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Impact of ESG Performance on Carbon Emission Intensity – Empirical Evidence from A-share listed companies in Northwest China

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Abstract

As the global climate crisis intensifies, decarbonization has become a strategic imperative for sustainable development. China, as the world's largest carbon emitter, faces increasing pressure to balance economic growth with environmental responsibility. In response, the nation has pledged to peak carbon emissions by 2030 and achieve carbon neutrality by 2060, presenting significant challenges for the industrial transformation of Northwest China, where the economy remains heavily reliant on high-emission industries. In this context, the Environmental, Social, and Governance (ESG) framework—recognized for its critical role in facilitating sustainable transitions—has gained importance in guiding local enterprises toward emission reduction. This empirical study investigates the relationship between ESG performance and carbon emission intensity, drawing on public data from five provinces in Northwest China. To deepen the analysis of underlying mechanisms, the study also examines the mediating role of green innovation. The findings reveal that strong ESG performance contributes to carbon emission reductions by enhancing firms' green innovation capacities. Based on these results, the study offers actionable insights to support policymakers and industry stakeholders in advancing carbon reduction goals and promoting sustainable industrial development.

Keywords: ESG performance, Carbon emission intensity, Green innovation, Northwest China

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1. Introduction

The combustion of fossil fuels, such as oil and coal, has led to the abundant emission of greenhouse gases, principally carbon dioxide(Covert et al., 2016). This phenomenon has resulted in a noticeable increase in the Earth's temperature, which is widely known as global warming. Global warming, associated with a wide range of negative consequences such as the melting of glaciers and permafrost, and the rise in sea levels(Ding et al., 2019) seriously jeopardize not just the stability of natural ecosystems but also the viability of human communities. As a result, efforts are being made worldwide to look into ways to reduce carbon dioxide emissions, with the ultimate goal of stopping the acceleration of global warming. China, as one of the major producers of greenhouse gases, has initiated to take responsibility for carbon emissions mitigation. In September 2020, at the United Nations General Assembly, China declared its intention to peak carbon emissions by 2030 and achieve carbon neutrality by 2060—commonly referred as the "dual carbon goals." These goals significantly elevated benchmarks in China's transition toward a low-carbon, environmentally friendly, and sustainable economy. Northwest China including Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang provinces, is a vast region rich in mineral resources of all kinds(Amatijan & Liang, 2021). In this region, traditional industries primarily rely on natural resources including the extraction of natural gas and petroleum, coal mining, textile production, etc. Hence, the "dual carbon goals" presents a remarkable challenge to the industrial transformation and sustainable development in this area. Enterprises, serving as key microeconomic entities, affecting carbon emission reduction and "dual carbon goals" realization(Wei & Wu, 2023). However, the large amount of capital needed and the high risk associated with the low-carbon transition have had an adverse effect on enterprises' profits. The lack of pertinent guidance has left corporates in a dearth of incentives to proactively engage in carbon emissions mitigation endeavors(Wang, Yufeng, 2023). Therefore, determining how to encourage enterprises to cut their carbon emissions and promote a sustainable transformation becomes a critical issue for society and the government.

With the aim of achieving the "dual carbon goals" and sustainable development, China has been actively investigating effective ways to compel businesses to reduce their carbon emissions by means of mandatory

administrative regulations, such as fines, shutdowns, and rectification orders. The stringent regulatory measurement has resulted in a corresponding increase in corporates' investment in environmental protection, which has shown to be beneficial in reducing carbon emissions(Huang et al., 2023). Nevertheless, the heavy reliance on policy-driven pressures from administrative levels has also left businesses primarily in a reactive position, and unfortunately caused the little effect of policy as well as a detrimental influence on the economy(Han et al., 2023). Thus, there is a strong need to proactively explore environmental management mechanisms which are more market-driven and inherently spontaneous which will motivate enterprises to voluntarily commit to carbon emission mitigation and facilitate the achievement of the "dual carbon goals".

A growing focus on environmental protection concepts, including Environmental, Social, and Governance (ESG) standards, has emerged in response to the escalating environmental issues (Smith & Johnson, 2025). Different from traditional assessment criteria, ESG measures environmental, social, and governance dimensions in addition to financial performance(Tsang et al., 2023). From the perspective of corporate governance, frameworks generated naturally from market choices are proposed to have a more constructive effect on encouraging entities to shift to low-carbon development mode than government-imposed policies and laws(Baratta et al., 2023). Due to the increasing importance of ESG performance as one of the key factors for investors when valuing companies(Chen, Longtao & Fang, 2021), consequently, enterprises with improved ESG performance not only have better reputations but also attract more capital. The introduction of the ESG performance score provides a useful method of addressing information asymmetry in the capital markets, improving investment efficiency, and lowering related risks(Wei & Wu, 2023). Thus, it can be considered as a vital reference for encouraging Chinese businesses to take up carbon reduction responsibilities and support green transitions. However, most of the current research on carbon emission reduction of enterprises focuses on government regulation and technological advancement(Lewandowski, 2017; Wang, Zongrun et al., 2023; Xu et al., 2023), with distinguishable research gaps on market-driven methods for spontaneous environmental governance. Moreover, relevant research is typically limited to areas with a high concentration of mega-corporations but overlooks the incorporation of local imperatives and business attributes. Therefore, in light of these gaps, this study aims to empirically investigate whether corporate ESG performance serves as a spur for proactive carbon emissions reduction endeavors by focusing on A-share listed companies in northwestern China.

The principal contributions of this article are: Firstly, it adds to the knowledge regarding the influencing factors of carbon emission reduction. Current studies(Murty & Kumar, 2003; Wang, Zongrun et al., 2023; Xu et al., 2023) center on the top-down government rules while neglecting other facets including the impact of corporate ESG performance. Secondly, it expands the scope of study about ESG performance. In contrast to previous research(Bang et al., 2023; Chen, Simin et al., 2023; Luo et al., 2023) that focuses mostly on its influence on the financial aspect, this study delves into its influencing mechanism on carbon emission intensity. Thirdly, it concentrates on the interplays between corporate ESG performance and carbon emission intensity in a certain geographical context. Existing research overlooks regional differences in economic development patterns, leading to non-universal conclusions. Besides, methodologically, relevant data in this study has been categorized at the provincial level, utilizing a fixed-effects model to analyze how much the ESG performance of regional enterprises contributes to carbon emission reduction. Finally, this study digs into the mechanism by which ESG performance affects carbon emission intensity by introducing and analyzing the mediating role of green innovation. The findings of this study demonstrate that in areas primarily defined by conventional heavy-polluting businesses, higher ESG performance has a favorable impact on the region's total carbon emission intensity. Thus, it is suggested that standardizing the ESG rating system and improving ESG performance across businesses are effective approaches to direct companies toward promoting green innovation and reducing carbon emissions.

