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Impacts of ESG Disclosure on Corporate Carbon Performance: Empirical Evidence from Listed Companies in Heavy Pollution Industries

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Abstract: With the increasing severity of global climate change, environmental issues have become a key factor constraining sustainable economic development. Environmental, social, and corporate governance (ESG) is in line with the concept of enterprises' sustainable development, and it is significant to study the mechanism of ESG disclosure on corporate carbon performance for the low-carbon transformation of enterprises. Based on the panel data of Chinese heavily polluting companies, a two-way fixed-effects model is used to analyze the relationship theoretically and validate the empirical data. It is found that ESG disclosure significantly contributes to corporate carbon performance, and corporate carbon performance will increase by 1.2% for each level of ESG disclosure. A series of robustness tools, such as endogeneity tests, replacement of critical variables, and control variable treatment, further verify that the main findings are robust and reliable. Heterogeneity analysis shows that the growth and ownership attributes of heavily polluting firms can lead to a heterogeneous characterization of the impact of ESG disclosure on firms' carbon performance. In addition, the institutional environment and media attention moderate the relationship between ESG disclosure and corporate carbon performance. The results of this study provide empirical support for promoting carbon performance in China's heavy-polluting industries and achieving the "double carbon" goal.

Keywords: ESG; corporate carbon performance; heavily polluting industries; institutional environment; media attention

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1. Introduction

The climate change problem caused by the excessive emission of greenhouse gases, mainly carbon emissions, has emerged as a global quandary concerning the sustainable progress of human society [1]. In accordance with the Paris Agreement, all parties will enhance their global response to climate change threats, keep the global average temperature within 2 degrees Celsius of pre-industrial levels, and strive to reduce global warming by 1.5 degrees Celsius [2]. The IPCC report states that it is imperative for all sectors to curtail their emissions of greenhouse gases [3]. In accordance with the European Union's (EU) Green Agreement, there is a pressing need to substantially mitigate greenhouse gas emissions, a strategy that holds the potential to foster global economic prosperity [4]. Greenhouse gas emissions have a significant impact on environmental development and sustainability [5]. From the perspective of high energy consumption leading to higher operating costs for enterprises, the primary impact of energy consumption is that greenhouse gas emissions should be controlled and reduced [6]. In the global context, the significance of sustainable development has escalated, consequently engendering a diverse array of novel frameworks and methodologies embraced by governments, society, and companies [7]. Upholding the concept of a community of human destiny, the Chinese government has

emerged as an exemplar of global climate governance through the implementation of tangible measures and initiatives. In virtue of the commitments undertaken, carbon peaking will occur by 2030 and carbon neutrality will be achieved by 2060, respectively. Enterprises are the micro-subjects of macroeconomic development and the essential organizations of meso-industry development. Thus, in order to attain the macro-level "dual carbon" goal, the implementation of carbon emission reduction responsibilities should be extended to the micro-enterprise level [8]. As stakeholders increasingly pressurize companies to adopt more sustainable ways to reduce their social and environmental impacts, manage and reduce their carbon footprints, and provide more detailed sustainability-related information through appropriate disclosure policies, ESG is becoming a global benchmark for assessing corporations' environmental and social responsibility [9,10]. Companies employ diverse strategies to attain carbon reductions while effectively conveying these efforts and outcomes to stakeholders through ESG disclosures [11]. The current consensus acknowledges the increasing urgency of climate change, primarily attributed to the accumulation of greenhouse gases (GHG) in the Earth's atmosphere. As this phenomenon is believed to approach a critical threshold where permanent and potentially catastrophic consequences are anticipated, the meticulous assessment of corporate greenhouse gas emissions performance is deemed an utmost priority in ESG reporting.

ESG is a corporate assessment system that underscores the need for companies to seek the optimization of profits and focus on multiple objectives, including environmental preservation and social responsibility [12]. There has been rapid progress in ESG, and an increasing amount of research is now being conducted related to ESG. Current research focuses on factors influencing ESG disclosure, the impact on financial performance, corporate financial irregularities, corporate financial risk, corporate value, etc. [13–18]. Zheng et al. examined the correlation between environmental, social, and governance factors and corporate green innovation. The findings of this study revealed that ESG substantially enhanced both the number and quality of green innovations within corporations [19]. The ESG performance demonstrates a significant correlation with the generation of green invention patents in polluting industries over an extended period. While extensive research has been conducted on corporations' financial performance and innovative performance, limited research has been given to the implications of company carbon performance. Heavy pollution-listed companies are major producers of carbon emissions; thus, understanding the relationship between ESG disclosure and carbon performance in heavy pollution-listed companies is necessary.

Corporate carbon performance refers to the revenue a company earns per unit of carbon emissions. Many scholars have conducted research on carbon performance, mainly focusing on exploring influencing factors. In terms of environmental influences, Haque and Ntim found that sustainable development policies had a positive impact on the carbon performance of European listed companies [20]. The findings showed a stronger relationship between sustainable development measures and carbon performance in polluting industries. Additionally, Ren et al. examined the impact of extreme climate risk on the environmental performance of Chinese companies at the national level [21]. In terms of social influences, based on Chen et al.'s study, corporations' carbon reduction performance was positively influenced by the implementation of low-carbon city construction initiatives [22]. Additionally, it was observed that government promotion incentives played a key role in enhancing corporate efforts towards carbon reduction. From the perspective of local government intervention and market segmentation, Kou and Xu quantified the impacts of internet infrastructure on carbon performance [23]. A significant improvement in total carbon emissions was found when internet infrastructure was implemented. Regarding governance influences, Haque conducted a study examining the impact of board features and sustainable compensation policies on business endeavors targeted at mitigating carbon emissions and greenhouse gas (GHG) emissions [24]. The findings indicated that corporate boards and top management primarily prioritize the company's process-oriented carbon performance rather than effectively mitigating greenhouse gas emissions. Using a sample

of multinational firms, Oyewo assessed the impact of corporate governance on carbon emission reduction efforts [25]. By combing through the literature, corporate carbon performance has been studied in corporate governance, social, and environmental dimensions. However, the relationship between ESG disclosure and corporate carbon performance has not been sufficiently investigated in existing studies.

