We further explore the dynamics of CP. Hoffmann and Busch [72] point out that carbon dependency is an index that can measure CP from a dynamic perspective, which is the change of carbon intensity of an enterprise in a given period. According to the method proposed by Hoffmann and Busch [72], we express the dynamic index of CP as: $CPd=CP_{i,t}/CP_{i,t-1}$. The level of CPd can, to some extent, reflect the degree of carbon management efforts of enterprises over time. Table 10 shows the results of regression test with CPd as the dependent variable. Column (1) shows that the relationship between CLA and CPd fails the significance test. However, the results in column (2) and column (3) show that the positive effects of ECC on CPd both pass the significance test. We believe that the carbon

Table 7
Test results of the moderating effect of firm size.

	(1)	(2)
	CLA	CLA
ECC	0.006***	0.006***
	(5.54)	(5.78)
Size	−0.001***	−0.001***
	(-2.86)	(-2.94)
*ECC*Size*		−0.001*
		(-1.67)
ATO	−0.002**	−0.002**
	(-2.45)	(-2.49)
INV	−0.013***	−0.012***
	(-3.47)	(-3.38)
Indep	−0.017**	−0.017**
	(-2.41)	(-2.43)
OC	−0.001	−0.001
	(-0.28)	(-0.07)
Board	−0.002	−0.002
	(-0.95)	(-0.97)
Mfee	−0.011	−0.011
	(-1.21)	(-1.19)
Lev	0.001	0.001
	(0.22)	(0.26)
Constant	0.028***	0.028***
	(3.09)	(3.10)
YEAR	Yes	Yes
Industry	Yes	Yes
Observations	1545	1545
R^2	0.105	0.107
Adj. R^2	0.092	0.093
F	7.79***	7.59***

Notes: (1) T statistics are reported in parentheses; (2) Significance at the 10 %, 5 %, and 1 % levels is indicated by *, **, and ***, respectively.

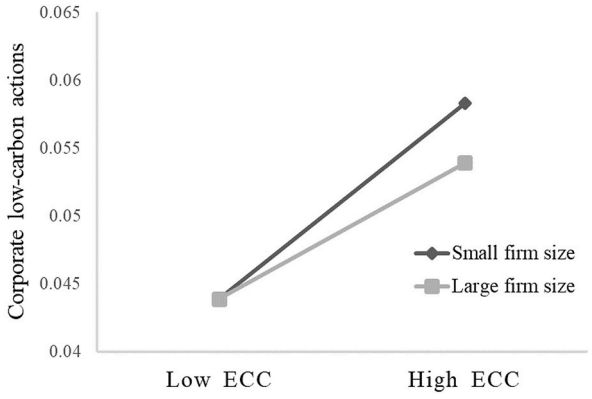

Fig. 2. Moderation of firm size.

Table 8
Conditional indirect effect of executives' carbon cognition on carbon performance via corporate low-carbon actions at different firm sizes.

Values of firm size	Conditional indirect effects			Index of moderated mediation		
	Indirect effect	S.E.	95%CI	Index	S.E.	95%CI
-SD	0.033	0.013	[0.0087, 0.0609]	−0.005	0.003	[-0.0116, −0.0001]
M	0.027	0.010	[0.0074, 0.0467]			
+SD	0.020	0.007	[0.0057, 0.0343]			

Notes: N = 1545; CI = confidence interval; Bootstrap samples = 5000.

cognition of executives can positively influence the carbon management efforts of enterprises, so as to achieve a long-term positive impact on CP. However, the mediating role of CLA has not been detected in this relationship, and there may be other influencing factors to be discussed.

5. Discussion

The purpose of this study is to explore whether ECC can improve CP through CLA, and how this mechanism behaves differently under the boundary condition of firm size. In order to confirm the above claims, we obtain evidence from the literature and empirical analysis. Our data comes from Chinese A-share listed companies from 2012 to 2021. The conclusions of the study provide implications for executives and the low-carbon development of enterprises.