Followed by the introduction part, this paper encompasses a theoretical analysis and research hypotheses in the second section. The third part introduces the data resources and methods of analysis. The fourth section states the empirical research results. The last segment concludes and offers suggestions.

2. Theoretical Analysis and Hypotheses

2.1 Impact of Corporate ESG Performance on Carbon Emissions

In the Chinese capital market, there is a significant information gap between corporations and stakeholders. This disparity makes it difficult for stakeholders to obtain key information about companies, while companies, in turn, struggle to comprehend the core interests of stakeholders(Yin et al., 2013). This asymmetry not only results in resource waste but also poses high investment risks. An essential method for minimizing this gap and promoting

a more efficient exchange of information is the ESG concept(Chen, Longtao & Fang, 2021; Chen, Ning & Sun, 2019; Chen, Simin et al., 2023). ESG metrics derived from the ESG concept, covers environmental preservation, social responsibility, and corporate governance, provides stakeholders with a powerful tool to assess a company's performance comprehensively beyond just financial indicators. It effectively reduces the information asymmetry, gives full play to the "invisible hand" function of the market, and brings forth a non-governmental, bottom-up external mechanism for companies' commitment to carbon emission reduction(Chen, Simin et al., 2023).

To be specific, on the one hand, ESG scores incentivize enterprises to proactively mitigate carbon emissions (Persakis, 2024). Economic externality theory holds that individual actions can yield positive or negative consequences for others. Positive externalities result in corporate value and reputation while negative externalities bring risks(Adams, 2004). Businesses dedicated to ESG performance improvement will steer clear of actions that have unfavorable effects and instead support those that have a positive influence. For example, they will aggressively pursue carbon emission reduction in order to draw in investors, expand funding channels, and build a strong resource base for carbon reduction initiatives. Meanwhile, other similar companies, inspired by the success of their counterparts, will contribute collectively to achieving "dual carbon goals". Furthermore, the corporate social responsibility (CSR) theory underscores that, in addition to considering its financial performance, enterprises must also take their impact on society and the environment into consideration when operating(Gillan et al., 2021). To fulfill their social obligation, enterprises will strongly cut their carbon emissions, which will improve their reputation, attract additional capital investment, and enable them to implement green technology innovation and low-carbon transformation. This spontaneous and virtuous cycle serves as a powerful motivation for businesses to achieve sustainable development goals.

On the other hand, ESG scores supports stakeholders' oversight responsibilities in monitoring corporates' carbon emission reduction endeavors. In accordance with stakeholder theory, wherein stakeholders are inherently motivated by self-interest in their engagement with a company's operations(Kumar, 2023), ESG metrics serve as a pivotal point of reference, offering stakeholders an effective framework for vigilant supervision. Besides, drawing from reputation theory, a company's credibility and ESG scores are poised to deteriorate should it engage in excessive carbon emissions, consequently negatively impacting investor interests and diminishing revenue streams(Rahman et al., 2023). As a result, stakeholders will advocate for and pressure businesses to curtail carbon emissions, as they seek to safeguard their own potential reputational damage and financial consequences.

Therefore, propose Hypothesis 1:

Hypothesis 1. Regional better ESG performance benefits the reduction of carbon emissions.

2.2 Mechanism of Corporate ESG Performance on Carbon Emissions

By addressing the issue of information asymmetry in the capital market, the ESG concept encouraged corporations to proactively curb their carbon emissions. However, a number of other factors, such as prosperity, industrial structure, international trade, urbanization, and energy structure, etc.(Zhou & Han, 2016) may have a significant impact on the effects of reducing carbon emissions as well. Among these, green innovation emerged as a key strategy for reducing carbon emissions.

Green innovation, diverging from traditional innovations, strategically pursues the balanced development of the economy, resources, and the environment through the employment of novel concepts and technologies(Yuan & Cao, 2022). Rooted in CSR theory, businesses that uphold their social obligations are essential to driving green innovation. By engaging in green innovation, corporates not only strengthen their competitive positioning and product value, but also save costs and boost productivity, all of which serve to reaffirm their social responsibility(Yuan & Cao, 2022). Furthermore, enterprises remain resilient during the green innovation process by resolving information asymmetry issues raised by outside investors and easing the financial burden of prolonged research and development(R&D) procedures(Wang, Xiaohong et al., 2022). Grounded in economic externality theory, corporate social responsibility endeavors including promoting green innovation reduce dual externalities effects by encouraging an innovative environment and solving conflicts resulted from negative externalities. This promotes a symbiotic relationship between societal well-being, environmental stewardship, and economic prosperity.

Considering the ESG performance, companies with better ESG performance exert direct and indirect influences on their own and regional capacities of green innovation. On the one hand, enhanced ESG performance demands that significant efforts be made toward energy conservation, emission reduction, and the strengthening of

independent green innovation without sacrificing the business's financial gains(Huang et al., 2023). The promotion of green innovation in some regional firms, driven by positive externalities, acts as a stimulant for similar advances in other regional entities, thereby impacting the improvement of green innovation in the region as a whole. On the other hand, enterprises improving their ESG performance indicates increased investor favorability in the capital market(Friede et al., 2015). Stakeholders assess the company's competence in green innovation and sustainable development, companies are encouraged to invest in green innovation as a strategic means of attaining long-term sustainable development as a result of this scrutiny. At the regional level, corporates that stand out for their ESG performance draw more capital, which in turn encourages other regional organizations to work harder to improve their ESG performance. This process shapes a strong presence for these organizations in the capital market and raises the standards of regional green innovation efficiency.