This article aims to examine the impact of ESG disclosure on the carbon performance of heavily polluting enterprises in China. Additionally, it seeks to investigate the moderating effect of institutional environment and media attention on the relationship between ESG disclosure and corporate carbon performance, taking into account the perspectives of institutional environment and media attention. To ensure accuracy in measuring ESG and corporate carbon performance, this study utilizes Huazheng ESG ratings, which are specifically tailored to the Chinese market, to assess corporate ESG disclosure. Furthermore, to address the limited disclosure of carbon dioxide emissions by corporations, corporate carbon emissions are estimated by leveraging operating costs and industry-specific carbon emissions data. This approach enables a more comprehensive evaluation of corporate carbon performance. In this study, ESG disclosure was found to improve the carbon performance of heavily polluting enterprises significantly, and the robustness of the conclusions was evaluated using instrumental variables and substitution of critical variables. Especially in the context of high-growth and privately owned companies, the impact of ESG disclosures on carbon performance is significant. In addition, this study investigated the role of institutional environment and media attention in moderating the relationship between ESG disclosure and the companies' carbon performance to assess their respective impacts. The research results will be used to support the government in formulating more effective and targeted policies. These policies aim to enhance the level of ESG disclosure by enterprises, strengthen the management of ESG disclosure practices, and facilitate a pathway for improving the carbon performance of heavily polluting enterprises. Ultimately, the research outcomes can contribute to the achievement of China's "dual carbon" goals by facilitating sustainable environmental practices and initiatives.

This paper presents the primary contributions as follows: Firstly, the contribution of this study is to provide more direct empirical evidence for the impact of ESG disclosure on corporate carbon performance, based on the perspective of linking ESG disclosure with corporate carbon performance for the first time, combined with data from heavily polluting enterprises in China. In previous research on ESG disclosure, based on panel data from multinational corporations, Wen et al. investigated the relationship between the quality of ESG disclosure and ESG investment growth [26]. Schiemann and Tietmeyer investigated whether ESG disclosure alleviated the relationship between ESG controversy and analyst prediction accuracy [27]. Using Chinese listed companies as a sample, Ge et al. studied the impact of ESG performance on corporate quality, and Chen et al. investigated how ESG disclosure effectively promoted technological innovation capabilities [28,29]. Regarding research on carbon performance, Cheng et al. examined global corporate carbon performance from a decentralized perspective at the national level [30]. Elsayih et al. used Australian companies as a sample to study the impact of corporate governance on carbon emission performance [31]. Du et al. and Jiang et al. studied the impact of corporate governance on carbon performance based on provincial panel data, high-tech enterprises, and manufacturing enterprises in China, respectively [32,33]. Previous studies have not yet examined the impact of ESG disclosure on carbon performance, specifically within the context of heavily polluting enterprises in developing countries.

Secondly, this study aims to establish a comprehensive research framework for ESG disclosure, corporate carbon performance, institutional environment, and media attention. Previous research has mainly focused on the impact of the media environment on green innovation, including the impact of the new media environment and environmental regulations on green technology innovation, the impact of online sentiment on green innovation [34,35], and the impact of the institutional environment on credit risk [36]. The integration of the institutional environment and media attention within a research

framework addresses a notable research gap in the literature regarding the moderating effect of the institutional environment and media attention on the relationship between ESG disclosure and corporate carbon performance.

Thirdly, this study delves into the examination of how ESG disclosure influences the carbon performance of different heavily polluting enterprises from the perspectives of corporate growth and the heterogeneity of corporate property rights attributes to address these research gaps. The empirical findings of this research indicate that ESG disclosure has a more significant impact on high-growth and private enterprises, thus providing empirical evidence to enhance carbon performance across different enterprise types.

2. Hypotheses Development

2.1. ESG Disclosure and Corporate Carbon Performance

With sustainable development gradually becoming a consensus, ESG, as a new indicator for measuring corporate sustainability, is gradually attracting attention from all walks of life [37]. Prior research has shown that ESG affects firms' total factor productivity, firm value, firm quality development, and green innovation [19,28,38–41]. According to signaling theory, managers possess the ability to alleviate the adverse consequences arising from information asymmetry between firms and stakeholders. This can be achieved by employing various disclosure strategies where managers are motivated to disclose their accomplishments in carbon emission reduction. By doing so, they aim to differentiate themselves from competitors within the industry and attain a competitive edge, particularly in light of the growing prominence of the green development paradigm [42]. Voluntary disclosure theory suggests that firms that voluntarily disclose carbon have better carbon performance and that the carbon information they disclose is truthful and of high quality, assisting in the mitigation of capital expenses and augmenting market valuation. According to signaling theory, ESG disclosure serves as a means to communicate to society that an enterprise attaches importance to environmental protection, social responsibility, and corporate governance. This, in turn, not only strengthens investor confidence in the sustainable development of the enterprise but also facilitates access to investment opportunities. By alleviating financing constraints, ESG disclosure enables enterprises to secure additional resources for implementing carbon emission reduction initiatives.

Stakeholder theory suggests that the interests of shareholders should not take precedence over those of other stakeholders and that only firms that are accountable to all stakeholders can achieve sustainable growth. Freeman defines a stakeholder as a component with a reasonable claim on the company, including shareholders, managers, employees, creditors, customers, suppliers, and the public [43]. Eweje points out that consumers in developed countries are increasingly concerned about the environmental performance of firms. As such, there is mounting consumer pressure that compels firms to implement environmental programs in response to these concerns [44]. Carbon emissions from heavily polluting enterprises account for most of China's carbon emissions. As consumers become increasingly concerned about climate change, they gradually realize the impact of carbon emissions from heavily polluting enterprises on environmental pollution and climate change. To satisfy consumer expectations about the environment, companies will force themselves to improve their carbon performance levels. ESG has emerged as a crucial avenue for communicating information, especially non-financial information. Therefore, research hypothesis H1 is proposed.

H1: *ESG disclosure is positively related to the carbon performance of heavily polluting enterprises.*

2.2. The Moderating Effect of the Institutional Environment

According to institutional theory, the institutional environment can critically impact the behavior and structure of firms. The institutional environment includes factors such as institutional constraints, legal sophistication, and enforcement efficiency in the region where the firm is located, which significantly impact the firm's operations and disclosure [45]. In

order to establish social legitimacy and enhance their ability to obtain the necessary external resources for survival and expansion, companies are obliged to proficiently navigate institutional constraints and abide by prevailing norms and regulations. As a result, firms need to cope with varying degrees of institutional pressure to operate smoothly and stably, and the extent of institutional pressure has a significant impact on the strategic decisions and overall performance of the company. The institutional environment is characterized by intense market competition and reputational risk, and a company's performance on ESG can directly affect its market competitiveness and reputation.