The results show that there is a significant positive correlation between ECC and CLA; there is a significant positive correlation between CLA and CP; CLA plays a mediating role in the relationship between ECC and CP; when the firm size is small, the positive relationship between ECC and CLA is strengthened; when the firm size is small, the mediating role of CLA is strengthened. Our research conclusions are supported by some previous studies [29,34,36,39]. Our research conclusions explain that when executives are more sensitive to carbon information, have a deeper understanding of low-carbon competitive advantages, and are more willing to assume environmental responsibility, the corporate strategy will be more inclined to low-carbon development, that is, enterprises will take more low-carbon actions, thus promoting the improvement of their CP. Our results are consistent with Elsayih, Datt and Hamid [73], who find that CEOs play an important role in addressing issues such as greenhouse gas emissions, and that personal characteristics of CEOs are positively correlated with CP. However, this relationship is limited by the size of the firm.

As for the role of firm size in the mechanism of "ECC-CLA-CP", some studies are contrary to our view. Some studies believe that the larger the enterprise size, the better the performance of low-carbon actions [5,6,43]. For example, Stanny and Ely [4] studied listed companies in the United States and found that the larger the company, the more actively it responded to the Carbon Disclosure Project. We acknowledge that larger companies do come under greater external regulatory pressure, which may force them to take more low-carbon actions. However, CLA can also be adversely affected by organizational structure (firm size) on organizational awareness (ECC). Our view is supported by some studies [73–75]. As an enterprise's response to environmental problems, CLA will vary with different production and operation activities in terms of interest demands, objectives, institutional constraints, etc. Therefore, CLA does change along with organizational structure and awareness. Based on this, the excessive size and complexity of the organizational structure may increase the complexity of governance [76], and executives lack the adaptability to play their ECC role, which leads to poor performance in CLA. In addition, Elsayih, Datt and Hamid [73] assert that larger firms emit more carbon and therefore firm size is negatively related to CP. Their study supports our proposed H4b.

ECC can be considered one of the executives' competencies. Marshall, Schumpeter and other economists have analyzed executives' competencies from different perspectives, and one of the common views is that executive competence plays an important role in the growth of enterprises. The executives' competence can be considered as a constant, and under the condition that other constraints

Table 9
Test results of robustness test.

	(1)				(2)	
	CLA	CP	CP	CLA	CLA	CP
ECC1	0.002***	0.013*	0.011	0.003***		
	(4.81)	(1.76)	(1.50)	(5.81)		
LagECC					0.002*	
					(1.66)	
CLA			0.913**			
			(2.06)			
LagCLA						1.020**
						(2.19)
Size				−0.001***		
				(-2.94)		
*ECC1*Size*				−0.001**		
				(-2.13)		
ATO	−0.002**	−0.107***	−0.105***	−0.002**	−0.003**	−0.095***
	(-2.32)	(-6.54)	(-6.41)	(-2.55)	(-2.12)	(-6.02)
INV	−0.011***	0.092	0.102	−0.012***	−0.011**	0.110*
	(-3.16)	(1.47)	(1.63)	(-3.26)	(-2.29)	(1.86)
Indep	−0.018**	0.027	0.043	−0.015**	−0.020**	−0.017
	(-2.56)	(0.23)	(0.36)	(-2.20)	(-2.22)	(-0.16)
OC	−0.003	0.062	0.064*	−0.001	−0.002	−0.010
	(-1.23)	(1.59)	(1.66)	(-0.17)	(-0.65)	(-0.25)
Board	−0.003	−0.005	−0.003	−0.002	−0.004*	0.007
	(-1.40)	(-0.17)	(-0.09)	(-1.04)	(-1.77)	(0.22)
Mfee	−0.003	0.708***	0.711***	−0.010	−0.004	0.818***
	(-0.34)	(4.70)	(4.73)	(-1.06)	(-0.32)	(5.51)
Lev	−0.003	−0.359***	−0.356***	0.001	−0.003	−0.319***
	(-1.52)	(-10.29)	(-10.22)	(0.12)	(-0.92)	(-9.34)
Constant	0.016**	6.857***	6.843***	0.035***	0.017*	6.824***
	(2.44)	(61.50)	(61.31)	(3.76)	(1.88)	(62.10)
Year	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1545	1545	1545	1545	915	915
R^2	0.100	0.905	0.905	0.107	0.117	0.932
Adj. R^2	0.087	0.903	0.904	0.093	0.096	0.930
F	7.67***	656.80***	629.77***	7.61***	5.63***	579.86***