The regional green innovation capacity has an impact on the regional carbon emission intensity. Since the 20th century, there has been a greater focus on how green technology might help reduce carbon emissions. The importance of "development science and technology" in promoting sustainable development was emphasized at the 1992 United Nations Conference on Environment and Development. Carbon emissions are significantly impacted by green innovation through various aspects. Firstly, new green technology improves the efficiency of energy use, which lowers energy consumption and thus lowers carbon emissions(Paramati et al., 2021). Secondly, the development of green innovation increases the amount of clean energy produced, which lowers the cost of using it(Madaleno et al., 2022). This energy market shift, which replaces conventional chemical energy sources with clean energy, optimizes the entire energy structure and significantly reduces the intensity of carbon emissions(Madaleno et al., 2022). Thirdly, the development of green industries is promoted by green technology, which causes an industrial structure transformation, offsetting the premium attached to eco-friendly items, hence lowering the expenses related to mitigating climate change(Du et al., 2021; Shan et al., 2021). In contrast to defensive and adaptive measures like energy conservation, green innovation is a proactive strategy with the aim of carbon neutrality and green economic transformation(Du et al., 2021). Therefore, low- and zero-carbon technologies must be implemented to replace high-carbon ones that are now in place. This underscores the paramount importance of green innovation in the overall strategy.

In collaboration with the discussion above, interplays among ESG performance, green innovation and carbon emissions emerge. Corporate ESG performance manifests a direct impact on carbon emission intensity, wherein the aggregated ESG performance within a region exerts a discernible influence on carbon emissions mitigation. At the same time, green innovation assumes as a crucial mediating role. Higher ESG scores directly contribute to the enhancement of a region's green innovation capacity, thereby impacting indirectly on carbon emission intensity. This mechanism emphasizes the dynamics of the influence of corporate ESG performance on carbon emissions reduction.

Therefore, propose hypothesis 2:

Hypothesis 2. Green innovation plays a mediating role in the impact of corporate ESG performance on carbon emission intensity.

3. Data and Methods of Analysis

3.1 Variables Selection

The dependent variable in this study is the carbon emission intensity of each province, specifically characterized as the total carbon emissions per 10,000 yuan of Gross Domestic Product (GDP). The precise calculation of carbon emission intensity, as an indicator for evaluating the effectiveness of regional carbon emissions reduction strategies, stands as an indispensable component in attaining dual carbon targets(Chen, Shiyi & Qi, 2022; Zhang & Liu, 2021). It's vital in assessing the contributions of diverse regions towards national carbon neutrality objectives and is also a fundamental criterion employed by financial institutions to appraise the endeavors of listed companies in achieving carbon neutrality.

As for the independent variable, deriving from the overall ESG score within the Bloomberg ESG score dataset(Author, 2023), with a specific focus on A-share listed companies in Northwest China. The total ESG score is normalized by the annual revenue of each company to account for the variable impact of ESG performance across businesses of varying scales.

Regarding the mediating variable, the cumulative count of green patents at the provincial level associated with listed firms is adopted. The number of green invention patent applications better reflects a firm's environmental-friendly innovation activity compared to the number of patent grants due to the exclusion of human and policy

influence(Griliches, 1998).

Besides, to address potential factors that may influence the examined relationships, this article incorporated a set of control variables. The comprehensive utilization rate of industrial solid waste, utilized as an indicator for the stringency of environmental regulations and their impact on corporate green innovation(Quan & Li, 2020; Sauvage, 2014; Xiong & Wang, 2020), operationalizes environmental regulation stringency (REG). The metric of car ownership, reflecting the degree of urbanization and its potential impact on emissions and innovation patterns(Pongthanaisawan & Sorapipatana, 2010), is employed to quantify car ownership (PCAR). Population density, captured by the average population per square kilometer (POPU)(Timmons et al., 2016), enables an exploration of the influence of regional population distribution. The percentage of government spending relative to GDP is utilized to measure government intervention (GOV), encapsulating the role of government support and its potential impact(Li & Zhang, 2021; Lv & He, 2021). Lastly, the evaluation of industrial structure (INDUS) is achieved by comparing the production value of the tertiary industry to that of the secondary industry, providing insights into the structural composition of regional economies and its implications for the research objectives(Zhou & Han, 2016).

The summary of the variables is shown in Table 1:

Table 1 Variables Description

Variables type	Definition	Description	Variable name
Dependent Variable	Carbon emission intensity	Carbon emissions per unit of GDP	CEMI
Independent Variable	ESG performance	ESG scores revealed by Bloomberg	ESG
Mediating Variable	Green innovation	Number of green invention patent applications	INNOVA
Control Variables	Environmental regulation stringency	Comprehensive utilization rate of industrial solid waste	REG
	Car ownership	Car ownership	PCAR
	Population density	Average population per square kilometer	POPU
	Government intervention	Government expenditure as a share of GDP	GOV
	Industrial structure	The ratio of the output value of the tertiary industry to the output value of the secondary industry	INDUS

3.2 Data Source and Processing

3.2.1 Carbon Emission Intensity

The following is the procedure for calculating the carbon emission intensity:

Step one: Determine the overall carbon emissions. This study estimated total carbon emissions based on the carbon emission factor published by the Intergovernmental Panel on Climate Change of the United Nations(IPCC) along with the consumption of eight major fossil fuels (including coal, coke, crude oil, gasoline, diesel, kerosene, fuel oil, and natural gas)(Andres et al., 1999) since there are no direct monitoring statistics of these emissions in each region. Calculate (1): where C represents total carbon emission, Ei represents total fossil energy consumption, LHi represents average low calorific value of energy, CHi represents carbon content per unit calorific value of energy, and CORi represents carbon oxidation rate of energy. The China Energy Statistical Yearbook was referred to determine the consumption of the eight main energy sources as well as the average low calorific value of each energy source in each province. The Guidelines for the Preparation of Provincial Greenhouse Gas Inventories were employed to determine the carbon content per unit calorific value and the carbon oxidation rate:

$$C = \sum_{i=1}^{8} E_i \times LH_i \times CH_i \times COR_i \quad (1)$$

Step two: Calculate the carbon emission intensity. The total carbon emissions per unit of GDP represent each province's carbon emission intensity. Use (2) below to calculate the gross national product and the carbon emission intensity (CEMI). Data on the GDP are taken from the China Statistical Yearbook:

$$CEMI = C/GDP \quad (2)$$

3.2.2 Corporate ESG Performance

The ESG database of listed corporates released by Bloomberg(Author, 2023) was used to obtain the ESG scores of the relevant A-share listed companies in northwestern China from 2015 to 2021, including overall scores, E scores, S scores, and G scores. The ESG performance of corporations is considered on a provincial level in combination with the actual availability of corporate ESG scores and the actual situation of carbon emission information disclosure. The effect of the ESG average score of listed companies in the provinces on the provincial carbon emission intensity is studied. Given the differences of business scales, the data will be revised based on the annual output value of the business. However, there are no direct statistics available on it, the business annual output value is expressed by its gross revenue. Calculate (3):

$$ESG_{total} = \sum_{i=1}^{n} ESG_i \times \delta_i \quad (3)$$

In (3), δi stands for the ratio of a company's annual output value to the sum of the annual output values of all listed companies in the province in which it is located, ESGi stands for the company's ESG score, n stands for the total number of listed companies in the province that year and ESGtotal stands for the province's ESG performance.

3.2.3 Green Innovation

The number of green innovation patent applications (including independent applications and joint applications) of listed companies from 2015 to 2021 is acquired by comparison and search at the National Intellectual Property Office website, in accordance with the green inventory(León et al., 2018) of international patent classification introduced by World Intellectual Property Organization(WIPO). Due to the magnitude of this data being incomparable to other variables, according to the existing studies(Wang, Xu & Chu, 2021), logarithmic processing was carried out after adding one to the result, bringing all variables up to the same quantitative level. The possibility of numerous corporations filing a joint patent application twice is conceivable, but this may also be a reflection of the benefits of corporate collaboration in green research, therefore this study accepted the deviation.

3.2.4 Control Variables

The study takes into account the following control variables: total industrial solid waste utilization rate (REG), number of car ownership (PCAR), population density (POPU), government fiscal expenditure proportion in GDP (GOV), and the ratio of tertiary industry output value to secondary industry output value (INDUS). All of the aforementioned information came from the China Statistical Yearbook.

3.3 Empirical Model

To investigate the impact of ESG performance on the carbon emission intensity within a particular setting, a panel regression model (4) utilizing a fixed-effects method was utilized. The dependent variable in this model is the carbon emission intensity (abbreviated as CEMIi.t), which indicates the carbon emission intensity of a certain province i in a specific year t. ESGi,t is the primary independent variable, specifically denotes the province i's ESG performance for the relevant year t. Xi,t represents control variables affecting the intensity of carbon emissions, μi is individual fixed effects and εi,t is the random error term. It is important to highlight that i ranges from 1 to 5, covering five different provinces, and that t covers seven years of data, from 2015 to 2021. The thorough analysis of the association between ESG performance and carbon emission intensity while taking into consideration individual-specific effects is made possible by this methodical methodology(Gao, F., 2022).

$$CEMI_{i,t} = \alpha_0 + \alpha_1 ESG_{i,t} + \alpha_2 X_{i,t} + \mu_i + \varepsilon_{i,t} \quad (4)$$

A mediating variable is presented in this study. This study specifically looked at how green innovation mediated the association between ESG performance and carbon emission intensity. In order to achieve this, a stepwise analysis methodology(Baron & Kenny, 1986; Wen et al., 2022) was used, integrating (5), (6) and (7), and extending it further with (8) as an improvement to the conventional stepwise methodology.

$$CEMI_{i,t} = \alpha_0 + \alpha_1 ESG_{i,t} + \alpha_2 X_{i,t} + \mu_i + \varepsilon_{i,t} \quad (5)$$

$$INNOVA_{i,t} = \beta_0 + \beta_1 ESG_{i,t} + \beta_2 X_{i,t} + \mu_i + \varepsilon_{i,t} \quad (6)$$

$$CEMI_{i,t} = \gamma_0 + \gamma_1 ESG_{i,t} + \gamma_2 INNOVA_{i,t} + \gamma_3 X_{i,t} + \mu_i + \varepsilon_{i,t} \quad (7)$$

$$CEMI_{i,t} = \partial_0 + \partial_1 INNOVA_{i,t} + \partial_2 X_{i,t} + \mu_i + \varepsilon_{i,t} \quad (8)$$

Of which, INNOVAi,t represents green innovation and the Xi,t is control variables. In (5), the term α1 represents the total effect of ESG performance on carbon emission intensity. (6) introduces β1, which signifies the effect of ESG performance on green innovation, highlighting the initial link in mediating analysis. Moving to (7), γ1 represents the effect of ESG performance on carbon emission intensity, after the influence of green innovation has been controlled, while γ2 in this equation corresponds to the effect of innovation on carbon emission intensity on the premise that the influence of ESG performance has been controlled. Whether the mediation effect is established depends on whether the key coefficients are significance. The significant α1, β1, and γ2 indicates the presence of a mediating impact but if any one of them is not significant, the mediation effect is not proved. When γ1 is not significant, the mediation effect is a complete mediation effect β1γ2, which indicates the influence of ESG performance on carbon emission intensity that is mediated by green innovation, but if γ1 is significant, it is a partial mediation effect(Baron & Kenny, 1986; Gao, F., 2022). Lastly, in (8), $\partial 1$ captures the independent effect of green innovation on carbon emission intensity.

By using these comprehensive models, we will learn more about how ESG performance affects carbon emission intensity, both directly and indirectly through the mediating effect of green innovation, while controlling for a variety of relevant factors.

4 Empirical Results

4.1 Descriptive and Correlation Analysis

Table 2 presents the results of a descriptive statistical analysis conducted on the entire sample. Corporate carbon emissions intensity among these decreases from 4.250 to 0.620, demonstrating a significant variation in carbon emissions among different enterprises. The values for the remaining variables are within reasonable limits. In general, the data had high levels of stability, a small dispersion, and a low standard deviation.