An unsound institutional system may lead to the indiscriminate allocation and mismatch of technological innovation resources in the market. In contrast, with a well-established institutional framework and enhanced administrative capacity of the government, the market can fully play the decisive role of resource assignment, enabling enterprises to execute technological innovation activities efficiently and further promoting the enhancement of enterprises' innovation capacity. In line with trends such as green supply chains, renewable energy, and low-carbon production, consumers, suppliers, and partners are increasingly inclined to choose companies that perform well on ESG, and this competition needs to drive companies to improve their carbon performance. The institutional environment can improve enterprises' ESG behaviors by promoting innovation and technological development. Government policies that provide support and incentives for low-carbon technological innovation and the development of green industries can offer innovative and technical assistance to help enterprises make breakthroughs in carbon performance. The public is increasingly concerned about corporate ESG practices as the institutional environment changes. To cope with stakeholder pressure, companies need to improve their ESG disclosure, so the impact of ESG information disclosure on corporate carbon performance may depend on the institutional environment in which they operate. It is necessary to study the impact of the institutional environment on corporate carbon performance through its interaction with corporate ESG disclosure. Therefore, research hypothesis H2 is proposed.

H2: *The institutional environment has a moderating effect on the relationship between ESG disclosure and the carbon performance of heavily polluting enterprises.*

2.3. The Moderating Effect of Media Attention

Media attention includes the attention of online media and newspaper media. Online media attention encompasses the reporting and coverage of company-related news by digital media platforms, while newspaper media refers to traditional print publications such as newspapers and journals, which constitute a significant component of the media landscape. Chang et al. showed that media attention was significantly influencing companies' environmental investment in polluting industries, and the media played a crucial role in fulfilling corporate social responsibility [46]. Tavakolifar et al. showed that firms were more likely to comply with their environmental responsibilities and commit to responding to climate change when there was an increase in media attention [47]. In addition, ESG disclosure has attracted widespread attention in society, and ESG disclosure is an effective channel for enterprises to communicate with many stakeholders on sustainability issues. It can also have a significant impact on an organization's reputation and its ability to attract stakeholders, including investors, to take part in carbon emission reduction initiatives.

In heavily polluting firms, media influence over ESG disclosure and carbon performance generally manifests itself in the following areas: First, drawing upon the reputation theory, it is evident that the media assumes a pivotal position as the primary conduit for information exchange between firms and stakeholders. In this capacity, the media serves as a critical mediator of information, thereby mitigating information asymmetry. The media collects information related to corporate ESG disclosure through professional channels, which helps investors understand corporate disclosure, and investors tend to invest in enterprises with better environmental performance. Secondly, media attention

plays the role of social supervisor. The media is an essential tool to guide public opinion. The enterprise's environmental pollution behavior and carbon emissions exceeding the standard to report will damage the enterprise's reputation. Stakeholders have the potential to exert pressure on enterprises, thereby increasing public awareness of their environmental preservation efforts. Consequently, this heightened focus can impact the environmental behavior of the firm, leading to a decrease in energy usage and a reduction in carbon emissions. Thirdly, based on the expectation theory, it can be deduced that as media coverage expands, stakeholders' expectations towards the enterprise also escalate. Conversely, when media coverage decreases, stakeholders' attention and expectations decrease. The greater the magnitude of media attention, the greater the awareness of the enterprise, thereby facilitating the promotion of environmental consciousness. In this context, media attention helps the enterprise make ESG disclosures and low-carbon emission reduction activities. Therefore, research hypothesis H3 is proposed.

H3: *Media attention has a moderating influence on the relationship between ESG disclosure and the carbon performance of heavily polluting enterprises.*

3. Research Design

3.1. Sample Selection and Data Sources

This study focuses on heavily polluting Chinese firms listed on the A-share markets to examine the influence of ESG disclosure on the carbon performance of these corporations. The research period spans from 2012 to 2021, as determined by the availability of the data. Selecting Chinese heavily polluting enterprises as the research sample primarily considers two key aspects. On one hand, the selection of heavily polluting enterprises as the research sample is justified by their substantial negative externalities as well as their prominent role in attracting attention from environmental protection departments due to their significant pollution emissions. Therefore, in theory, the ecological management efforts of heavily polluting enterprises are more representative when compared to those of non-heavily polluting enterprises. On the other hand, considering the particularity of production in heavily polluting industries and the significant harm they pose to the environment, the environmental governance needs of heavily polluting enterprises are more urgent. Conducting research on ESG disclosure and carbon performance within this context holds practical significance in alleviating the conflict between enterprise development and the low-carbon requirements of stakeholders. Regarding the definition of polluting industries: In 2003, the State Environmental Protection Administration proposed 13 polluting industries for listed companies' environmental protection verification, and in 2010, the Ministry of Environmental Protection (MEP) required the disclosure of environmental protection reports for 16 categories of polluting industries. Based on the 2012 China Securities Regulatory Commission Guidelines for Industry Classification of Listed Companies, this paper compares the corresponding industry codes with the above 16 categories of heavily polluting enterprises. Finally, it determines the codes of polluting industries as follows: B6, B7, B8, B9, B10, B11, C15, C17, C18, C19, C22, C25, C26, C27, C28, C29, C30, C31, C32, and D44. This paper defines listed companies belonging to the above industry codes as heavily polluting enterprises. After excluding ST and ST* companies and enterprises with serious data missing, a total of 529 enterprises were included in the analysis. Furthermore, a 1% winnowing technique was implemented to address the potential influence of outliers. Data from the China Energy Statistical Yearbook, the China Statistical Yearbook, the CSMAR database, and the WIND database.

3.2. Econometric Modelling

A bidirectional fixed effects model was applied to benchmark regression to explore the association between ESG disclosure and the carbon performance of heavily polluting Chinese companies between 2012 and 2021. According to Gallego-Alvarez et al., panel data models offer enhanced efficiency and improved inference by addressing the issue of

omitted variables and by capturing unobserved heterogeneity between individual units or over time [48]. The fixed effects model emerges as a more appropriate choice due to its ability to produce more robust and unbiased results. Specifically, Formula (1) is developed to test ESG disclosure's effect on heavily polluting enterprises' carbon performance.

$$CP_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \sum \beta_k Controls_{i,t} + Year_t + Ind_i + \varepsilon_{i,t} \quad (1)$$

where $CP_{i,t}$ is the carbon performance of firm i in period t, and $ESG_{i,t}$ is the ESG disclosure level of firm i in period t, $Controls_{i,t}$ are control variables; $Year_t$ and Ind_i are year dummy variables and industry dummy variables, respectively; and $\varepsilon_{i,t}$ is a random disturbance term. This paper focuses on the regression coefficients β_1, which are used to measure the impact of ESG disclosure on firms' carbon performance. If significantly positive, it indicates that ESG can significantly promote the carbon performance improvement of heavy polluting firms, and if significantly negative, it indicates that ESG inhibits the carbon performance improvement of heavy polluting firms.