Notes: (1) T statistics are reported in parentheses; (2) Significance at the 10 %, 5 %, and 1 % levels is indicated by *, **, and ***, respectively.

remain unchanged, the scale of the enterprise they can control is limited. If the scale of the enterprise breaks through this range, the complexity of enterprise management exceeds the limit of executives' competence. If executives' competence is not improved in the short term, it is difficult for them to exert control and management over the expanded enterprise, which ultimately leads to increased production costs and inefficient asset allocation. In other words, when enterprises are too large, ECC will be constrained by the high complexity of enterprise management, which will inhibit the subjective initiative of enterprises to take low-carbon actions, and then lead to the poor performance of CP. This view is supported by the data results from our proposed H4b.

Our measure of CP comes from Clarkson et al. [64]. This measurement is essentially a measure of carbon intensity, which is a relatively more objective quantitative measure [77]. Some studies have also adopted carbon intensity as an indicator of CP [73,77,78]. We also explore the dynamic changes of CP in a further empirical test. The findings show that ECC can positively affect the dynamic indicators of CP, implying that not only ECC can positively affect CP in the current period, but also this positive effect is persistent. However, CLA is not detected to have a significant effect on the dynamic indicators of CP. This may be due to the fact that there are other variables that have yet to be investigated that play a key role in the "ECC-CP" relationship when CP is considered as a continuous dynamic indicator. This result, in turn, correlates with the results of our H3 test that CLA partially mediates the relationship between ECC and CP. ECC, as an abstract concept of cognition, does not produce results directly in practice, but necessarily through some kind of action. Our findings therefore reveal the possibility of exploring other mediators in the future.

5.1. Theoretical contributions

Based on the theory of strategic cognition, we conduct an empirical study on the mechanism of ECC's influence on CP through CLA. Current research on the factors influencing CP mostly focuses on external factors such as government environmental regulation [79,80] and stakeholder pressure [81–84], as well as internal factors such as carbon disclosure [85–87], while the role played by executives, who act as corporate decision makers, has been neglected. Executives' governance decisions influence the assumption of corporate social functions [88]. Our research fills some of this gap. In addition, we also discuss the role of firm size in the "ECC--CLA-CP" relationship based on the theory of "Attitude-Context-Behavior". For the theories we used, our findings extend them to carbon related research. The results suggest that when executives have a deeper understanding of carbon management and a focus on better

Table 10
Regression results of the direct and mediating effects.

	(1)	(2)	(3)
	CPd	CPd	CPd
ECC		0.014*	0.016**
		(1.88)	(2.09)
CLA	−0.030		−0.038
	(-1.22)		(-1.53)
ATO	−0.001	0.001	−0.001
	(-0.25)	(0.03)	(-0.06)
INV	−0.009***	−0.009***	−0.010***
	(-2.68)	(-2.70)	(-2.82)
Indep	−0.017***	−0.017***	−0.018***
	(-2.67)	(-2.63)	(-2.74)
OC	0.001	0.001	0.001
	(0.22)	(0.09)	(0.05)
Board	−0.001	−0.001	−0.001
	(-0.47)	(-0.42)	(-0.51)
Mfee	−0.038***	−0.036***	−0.036***
	(-4.34)	(-4.10)	(-4.10)
Lev	−0.003	−0.003	−0.003
	(-1.60)	(-1.53)	(-1.57)
Constant	1.035***	1.030***	1.031***
	(161.22)	(152.62)	(152.74)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
Observations	915	915	915
R^2	0.553	0.554	0.555
Adj. R^2	0.542	0.543	0.544
F	52.52***	52.73***	50.52***

Notes: (1) T statistics are reported in parentheses; (2) Significance at the 10 %, 5 %, and 1 % levels is indicated by *, **, and ***, respectively.

reducing GHG emissions, they are able to improve CP by developing low-carbon strategies that lead to the implementation of low-carbon actions in their organizations, but their initiative is constrained by the size of their organizations. Our study illustrates the importance of interdisciplinary research and provides some insights into cognitive psychology, management, and human resource management research.