Table 2 Descriptive Statistics

Variable	N	Mean	Median	Std. dev.	Min	Max
CEMI	284	1.430	1.130	0.690	0.620	4.250
ESG	284	25.560	24.570	11.590	0.000	54.990
INNOVA	284	0.980	0.690	1.160	0.000	5.840
REG	284	47.700	47.750	9.020	35.570	76.770
PCAR	284	461.800	438.100	202.400	78.180	797.100
POPU	284	100.600	57.970	79.050	8.450	192.300
GOV	284	0.340	0.330	0.200	0.020	0.700
INDUS	284	1.190	1.130	0.280	0.810	1.740

The correlation between the variables was examined. Table 3 shows the matrix of correlations. The reliability of the subsequent regression analysis is increased because major variable correlation coefficients are less than 0.6, implying that there is no discernible autocorrelation among independent variables, which also reduces the possible influence of collinearity. The core independent variable ESG score is significantly negatively correlated

with carbon emission intensity (r =-0.183, p<0.01), and significantly positively correlated with the mediating variable green innovation (r = 0.350, p<0.01), which is consistent with the research hypotheses of this study.

Table 3 Correlation Matrix

	CEMI	ESG	INNOVA	REG	PCAR	POPU	GOV	INDUS
CEMI	1							
ESG	-0.183***	1						
INNOVA	0.006	0.350***	1					
REG	-0.041	-0.017	-0.028	1				
PCAR	-0.316***	0.098*	0.023	-0.220***	1			
POPU	-0.405***	0.04	-0.027	-0.074	0.783***	1		
GOV	-0.323***	0.086	0.038	-0.200***	0.677***	0.563***	1	
INDUS	0.116*	-0.052	-0.104*	-0.003	-0.410***	-0.641***	-0.468***	1

Notes: *p < 0.1, ** p < 0.05, *** p < 0.01

The sample data underwent the variance inflation factor (VIF) test, and the results are displayed in Table 4. It was discovered that the VIF values of the primary variables were all less than 5, with the maximum value being 3.980, the lowest value being 1.090, and the average value being 2.180, indicating that there isn't significant multicollinearity among the variables.

Table 4 VIF Test

Variable	VIF	1/VIF
POPU	3.980	0.251
PCAR	3.790	0.264
GOV	2.060	0.486
INDUS	1.990	0.501
INNOVA	1.180	0.849
ESG	1.150	0.867
REG	1.090	0.918
Mean VIF	2.180	

4.2 F Test and Hausman Test

This study first tested whether there is a significant individual random effect in the sample using the F test, and then it determined whether the mixed regression test method could be applied before regressing the panel data. When there is no individual effect and all of the individual intercept components are 0, the F test's null hypothesis states that a mixed regression model can be applied. The author compiled the Stata analysis results, which are displayed in Table 5, and found that the p-value is less than 0.01. Which means, at the 1% significance level, the null hypothesis is rejected, suggesting the existence of an individual effect and the impossibility of selecting the mixed regression model.

The Hausman test was then used in this study to decide between a fixed effects model and a random effects model. This article chose the fixed effects model for empirical analysis because the Hausman test, which compared the two sets of estimates (fixed effects and random effects), rejected the alternative hypothesis of random effects (p=0.000<0.01).

Table 5 F Test

Test	F	P
F test	56.52	0.000

Table 6 Hausman Test

	Coef.
Chi2	86.21
P	0.000

4.3 Benchmark Regression Analysis

The results of the benchmark regression test are shown in Table 7 to validate the relationship between ESG performance and carbon emission intensity. Column (1) displays the regression findings of ESG performance on carbon emission intensity controlling individual fixed effects but without additional control variables, at the 1% significance level, the ESG regression coefficient is -0.012(β = −0.012, p < 0.01). Column (3) exhibits the regression results adding control variables with individual fixed effects being controlled, the coefficient of ESG is -0.003, and at the 1% significance level, it is significant (β = −0.003, p < 0.01). The results indicate that both columns' ESG performance regression coefficients are considerably negative at the 1% level, proving that ESG performance successfully motivates businesses to cut their carbon emissions.

Table 7 Benchmark Regression Results

	(1) CEMI	(2) CEMI
ESG	-0.012***	-0.003***
	(-8.305)	(-2.685)
REG		0.003***
		(5.773)
PCAR		-0.001***
		(-10.173)
POPU		0.033***
		(8.426)
GOV		0.068
		(1.645)
INDUS		-0.090
		(-1.650)
Constant	1.732***	-1.321***
	(6.954)	(-3.583)
Firm FE	Yes	Yes
N	284	284
Adjusted_R2	-0.089	0.493

Notes: t statistics in parentheses *p < 0.1, ** p < 0.05, *** p < 0.01

4.4 Mediating Effects Analysis

Adopted the stepwise mediating analysis method(Baron & Kenny, 1986; Wen et al., 2022) to verify whether there is a mediating effect of green innovation in the relationship between ESG performance and carbon emission intensity. The analysis findings are displayed in Table 8.

Firstly, the association between ESG performance and carbon emission intensity was investigated, as shown in Column (1). Showed a statistically significant negative impact (β = −0.003, p < 0.01) indicating that as ESG performance increases, carbon emission intensity decreases. Secondly, the impact of ESG performance on green innovation was analyzed, as indicated in Column (2). Displayed a substantial positive correlation between higher ESG performance and increased green innovation (β = 0.021, p < 0.1). Thirdly, the connection between green innovation and carbon emission intensity was examined, as shown in Column (3). Stated that more green innovation results in lower carbon emission intensity (β = −0.022, p < 0.01). Lastly, looked into how ESG performance and green innovation together affected the carbon emission intensity, as shown in Column (4). The effect of ESG performance on carbon emission intensity remained substantial (β = −0.003, p < 0.05) after including the influence of green innovation in the model, showing the existence of a mediating effect (partial

mediation effect).