In order to further explore the moderating effect of the institutional environment on the relationship between ESG disclosure and corporate carbon performance, Formula (2) was developed.

$$CP_{i,t} = \alpha_0 + \alpha_1 ESG_{i,t} + \alpha_2 MARKET_{i,t} + \alpha_3 ESG_{i,t} \times MARKET_{i,t} + \sum \alpha_k Controls_{i,t} + Year_t + Ind_i + \varepsilon_{i,t} \quad (2)$$

To investigate the role of media attention on the relationship between ESG disclosure and corporate carbon performance, Formula (3) was developed.

$$CP_{i,t} = \gamma_0 + \gamma_1 ESG_{i,t} + \gamma_2 MEDIA_{i,t} + \gamma_3 ESG_{i,t} \times MEDIA_{i,t} + \sum \gamma_k Controls_{i,t} + Year_t + Ind_i + \varepsilon_{i,t} \quad (3)$$

3.3. Variable Description

Explained variable: corporate carbon performance (CP). Since the carbon emissions of Chinese firms are not directly available, this study draws on the approach of Clarkson's conversion formula at the enterprise level to evaluate the carbon performance of enterprises [49]. Given that enterprises disclose carbon dioxide emissions less often, considering the accessibility of data at the micro level, this paper, with the help of operating costs, estimates the corporate carbon emissions based on the industry's carbon emissions, i.e., the revenue obtained per unit of carbon emissions as an indicator of the enterprise's carbon performance. A higher value of this indicator signifies a more favorable carbon performance. Industry carbon emissions are calculated through industry energy consumption and the corresponding energy carbon emission factor, and the carbon performance estimation formula is as follows.

$$CP = \frac{revenue}{\frac{carbon\ emission_{industry}}{operating\ costs_{industry}} \times operating\ costs} \quad (4)$$

Explanatory variable: ESG disclosure (ESG). Given the emphasis on harmonizing the economy with the environment, numerous prominent rating agencies, such as Bloomberg and Wind, undertake evaluations of corporate ESG performance. A growing level of attention has been paid to the ESG performance of companies by the Chinese government and society in recent years. Therefore, this study employs the Huazheng ESG rating, a rating system designed specifically for the Chinese market, as a standardized measure to evaluate the extent of ESG disclosure by enterprises. The Huazheng ESG evaluation data is characterized by a wide range of coverage and a high degree of timeliness, and the index has been widely recognized and applied by industry and academia at present. The ESG ratings provided by Huazheng are classified into nine distinct levels, ranging from the lowest to the highest as follows: C, CC, CCC, B, BB, BBB, A, AA, and AAA. This paper assigns values to the above rating data in order to serve as explanatory variables to measure corporate ESG disclosure. The ratings C-AAA are sequentially assigned as 1–9: ESG = 1 when the rating is C, ESG = 9 when the rating is AAA, etc.

Moderating variable: Institutional Environment (MARKET). The overall marketization index constructed in the China Provincial Marketization Index Report (2021) is used to measure the institutional environment. The index assesses distinct market environments from a multidimensional perspective, encompassing five key dimensions: the government-market relationship, the growth of non-state-owned economies, the expansion of product markets, the advancement of factor markets, the progress of market intermediary organizations, and the state of the rule of law. Media Attention (MEDIA): Refer to Yang and Zhang to measure media attention by the total media coverage a company receives, including print and online media [50].

Referring to previous studies, this study incorporates several control variables, namely equity concentration (OC), firm size (SIZE), institutional investor's shareholding (II), firm's growth capacity (GROWTH), number of years listed (LY), board size (BOARD), board independence (INDEP), and CEO-Chair separation (DUAL) [20,24]. Furthermore, the paper eliminates differences between industries and years by controlling for industry effects (Ind) and year effects (Year). As shown in Table 1, the variables are defined in more detail.

Table 1. Variable definitions.

Variables	Symbols	Descriptions
Corporate carbon performance	CP	The natural logarithm of firms per million of operating revenue divided by carbon emissions
ESG disclosure	ESG	Huazheng ESG Rating
Institutional environment	MARKET	Total marketization index
Media attention	MEDIA	The natural logarithm of the total amount of media coverage of the company
Equity concentration	OC	Majority shareholders' percentage ownership of shares
Firm size	SIZE	The natural logarithm of the aggregate annual assets.
Institutional investor's shareholding	II	The ratio of institutional investors' total shareholdings to the total outstanding share capital.
Firm's growth capacity	GROWTH	Growth rate of operating revenue
Age	LY	Ln(current year–year of listing + 1)
Board size	BOARD	The uumber of board members is represented by the natural logarithm of the quantity.
Board independence	INDEP	The proportion of independent directors serving on a board of directors.
CEO-Chair separation	DUAL	If the CEO and Chairperson are separate individuals, a binary variable would have a value of 1, while if they are not, it would have a value of 0.

3.4. Descriptive Statistics Analysis

An analysis of the descriptive statistics carried out on the variables is presented in Table 2. The minimum value of corporate carbon performance (CP) is 2.707, and the maximum is 8.998, indicating a significant gap in carbon performance across enterprises. There is significant potential for improvement. Regarding explanatory variables, the mean of ESG disclosure (ESG) is 4.207, the minimum is 1.000, and the maximum is 8.000. Some companies still need to further improve their ESG disclosure level. The firm size (SIZE) is measured at 22.590, suggesting that the enterprises included in our sample are characterized by a substantial scale.

Table 2. Descriptive statistics.

Variable	N	Mean	SD	Min	Max
CP	5290	5.701	1.643	2.707	8.998
ESG	5290	4.207	1.125	1.000	8.000
OC	5290	0.350	0.148	0.091	0.750
SIZE	5290	22.590	1.315	20.290	26.420
II	5290	0.440	0.234	0.005	0.906
GROWTH	5290	0.123	0.265	−0.396	1.345
LY	5290	2.453	0.609	0.693	3.332
BOARD	5290	2.172	0.197	1.609	2.708
INDEP	5290	0.370	0.051	0.333	0.571
DUAL	5290	0.203	0.402	0.000	1.000
MARKET	5290	9.103	1.798	−0.161	12.390
MEDIA	5290	5.760	1.261	3.466	9.808