5.2. Practical implications

On the one hand, from the perspective of executives themselves, they should continuously improve their carbon cognition and actively respond to the call of low-carbon development strategy. As the decision makers of the enterprise, the level of ECC will have an important impact on the strategy, system and even specific behaviors of the enterprise, which will ultimately be reflected in CP. Therefore, executives should pay attention to the national strategy of ecological civilization and the national strategy of "carbon neutrality", deeply interpret the carbon-related policies, suppress the high pollution and high energy consumption behaviors of enterprises, and actively take low-carbon actions to enhance the sustainable development of companies. On the other hand, in terms of the organization, CLA should be integrated into corporate strategies to effectively promote corporate low-carbon development. First, the organization should actively seek low-carbon resources and properly plan and allocate them, and implement low-carbon management throughout the product life cycle. Second, the organization should pay attention to low-carbon technology innovation, as it is the most direct and effective way to achieve low-carbon growth. Additionally, for the purpose of breaking through the dilemma that low-carbon technology innovation is difficult and slow to achieve results, the organization can introduce the innovation achievements of others and flexibly integrate them with its own technology, or join the low-carbon technology innovation projects established by research institutions or universities to obtain the latest technological innovation achievements in time.

5.3. Limitations and future research

This study explores the internal mechanism and boundary condition of the relationship of "ECC-CLA-CP", but there are still some limitations. First of all, the measurement method of ECC in this study is text mining. Although existing studies have pointed out that text data is a very feasible method to analyze executives' cognition, future studies can consider multiple data sources to increase the reliability and validity of research. Secondly, not all listed companies have published data on low-carbon actions, so this study has limitations in the completeness of mediating variable data. Thirdly, the basis of the CP measurement in this study comes from the concept of carbon intensity proposed by Hoffmann and Busch [72]. It is essentially a static indicator, and there is a loophole that firms can increase their CP by manipulating their operating revenues without making efforts to reduce carbon emissions. We use the dynamic indicator of CP in the subsequent robustness tests, but the mediating role of CLA in the relationship between ECC and dynamic

indicator of CP is not supported. In the future, we can continue to explore the mediating variables between ECC and the dynamic indicator of CP, and we can also optimize the measurement of the dynamic indicators of CP. Finally, this study takes listed companies in the Chinese context as the research object, and it can be considered to study the differences in the relationship of "ECC-CLA-CP" in cross-social and cross-cultural situations in the future.

6. Conclusions

Based on the data of listed companies in China, this study explores the influence mechanism among ECC, CLA and CP by establishing a moderated mediation effect model, and draws the following main conclusions. (1) In general, ECC has a positive effect on CP by influencing CLA. In terms of the sub-path of the model, ECC significantly and positively affects CLA, and CLA significantly and positively affects CP. The factor that directly influences the formulation of corporate strategy is executives' subjective cognition. Executives with high carbon cognition are more likely to formulate corporate strategies that adopt low-carbon actions, and therefore the corporate low-carbon development is better. The improvement and update of production equipment and product manufacturing processes can reduce energy consumption and pollutant emission, thus promoting the improvement of CP of enterprises. (2) Firm size negatively moderates the relationship between ECC and CLA, and at the same time, firm size negatively moderates the mediating effect of CLA. From the perspective of organizational structure and environmental regulation, smaller firms have more flexible organizational structures and are subject to less intense environmental regulation than larger firms, so their executives can more effectively exert their own initiative, that is, promote the implementation of low-carbon actions with their own carbon cognition. In addition, from the perspective of market competition, smaller firms are more inclined to adopt radical low-carbon innovation, rapidly gather innovation resources in a short time, and then significantly improve the level of CP. Therefore, the low-carbon actions of smaller enterprises play a more significant mediating role in the relationship between ECC and CP.

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Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Wei Gao: Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Subin Wen:** Writing – review & editing, Supervision, Funding acquisition. **Hui Li:** Writing – review & editing, Software. **Xin Lyu:** Writing – review & editing, Software, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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