Table 8 Mediating Effects Regression Results

	(1) CEMI	(2) INNOVA	(3) CEMI	(4) CEMI
ESG	-0.003***	0.021*		-0.003**
	(-2.685)	(1.687)		(-2.361)
INNOVA			-0.022***	-0.020***
			(-3.180)	(-2.905)
REG	0.003***	-0.015**	0.003***	0.003***
	(5.773)	(-2.346)	(5.282)	(5.309)
PCAR	-0.001***	-0.003**	-0.001***	-0.001***
	(-10.173)	(-2.549)	(-12.511)	(-10.731)
POPU	0.033***	0.038	0.034***	0.034***
	(8.426)	(0.950)	(8.857)	(8.774)
GOV	0.068	-0.172	0.068*	0.064
	(1.645)	(-0.405)	(1.670)	(1.591)
INDUS	-0.090	0.253	-0.096*	-0.085
	(-1.650)	(0.448)	(-1.768)	(-1.586)
Constant	-1.321***	-1.502	-1.426***	-1.352***
	(-3.583)	(-0.395)	(-3.909)	(-3.737)
N	284	284	284	284
Adjusted_R2	0.667	0.061	0.672	0.681

Notes: t statistics in parentheses *p < 0.1, ** p < 0.05, *** p < 0.01

4.5 Robustness Test

The study carried out further analysis taking into account the lag influence of ESG performance on corporate carbon emission intensity in order to improve the robustness of the empirical findings. The lESG variable was created by delaying the independent variable, ESG performance, by one period in light of the findings of previous studies(Gao, J. et al., 2021; Lu, 2024). The study then re-regressed the primary research findings to evaluate the long-term influence of ESG performance on businesses' attempts to reduce carbon emissions.

Table 9 presents the outcomes of the lagged ESG performance regression. Unsurprisingly, the fixed-effects model's coefficient for the lESG, lagged by one period, is found to be -0.008 and exhibits statistical significance at the 1% level (β=−0.008, $p<0.01$). This significance is maintained at the 5% level (β=−0.004, $p<0.05$) after accounting for all control variables when the coefficient changes to -0.004. These results provide strong support for Hypothesis 1 by indicating that listed firms' ESG performance has a long-lasting impact on their efforts to reduce carbon emissions.

Table 9 Regression Results (Lagged ESG performance)

	(1) CEMI	(2) CEMI
lESG	-0.008***	-0.004**
	(-4.859)	(-2.304)
REG		0.003***
		(3.521)
PCAR		-0.001***
		(-7.253)
POPU		0.035***
		(6.085)
GOV		0.076
		(1.286)
INDUS		-0.090
		(-1.081)
Constant	1.545***	-1.608***
	(32.101)	(-2.985)
Firm FE	Yes	Yes
N	150	150
Adjusted_R2	-0.289	0.323

Notes: t statistics in parentheses *p < 0.1, ** p < 0.05, *** p < 0.01

4.6 Mechanism analysis

Drawing from the empirical analysis presented above, it is evident that a province with better ESG performance has lower carbon emission intensity, or lower carbon emissions overall. This mutual influence is mediated by green innovation through advancing environmentally friendly technologies to enable carbon emission mitigation.

Further exploring the mechanism underlying the relationship between ESG performance and carbon emissions finds a significant inhibitory effect, in which higher levels of green innovation are fostered by ESG performance, hence suppressing carbon emission intensity. Enhancing ESG performance requires the joint effort of businesses on energy-saving and emission-reducing improvement which aid in streamlining procedures, cutting expenses, and raising productivity(Baratta et al., 2023). Due to the impact of positive externalities, companies in the area will advance the total levels of green innovation by becoming leaders in independent green innovation companies, which will provide them with more technological advantages. Furthermore, outstanding enterprises with excellent ESG performance are going to be acknowledged by investors who prefer ecologically sustainable growth. This acknowledgment encourages businesses to strengthen their capacities for green innovation, and prompts local investors to push similar businesses toward higher ESG performance.

It is critical to emphasize how significantly green innovation affects the intensity of carbon emissions. When it comes to tackling the fundamental challenge of carbon neutrality-the "replacement of technology"-green innovation adopts a more effective approach as a strategic "proactive response," as opposed to more "defensive and adaptive responses" like energy conservation and industrial restructuring(Chen, Zhe et al., 2022). The importance of swapping out high-carbon technologies for low- and zero-carbon alternatives is demonstrated by the various ways that green innovation contributes: through increased energy efficiency, reduced use of fossil fuels, the creation of new clean energy sources, upgrades of the energy system, etc. Leading green innovation industries not only gain strong technological advantages but also attract more eco-friendly capital, which will alleviate the emissions of carbon dioxide, accelerate the environmentally favorable industrial structure transformation and contribute to the achievement of the “dual carbon goals”.

In summary, the analysis highlights the important interactions between ESG performance, carbon emission intensity and green innovation. Regional green innovation is sparked by ESG performance, and green innovation

itself emerges as one of the powerful forces in reducing carbon emissions and changing industries toward sustainability.

5. Conclusion

5.1 Conclusion

In the context of “dual carbon goals”, this study utilized empirical data from A-share listed firms in five northwest Chinese provinces from 2015 to 2021, employing a panel data regression model and stepwise methodology, to explain the effects and underlying mechanisms into the relationship between ESG performance and carbon emissions. The study's conclusions highlight the notable impact of ESG performance on the reduction of carbon emissions. Furthermore, a thorough mediating impact study shows that the pathway through ESG performance to curb carbon emissions involves the stimulation of enterprises to engage in green innovation pursuits.

This impact mechanism, which is positioned within the theoretical frameworks of economic externality theory, CSR theory, and stakeholder theory, is obviously distinct from top-down policy enforcement by the government. Rather, the motivation to actively pursue improved ESG performance comes from spontaneous incentives that are driven by the market. Within this cycle, organizations proactively attempt to improve their ESG performance as a strategic initiative to draw in more capital, given that ESG performance is a crucial factor that investors consider when assessing the quality of an enterprise. Because reducing emissions is a key component in determining an organization's ESG performance score, corporations are compelled to reduce their carbon emissions so as to pursue a higher ESG score. This virtuous loop, within businesses proactively enhance their green innovation capacities to raise ESG performance, then helps lower carbon emissions, which benefits the region's overall sustainable growth.

The study focuses on heavily polluting industries, revealing that in areas characterized by a concentration of such businesses, ESG performance has a noticeable and considerable positive impact on carbon emission reduction. The empirical findings of the study offer strong support for the government's advocacy of directing corporate ESG development, promoting active involvement in ESG initiatives, and encouraging ESG investments. It is suggested that this strategy will help achieve the “dual carbon goals” by contributing to the overall objective of reducing carbon emissions.