4. Results and Discussion

4.1. Multivariate Results and Discussion

The regression results of ESG disclosure and carbon performance of heavily polluting enterprises are shown in Table 3. The result of column (1) displays the coefficients associated with ESG disclosure and the carbon performance of enterprises, revealing a statistically significant positive relationship. Based on the empirical findings of this study, it can be concluded that ESG disclosure exerts a positive influence on carbon emissions among heavily polluting enterprises, which provides support for research hypothesis H1. The results are in accordance with those of some previous studies, which emphasized the significant negative relationship between ESG and carbon emissions [11,25,51]. Firms can reduce environmental impacts and improve carbon performance by improving ESG disclosure. There may be three reasons for this: First, through ESG disclosure, heavily polluting enterprises need to publicly disclose their environmental, social, and governance-related data and information. This increases the transparency of enterprises, enabling investors, regulatory agencies, and stakeholders to better understand their carbon emissions and environmental impacts. By fostering transparency and implementing effective supervision, this approach can encourage heavily polluting enterprises to adopt more proactive measures to enhance their carbon performance. Consequently, these enterprises can mitigate potential reputational risks, comply with the expectations of investors and regulatory bodies, and strive for continuous improvement in their environmental practices. Secondly, ESG disclosure has become one of the crucial factors for many investors and consumers to choose companies. For heavily polluting enterprises, improving their ESG performance, including reducing carbon emissions and improving the environment, can enhance their market competitiveness. Consumers and investors increasingly favor environmentally friendly and sustainable business concepts, which incentivize heavily polluting enterprises to improve carbon performance to meet market demand. Thirdly, ESG disclosure can help regulatory agencies better monitor and review corporate environmental behavior. Heavy-polluting enterprises must disclose their environmental data and carbon emissions transparently and responsibly to comply with government compliance requirements. These regulatory pressures and compliance requirements can drive heavily polluting enterprises to improve their carbon performance.

As shown in column (2), the institutional environment has a moderating effect on the impact of ESG disclosure on the carbon performance of heavily polluting companies. During the analysis, a statistically significant negative coefficient is observed for the interaction term, suggesting that the institutional environment plays a moderating role in attenuating the positive influence of ESG disclosure on corporate carbon performance. This finding confirms the research hypothesis H2, which posits the existence of such a relationship. This result may be explained by the fact that sometimes firms take advantage of the institutional environment to improve ESG indicators by meeting minimum standards

and pursuing only short-term economic benefits without taking effective environmental measures. Second, a conducive institutional environment promotes more effective disclosure and transparency, allowing firms' ESG performance to be more thoroughly assessed and considered. However, in some cases, firms may take advantage of the institutional environment to boost their ESG ratings through superficial environmental programs and green initiatives without reducing carbon emissions. Finally, a favorable institutional environment may mean a more competitive and developed market, which may result in firms adopting more environmentally damaging strategies to gain an advantage over their competitors, leading to a rise in carbon emissions.

Table 3. Regression analysis results.

	(1)	(2)	(3)
VARIABLES	**CP**	**CP**	**CP**
ESG	0.012 ***		
	−0.004		
c_ESG		0.013 ***	0.011 ***
		−0.004	−0.004
c_MARKET		−0.014 ***	
		−0.003	
c_ESGc_MARKET		−0.005 *	
		−0.003	
c_MEDIA			0.047 ***
			−0.006
c_ESGc_MEDIA			0.007 *
			−0.004
OC	−0.031	−0.049	−0.01
	−0.04	−0.039	−0.04
SIZE	0	0	−0.021 ***
	−0.005	−0.005	−0.005
II	0.006	0.015	−0.003
	−0.028	−0.028	−0.028
GROWTH	0.058 ***	0.059 ***	0.047 **
	−0.021	−0.021	−0.02
LY	−0.059 ***	−0.064 ***	−0.064 ***
	−0.01	−0.01	−0.01
BOARD	−0.059 **	−0.071 **	−0.068 **
	−0.028	−0.028	−0.028
INDEP	−0.202 *	−0.264 **	−0.270 **
	−0.108	−0.107	−0.106
DUAL	0.013	0.017	0.009
	−0.012	−0.012	−0.011
Constant	5.997 ***	6.100 ***	6.585 ***
	−0.127	−0.126	−0.134
Observations	5290	5290	5290
R-squared	0.962	0.962	0.962

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Based on column (3), it was demonstrated that media attention moderated the relationship between ESG information disclosure and corporate carbon performance. The coefficient of the interaction term is statistically significant and positive, indicating that media attention amplifies the influence of ESG information disclosure on enhancing the carbon performance of heavily polluting enterprises. This finding provides empirical support for the verification of research hypothesis H3. The media serves a dual role in society, encompassing the duties of disseminating information and providing social monitoring. By performing these dual functions, the media can improve the information transparency of companies, stimulate the response behavior of stakeholders, and strengthen the link between the disclosure of ESG information and the carbon performance of heavy polluters.

4.2. Endogeneity Test

Although this paper controls for a series of variables such as equity concentration, firm size, institutional investor shareholding, and firm growth ability, it adopts an instrumental variable approach to control the potential influence of unobservable omitted variables on the relationship between ESG disclosure and the carbon performance of heavily polluting enterprises. Referring to Wang et al., this paper uses the mean ESG score of other publicly traded companies based in the area in which the company is located (ESGPro) and the lagged ESG score for one period (L.ESG) as instrumental variables [52]. The reason is that the ESG disclosure of a listed company at a specific time is correlated with the ESG disclosure practices of other listed companies operating within the same province. In contrast, the ESG disclosure of other listed companies within the same province should not directly impact the listed company's enterprise value in the current period. Due to the fact that ESG information disclosure in enterprises is still lagging in terms of investor reactions, improving the level of ESG information disclosure in the early stages will be able to provide a good foundation for later development and innovation. To investigate the effectiveness of instrumental variables, the main tests were conducted, including the unidentifiable test, the weak instrumental variable test, and the over-identification test. The results of the instrumental variable method calculations are shown in Table 4.

Table 4. Instrumental variable method.

	Phase I	**Phase II**
VARIABLES	**ESG**	**CP**
ESGPro	0.1157 ***	
	−0.0383	
L.ESG	0.6609 ***	
	−0.0112	
ESG		0.0157 **
		−0.0065
Control variable	YES	YES
Year effect	YES	YES
Industry effect	YES	YES
Observations	5290	5290
Non-identification test	Kleibergen-Paap rk LM statistic = 1040.243, P_val = 0.000	
Weak instrumental variable	Kleibergen-Paap rk Wald F statistic = 1752.847	
Exogeneity test	Hansen J chi = 0.399, p = 0.5276	

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$.