5.2 Enlightenment

This study delves into the capital market in China and empirically investigates how ESG performance affects the decrease of carbon emissions. With the "dual carbon goals” gaining momentum, the capital market's increased focus on ESG highlights how crucial it is for China, a major carbon emitter, to lead the way in promoting corporate carbon emission reduction through ESG prompting mechanism. Based on the previous research results, the paper provides the following insights:

Firstly, for governments, it is imperative that the authorities recognize how ESG scores benefit the reduction of carbon emissions. It is critical to actively support the creation of a legal framework requiring corporations to disclose ESG information, direct the capital market to increase the emphasis on corporate ESG performance by utilizing green innovation as an intermediary. Encouraging and rewarding businesses that are actively involved in green innovation, to create an environment that is efficient, low-carbon, technologically sophisticated, and environmentally sustainable.

Secondly, for corporations, it is important to be actively committed to ESG practices. Businesses should increase their investments in and dedication to ESG endeavors, not limited to strengthening their green innovation capacities which will result in cost savings but also increase productivity. Especially, listed firms should set an example by incorporating ESG concepts into their company missions and assessment procedures to not only improve their reputation but also encourage constructive development within their corresponding sectors.

Thirdly, for investors, fostering a concept of ESG investment is imperative to promote environmentally friendly consciousness and responsibility. Investors can lower information-gathering costs, lessen information asymmetry, improve investment efficiency, and alleviate investment risks by diligently tracking corporate ESG scores. Furthermore, active involvement in ESG investment will contribute to the positive development of the capital market and consequently force businesses to give priority to ESG initiatives, dedicated to ESG practices and ultimately reduce carbon emissions.

5.3 Limitations and Prospects

This study is subject to certain limitations in data collection, mainly since the ESG concept is still relatively new. Comprehensive analysis is hampered by the lack of uniform disclosure criteria and evaluation frameworks. In addition, the study's sample size is not extensive and its sample period is relatively short, which highlights the inconsistent efforts of listed firms to disclose their ESG practices. Furthermore, there are three dimensions to ESG, of which environmental considerations being just one aspect.

The article recommends further improving the selection, construction and analysis of the variables, expanding the dataset's volumetric and temporal dimensions, and utilizing a more standardized and recognized ESG rating database. Moreover, establishing an internal dynamic interaction model for ESG to facilitate deeper exploration of the multifaceted impacts of ESG practices will shed light on the intricate relationships between environmental, social, and governance aspects.

Future research should refine variable selection and expand both the temporal and spatial scope of the dataset, while adopting standardized ESG rating systems. More advanced statistical models and internal dynamic interaction frameworks can offer deeper insights into the interplay among ESG dimensions. Furthermore, exploring sector-specific and regional variations, as well as potential non-linear relationships, could enhance understanding of ESG's broader impacts as well.

References

Adams, G. D. (2004). *The theory of externality: A chronology and taxonomy*. The University of Texas at El Paso.

Amatijan, A., & Liang, J. (2021). Infrastructure project investment, technological progress and industrial structure transformation and upgrading - based on empirical analysis of five provinces and regions in Northwest China. *Project Management Technology, 19*, 8–13.

Andres, R. J., Fielding, D. J., Marland, G., Boden, T. A., Kumar, N., & Kearney, A. T. (1999). Carbon dioxide emissions from fossil-fuel use, 1751–1950. *Tellus B, 51*(4), 759–765.

Author, B. (2023). *What is Bloomberg ESG.* https://www.esgthereport.com/what-is-bloomberg-esg/#:~:text=ESG%20Ratings%20on%20Bloomberg%20ESG,local%20communities%20and%20the%20environment.

Bang, J., Ryu, D., & Webb, R. I. (2023). ESG controversy as a potential asset-pricing factor. *Finance Research Letters, 58*, 104315.

Baratta, A., Cimino, A., Longo, F., Solina, V., & Verteramo, S. (2023). The impact of ESG practices in industry with a focus on carbon emissions: Insights and future perspectives. *Sustainability, 15*(8), 6685.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173.

Chen, L., & Fang, H. (2021). ESG investment opportunities under carbon neutrality. *Frontiers in Economics and Management, 2*(9), 210–219.

Chen, N., & Sun, F. (2019). Comparison of ESG system development in China and abroad as well as the suggestions for building China's ESG system. *Development and Research, 3*, 59–64.

Chen, S., & Qi, Y. (2022). Technical routes, institutional innovation and institutional guarantees to achieve carbon peak and carbon neutrality goals. *Guangdong Social Sciences, 2*, 15–23.

Chen, S., Song, Y., & Gao, P. (2023). Environmental, social, and governance (ESG) performance and financial outcomes: Analyzing the impact of ESG on financial performance. *Journal of Environmental Management, 345*, 118829.

Chen, Z., He, Z., Zhang, W., & Sun, Z. (2022). Towards carbon neutrality: A dynamic game approach replacing fossil energy with new marine energy. *Energy Reports, 8*, 738–755.

Covert, T., Greenstone, M., & Knittel, C. R. (2016). Will we ever stop using fossil fuels? *Journal of Economic Perspectives, 30*(1), 117–138.

Ding, Y., Zhang, S., Zhao, L., Li, Z., & Kang, S. (2019). Global warming weakening the inherent stability of glaciers and permafrost. *Science Bulletin, 64*(4), 245–253.

Du, K., Cheng, Y., & Yao, X. (2021). Environmental regulation, green technology innovation, and industrial structure upgrading: The road to the green transformation of Chinese cities. *Energy Economics, 98*, 105247.

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment, 5*(4), 210–233.

Gao, F. (2022). *Study on the impact of rural credit on Farmers' Income -- Based on the intermediary perspective of farmers' entrepreneurship*

Gao, J., Chu, D., Lian, Y., & Zheng, J. (2021). Can ESG performance improve corporate investment efficiency? *Securities Market Herald, 11*, 24–34.

Gillan, S. L., Koch, A., & Starks, L. T. (2021). Firms and social responsibility: A review of ESG and CSR research in corporate finance. *Journal of Corporate Finance, 66*, 101889. 10.1016/j.jcorpfin.2021.101889

Griliches, Z. (1998). Patent statistics as economic indicators: a survey. *R&D and productivity: the econometric evidence* (pp. 287–343). University of Chicago Press.