As can be seen in Table 4, the weak instrumental variable test shows that the F-statistic is 1752.847 (over 10), at a level of 1%. This finding is statistically significant, indicating that the instrumental variables meet the correlation requirement. Additionally, with the application of the Hansen J-statistics, the p-value of 0.5276 exceeds 0.050, indicating that the instrumental variables are homogeneous. The two selected instrumental variables can be considered valid based on the above. In Table 4, the results of the test of hypothesis H1 using a 2SLS instrumental variable regression are presented. According to the results of the first-stage regression, the instrumental variables ESGPro and ESGS are positively correlated with the level of ESG disclosure. The coefficients of ESG disclosure on the carbon performance of heavy-polluting firms remain significantly positive. Hence, this paper's conclusions still hold after considering the issue of endogeneity.

4.3. Robustness Test

4.3.1. Substitution of Explanatory Variables

In the benchmark regression, this paper assigns values ranging from 1 to 9, corresponding to the segmentation levels of Huazheng ESG ratings, and uses these values as a proxy variable for ESG disclosure. The selection of explanatory variables significantly

impacts the reliability of model estimation results. In order to eliminate the bias in the estimation results caused by the influence of variable selection, we re-estimated the ESG score disclosed by Bloomberg as the explanatory variable. The regression is carried out by using the ESG scores disclosed by Bloomberg as a proxy explanatory variable for Huazheng ESG ratings, and the results of this test are presented in Table 5. The results obtained are in agreement with the conclusions reached in the basic study. Further, it demonstrates that the core conclusion is reliable.

Table 5. Robustness testing.

	Substituting Explanatory Variables	**Adding Control Variables**			**Lagging Phase I**	**Lagging Phase II**
VARIABLES	**CP**	**CP**	**CP**	**CP**	**CP**	**CP**
ESGP	0.021 ***					
	(0.007)					
ESG		0.012 ***	0.010 **	0.012 ***		
		(0.004)	(0.004)	(0.004)		
L.ESG					0.011 **	
					(0.004)	
L2.ESG						0.008 *
						(0.005)
OC	0.054	−0.029	−0.032	−0.031	−0.030	−0.033
	(0.064)	(0.039)	(0.039)	(0.040)	(0.041)	(0.044)
SIZE	−0.007	0.004	−0.000	−0.002	0.002	0.004
	(0.008)	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)
II	−0.045	0.008	0.002	0.005	0.002	−0.004
	(0.049)	(0.027)	(0.028)	(0.028)	(0.029)	(0.031)
GROWTH	0.020	0.049 **	0.044 **	0.058 ***	0.054 ***	0.052 **
	(0.018)	(0.021)	(0.021)	(0.021)	(0.020)	(0.021)
LY	−0.068 ***	−0.046 ***	−0.057 ***	−0.059 ***	−0.060 ***	−0.062 ***
	(0.019)	(0.010)	(0.010)	(0.010)	(0.011)	(0.012)
BOARD	−0.100 ***	−0.046*	−0.061 **	−0.057 **	−0.064 **	−0.063 **
	(0.036)	(0.027)	(0.027)	(0.028)	(0.028)	(0.029)
INDEP	−0.067	−0.179*	−0.198*	−0.202*	−0.228 **	−0.234 **
	(0.151)	(0.106)	(0.108)	(0.108)	(0.113)	(0.119)
DUAL	0.020	0.008	0.012	0.012	0.018	0.021 *
	(0.022)	(0.011)	(0.012)	(0.012)	(0.012)	(0.012)
FIXED		−0.339 ***				
		(0.034)				
LOSS			−0.069 ***			
			(0.016)			
BIG4				0.024		
				(0.018)		
Constant	6.077 ***	5.939 ***	6.023 ***	6.034 ***	6.010 ***	6.005 ***
	(0.193)	(0.126)	(0.127)	(0.136)	(0.132)	(0.138)
Observations	2350	5290	5290	5290	4761	4232
R-squared	0.961	0.962	0.962	0.962	0.964	0.966

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.3.2. Controlling the Impact of Other Factors

Given the fact that heavy polluting enterprises may suffer from other factors that affect their carbon performance, to avoid the estimation bias caused by missing variables affecting the results, drawing on Tanthanongsakkun et al. and Cahyono et al., fixed asset ratio (FIXED), whether it is loss-making (LOSS), and whether it is audited by the Big Four (PricewaterhouseCoopers, Deloitte, KPMG, Ernst & Young) (BIG4) are incorporated into the model as the control variables for regression, respectively, as shown in Table 5 [53,54]. Accordingly, the regression coefficients of the explained variables and explanatory vari-

ables are in agreement with the findings of the previous study. This further validates the robustness of the conclusion, as reaffirmed by the test results.

4.3.3. Lagged Explanatory Variables

Since ESG disclosures are generally made towards the end of the year, current ESG disclosures could have an impact on carbon performance in the subsequent period. Considering the potential lag effect of ESG disclosures on carbon performance, we will regress the explanatory variable (ESG) after lagging behind the first and second periods, respectively. In addition, considering the potential presence of bidirectional causal problems in the basic regression analysis, in order to minimize the interference caused by such problems, drawing on the approach of Zhang et al., incorporating the lagged terms of explanatory variables (lagged one and lagged two) into the model will mitigate the impact of such problems [55]. In summary, we tested the explanatory variables lagged by one and lagged by two as new explanatory variables. In Table 5, the regression results are presented. Drawing from the regression findings, a statistically significant positive correlation has been observed between corporate ESG disclosure and carbon performance. This provides additional evidence to support the robustness and reliability of the core findings presented in this study.

4.4. Heterogeneity Analysis

4.4.1. Corporate Growth

This work utilizes the research methodology proposed by Wang et al. to assess the growth of firms [56]. To measure this growth, the growth rate of operating income is specifically utilized as a metric. Following this, the enterprises are categorized into two distinct groups, namely low-growth and high-growth, based on the median. Subsequently, we conducted a regression analysis of both groups. In Table 6, columns (1) and (2) present the findings, where the regression coefficients of ESG disclosure of low-growth firms do not pass the test, indicating that ESG disclosure of low-growth firms does not significantly affect carbon performance. The regression coefficients of ESG disclosure of high-growth firms exhibit positive values, meaning that ESG disclosure has a substantial and positive correlation to carbon performance. Tascón et al. showed that growth enterprises with better carbon performance have more opportunities to obtain external financing, and the future cash flows of high-growth enterprises, although reflecting more investment opportunities, also face high risk and uncertainty [57]. ESG disclosure can be an effective tool for enterprises to communicate to stakeholders their better carbon performance in order to attract investment.

Table 6. Heterogeneity analysis.

VARIABLES	(1) High-Growth Enterprises CP	(2) Low-Growth Enterprises CP	(3) State-Owned Enterprises CP	(4) Private Enterprises CP
ESG	0.019 ***	0.009	0.012 **	0.024 ***
	(0.006)	(0.006)	(0.006)	(0.006)
OC	−0.086	0.018	−0.118 **	0.157 ***
	(0.058)	(0.052)	(0.054)	(0.057)
SIZE	0.001	−0.003	0.030 ***	−0.037 ***
	(0.008)	(0.007)	(0.006)	(0.008)
II	0.024	−0.008	0.071	0.009
	(0.039)	(0.038)	(0.046)	(0.035)
GROWTH	0.077 **	−0.090	0.066 ***	0.032
	(0.031)	(0.060)	(0.025)	(0.031)
LY	−0.051 ***	−0.072 ***	−0.025	−0.023
	(0.016)	(0.013)	(0.018)	(0.014)
BOARD	−0.075 *	−0.034	−0.128 ***	0.064
	(0.039)	(0.038)	(0.036)	(0.042)
INDEP	−0.286 *	−0.178	−0.366 **	0.012
	(0.153)	(0.145)	(0.149)	(0.149)

Table 6. *Cont.*

VARIABLES	(1) High-Growth Enterprises CP	(2) Low-Growth Enterprises CP	(3) State-Owned Enterprises CP	(4) Private Enterprises CP
DUAL	0.020	0.007	−0.029	0.023 *
	(0.018)	(0.015)	(0.022)	(0.013)
Constant	6.056 ***	5.968 ***	4.819 ***	6.774 ***
	(0.184)	(0.162)	(0.168)	(0.189)
Observations	2645	2645	2340	2950
R-squared	0.956	0.969	0.968	0.951

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.4.2. Enterprise Property Attributes

The enterprises included in this study are categorized into two groups based on their property rights attributes: state-owned and private. The association between ESG disclosure and the performance of carbon emissions is then categorized and examined using regression analysis. Table 6 displays the regression outcomes for both state-owned and private firms, specifically in columns (3) and (4), respectively. Based on Table 6, ESG disclosure and carbon performance of state-owned enterprises have a regression coefficient of 0.012. The significance level test of 1% was passed. The regression coefficient of ESG disclosure and carbon performance of private enterprises is 0.024. It passes the significance level test of 1%, thereby indicating that ESG disclosure significantly contributes to carbon performance in both state-owned and private enterprises. Additionally, it is noteworthy that the impact of ESG disclosure on carbon performance is greater in private enterprises compared to state-owned enterprises. It is due to the attribute of public property rights that state-owned enterprises are the main contributors to policy initiatives to conserve energy and reduce emissions, and they need to fulfill environmental protection policies, disclose ESG information to reduce harmful production and operation externalities, and improve carbon performance. It is more likely that private enterprises with relatively low natural resource endowments are more likely to disclose ESG information in order to demonstrate their social and environmental responsibility to the government and attract investors. From the standpoint of decision-making mechanisms, private enterprises pay more attention to market competition and profitability. As a result, they possess greater flexibility in making strategic choices, making it easier for private enterprises to adjust their business strategies to meet the needs of carbon emissions reduction and sustainable development. State-owned enterprises often receive more environmental supervision and policy guidance, resulting in a relatively slow decision-making process. From the perspective of the capital market, ESG disclosure is increasingly receiving attention. Investors tend to support environmentally friendly and sustainable enterprises, and private enterprises are more likely to have access to the capital market and better utilize ESG indicators to obtain financing. This has the potential to enhance the performance of private enterprises in the realm of carbon emission reduction. From the perspective of enterprise innovation, local governments often maintain and strengthen the market position of state-owned enterprises through biased policies such as low taxes and strengthened market monopolies, thereby exacerbating the problem of insufficient innovation incentives for state-owned enterprises. Private enterprises have strong innovation capabilities and are more likely to recognize consumers' concern for the environment and social responsibility and quickly take measures to address the challenge of carbon emissions reduction.

4.4.3. Heterogeneity Test for Moderating Effects

Given the varied attributes of different growth enterprises and enterprises with different ownership characteristics, this leads to differences in the paths of the institutional environment and media attention on corporate carbon performance. Consequently, the impact of ESG disclosure on the carbon performance of heavily polluting corporations manifests with heterogeneity. Therefore, this paper estimates the relationship between

institutional environment, media attention, ESG disclosure, and corporation carbon performance from the perspectives of enterprise growth and heterogeneity of enterprise ownership attributes, and Table 7 presents the results of the regression analysis.

Table 7. Heterogeneity tests for moderating effects.

VARIABLES	(1) High-Growth CP	(2) Low-Growth CP	(3) State-Owned CP	(4) Private CP	(5) High-Growth CP	(6) Low-Growth CP	(7) State-Owned CP	(8) Private CP
c_ESG	0.022 ***	0.008	0.010 *	0.026 ***	0.015 **	0.010 *	0.010 *	0.022 ***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
c_MARKET	−0.014 ***	−0.014 ***	−0.017 ***	−0.010 **				
	(0.005)	(0.004)	(0.004)	(0.005)				
c_ESGc_MARKET	−0.008 *	−0.001	−0.009 ***	−0.004				
	(0.004)	(0.003)	(0.004)	(0.004)				
c_MEDIA					0.048 ***	0.035 ***	0.034 ***	0.053 ***
					(0.009)	(0.008)	(0.009)	(0.009)
c_ESGc_MEDIA					0.005	0.005	0.010 *	0.002
					(0.005)	(0.005)	(0.006)	(0.005)
OC	−0.102 *	0.000	−0.137 **	0.141 **	−0.063	0.031	−0.094 *	0.177 ***
	(0.057)	(0.052)	(0.053)	(0.056)	(0.058)	(0.052)	(0.054)	(0.057)
SIZE	0.003	−0.004	0.031 ***	−0.036 ***	−0.021 **	−0.019 **	0.012 *	−0.058 ***
	(0.008)	(0.007)	(0.006)	(0.008)	(0.008)	(0.007)	(0.007)	(0.008)
II	0.032	−0.001	0.127 ***	0.010	0.014	−0.015	0.053	−0.002
	(0.040)	(0.038)	(0.048)	(0.035)	(0.039)	(0.038)	(0.046)	(0.035)
GROWTH	0.075 **	−0.080	0.067 ***	0.033	0.066 **	−0.082	0.058 **	0.019
	(0.031)	(0.060)	(0.025)	(0.031)	(0.030)	(0.059)	(0.024)	(0.030)
LY	−0.055 ***	−0.077 ***	−0.026	−0.023	−0.055 ***	−0.076 ***	−0.036 **	−0.028 **
	(0.016)	(0.014)	(0.018)	(0.015)	(0.016)	(0.013)	(0.018)	(0.014)
BOARD	−0.094 **	−0.041	−0.138 ***	0.057	−0.094 **	−0.035	−0.130 ***	0.046
	(0.039)	(0.038)	(0.036)	(0.042)	(0.039)	(0.038)	(0.036)	(0.042)
INDEP	−0.380 **	−0.209	−0.448 ***	−0.028	−0.340 **	−0.229	−0.410 ***	−0.075
	(0.150)	(0.144)	(0.143)	(0.149)	(0.150)	(0.144)	(0.144)	(0.147)
DUAL	0.025	0.013	−0.021	0.025*	0.017	0.004	−0.028	0.018
	(0.017)	(0.015)	(0.022)	(0.013)	(0.017)	(0.015)	(0.022)	(0.013)
Constant	6.188 ***	6.057 ***	4.887 ***	6.889 ***	6.695 ***	6.386 ***	5.331 ***	7.412 ***
	(0.184)	(0.163)	(0.168)	(0.192)	(0.198)	(0.177)	(0.178)	(0.206)
Observations	2645	2645	2340	2950	2645	2645	2340	2950
R-squared	0.956	0.969	0.969	0.951	0.956	0.969	0.969	0.952

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Based on columns (1)–(4) of Table 7, the moderating effect of the institutional environment on ESG disclosure and carbon performance of heavily polluting enterprises is significantly negative for high-growth firms and state-owned enterprises. The coefficients of the remaining interaction terms are insignificant, suggesting that the moderating effect of the institutional environment embodies heterogeneity for firms with different growth and ownership attributes. From the perspective of firm growth heterogeneity, the c_ESGc_MARKET regression coefficient is significantly negative, which indicates that the institutional environment has a facilitating solid effect on the carbon performance enhancement of high-growth, heavy-polluting firms when the level of ESG disclosure is low. In contrast, this facilitating effect is anticipated to diminish for firms that possess a higher level of ESG disclosure. From the perspective of heterogeneity of firms' property rights attributes, c_ESGc_MARKET is significantly negatively correlated at the 1% level (shown in column (3)), with a regression coefficient of -0.009. Moreover, the institutional environment serves to attenuate the promotional effect of ESG disclosure on the carbon performance of state-owned enterprises.

From columns (5)–(8) of Table 7, it is evident that media coverage exerts a notable and statistically significant influence on the relationship between ESG disclosure and carbon performance, particularly for state-owned enterprises. However, it appears that the moderating effect of media attention is different for firms with different ownership characteristics, as evidenced by the coefficients of the other interaction terms. From column (7), the coefficient of c_ESGc_MEDIA amounts to 0.010, surpassing the significance threshold of 10%. These findings suggest that media attention has a beneficial moderating impact on the association between ESG disclosure and the carbon performance of state-owned enter-

prises. Furthermore, as media attention increases, the influence of ESG disclosure on the improvement of state-owned enterprises' carbon performance becomes more pronounced.

5. Conclusions and Implications

ESG is in line with the concept of sustainable development. This article aims to examine the influence of ESG disclosure on corporate carbon performance within the context of China's "dual carbon" objective. Moreover, it seeks to explore the moderating effects of the institutional environment and media attention on the relationship between ESG disclosure and corporate carbon performance.

The findings can be summarized as follows: First, ESG information disclosure enhances the carbon performance of heavily polluting enterprises; a higher level of ESG disclosure helps heavy polluters achieve better carbon performance. Second, the impact of ESG information disclosure on the carbon performance of heavily polluting enterprises is negatively moderated by the institutional environment and positively moderated by media attention. Media attention exerts a positive regulatory influence on ESG disclosure pertaining to the carbon performance of significantly polluting firms. Finally, the heterogeneity analysis reveals that the ESG disclosure has a noteworthy and positive impact on the carbon performance of heavily polluting enterprises experiencing high growth. Moreover, private enterprises exhibit a more pronounced effect on enhancing carbon performance when compared to state-owned enterprises.

Our findings have the following implications: First, enterprises should reconsider their previous unilateral perspective toward investments in environmental protection and social responsibility, which will crowd out corporate resources and increase costs. They should also realize that good corporate ESG management can not only reduce financing costs in the short term but also consider the sustainable development of the company in the long term, strengthen their awareness of carbon risks, and reduce corporate carbon risks through low-carbon production, green innovation, and other behaviors to improve carbon performance. Secondly, establishing a favorable market environment that encourages enterprises to proactively disclose ESG-related information can effectively mitigate the information asymmetry between stakeholders and enterprises. In turn, this facilitates public comprehension of the environmental status of enterprises and subsequently motivates them to engage in energy conservation and emission reduction efforts, thereby achieving sustainable development. Thirdly, in the era of pervasive media, the media report in various ways with fast speed and a wide range of audiences, which makes the media's role in the behavior of the enterprise market guidance stronger and strengthens the media management so that the media can accurately and timely report on the enterprise's environmental violations and track the later development of the incident. At the same time, the media should actively report on enterprises that have achieved notable accomplishments in energy savings, carbon reduction, and green transformation. This approach aims to foster a conducive atmosphere of green and low-carbon development across society as a whole and collectively contribute to the achievement of macro-level reductions in carbon emissions.

The limitations of this article and suggestions for future research directions. Firstly, research has focused on the impact of technology and digital elements on corporate carbon emission reduction; we ignore the interference of technological innovation in corporate emission reduction actions and more from the perspective of management and regulation to build the ESG disclosure on corporate carbon performance. Future research can continue to deepen the issue of corporate carbon performance from the perspective of integrating corporate management, technology, and regulation. Secondly, the scope of the impact of ESG disclosure is extensive, and there may be additional influencing mechanisms in the impact on corporate carbon performance. More research is needed to investigate its impact mechanism further. Thirdly, the research sample in this paper is selected from Chinese-listed, heavily polluting enterprises. Future research endeavors could enhance the sample capacity, for example, by selecting all listed companies in China as a sample for research, and cross-country comparisons can be made with other economies. Finally,

the data utilized in this study are limited to static data. Future research endeavors should incorporate longitudinal tracking data to enhance the validity of the findings. This would enable a more comprehensive assessment of the influence of ESG disclosure on the carbon performance of significantly polluting firms.

In conclusion, ESG disclosure plays a crucial role in fostering the sustainable development of future social enterprises and economic progress. Within this context, carbon performance emerges as a crucial and indispensable topic that demands attention and cannot be ignored. This study aims to build a bridge between the two and provide empirical evidence for future development. We provide additional supporting evidence for ESG disclosure by enterprises under the Sustainable Development Goals and a reference for developing countries' plans to improve corporate carbon performance.

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