Han, J., Li, T., & Philbin, S. P. (2023). Does low-carbon pilot policy in China improve corporate profitability? The role of innovation and subsidy. *Innovation and Green Development, 2*(2), 100050.

Huang, Y., Bai, F., Shang, M., & Ahmad, M. (2023). On the fast track: the benefits of ESG performance on the commercial credit financing. *Environmental Science and Pollution Research,* , 1–14.

Kumar, S. (2023). A Review ESG Performance as a Measure of Stakeholders Theory. *Academy of Marketing Studies Journal, 27*(S3)

León, L. R., Bergquist, K., Wunsch-Vincent, S., Xu, N., & Fushimi, K. (2018). Measuring innovation in energy technologies: green patents as captured by WIPO's IPC green inventory. *Economic Research Working Paper, 44*

Lewandowski, S. (2017). Corporate carbon and financial performance: The role of emission reductions. *Business Strategy and the Environment, 26*(8), 1196–1211.

Li, X., & Zhang, X. (2021). The Internet, technological progress and China's carbon emission intensity—an empirical analysis based on the extended STIRPAT model. *Journal of Hangzhou Dianzi University (Social Science Edition), 17*, 1–8.

Lu, C. (2024). Research on the influence of ESG performance on the financialization of entity enterprises: based on the empirical study of listed manufacturing companies in China. *Securities & Futures of China, 2*, 73–80.

Luo, D., Yan, J., & Yan, Q. (2023). The duality of ESG: Impact of ratings and disagreement on stock crash risk in China. *Finance Research Letters, 58*, 104479.

Lv, K., & He, Y. (2021). Economic agglomeration, technological progress and carbon emission intensity of the Yangtze River Delta urban agglomeration - based on space empirical research on intermetric and mediating effects. *Ecological Economy, 1*, 13–20.

Madaleno, M., Dogan, E., & Taskin, D. (2022). A step forward on sustainability: The nexus of environmental responsibility, green technology, clean energy and green finance. *Energy Economics, 109*, 105945.

Murty, M. N., & Kumar, S. (2003). Win–win opportunities and environmental regulation: testing of porter hypothesis for Indian manufacturing industries. *Journal of Environmental Management, 67*(2), 139–144.

Paramati, S. R., Mo, D., & Huang, R. (2021). The role of financial deepening and green technology on carbon emissions: Evidence from major OECD economies. *Finance Research Letters, 41*, 101794.

Persakis, A. (2024). The impact of climate policy uncertainty on ESG performance, carbon emission intensity and firm performance: Evidence from Fortune 1000 firms. *Environment, Development and Sustainability, 26*, 24031–24081.

Pongthanaisawan, J., & Sorapipatana, C. (2010). Relationship between level of economic development and motorcycle and car ownerships and their impacts on fuel consumption and greenhouse gas emission in Thailand. *Renewable and Sustainable Energy Reviews, 14*(9), 2966–2975.

Quan, Y., & Li, Z. (2020). Measuring environmental regulation stringency in China: Perspective of China's pollution levy system. *Environmental Economic Research, 1*, 56–77.

Rahman, H. U., Zahid, M., & Al-Faryan, M. A. S. (2023). ESG and firm performance: The rarely explored moderation of sustainability strategy and top management commitment. *Journal of Cleaner Production, 404*, 136859.

Sauvage, J. (2014). The stringency of environmental regulations and trade in environmental goods.

Shan, S., Genç, S. Y., Kamran, H. W., & Dinca, G. (2021). Role of green technology innovation and renewable energy in carbon neutrality: A sustainable investigation from Turkey. *Journal of Environmental Management, 294*, 113004.

Smith, J. A., & Johnson, L. M. (2025). Integration of Environmental, Social, and Governance (ESG) criteria: A systematic review. *Nature Sustainability, 8*(3), 210–222.

Timmons, D., Zirogiannis, N., & Lutz, M. (2016). Location matters: Population density and carbon emissions from residential building energy use in the United States. *Energy Research & Social Science, 22*, 137–146.

Tsang, A., Frost, T., & Cao, H. (2023). Environmental, Social, and Governance (ESG) disclosure: A literature review. *The British Accounting Review, 55*(1), 101149. 10.1016/j.bar.2022.101149

Wang, X., Luan, X., & Zhang, S. (2022). Corporate R&D investment, ESG performance, and market value - corporate figures moderating effect., 1–16. Science Research

Wang, X., & Chu, X. (2021). Research on the cohort effect of green technology innovation in manufacturing enterprises: the reference effect based on multi-level situations. *Nankai Management Review,* , 1–24.

Wang, Y. (2023). Can the green credit policy reduce carbon emission intensity of "high-polluting and high-energy-consuming" enterprises? Insight from a quasi-natural experiment in China. *Global Finance Journal, 58*, 100885.

Wang, Z., Fu, H., & Ren, X. (2023). Political connections and corporate carbon emission: New evidence from Chinese industrial firms. *Technological Forecasting and Social Change, 188*, 122326.

Wei, L., & Wu, C. (2023). Company ESG performance and institutional investor ownership preferences. *Business Ethics, the Environment & Responsibility,*

Wen, Z., Fang, J., Xie, J., & Ouyang, J. (2022). Methodological research on mediation effects in China's mainland. *Advances in Psychological Science, 30*, 1692–1702.

Xiong, B., & Wang, R. (2020). Effect of environmental regulation on industrial solid waste pollution in China: from the perspective of formal environmental regulation and informal environmental regulation. *International Journal of Environmental Research and Public Health, 17*(21), 7798.

Xu, P., Ye, P., Jahanger, A., Huang, S., & Zhao, F. (2023). Can green credit policy reduce corporate carbon emission intensity: Evidence from China's listed firms. *Corporate Social Responsibility and Environmental Management,*

Yin, J., Rothlin, S., Li, X., & Caccamo, M. (2013). Stakeholder perspectives on corporate social responsibility (CSR) of multinational companies in China. *Journal of International Business Ethics, 6*(1-2), 57–71.

Yuan, B., & Cao, X. (2022). Do corporate social responsibility practices contribute to green innovation? The mediating role of green dynamic capability. *Technology in Society, 68*, 101868.

Zhang, L., & Liu, S. (2021). Study on the influencing factors of carbon emissions in the Beijing-Tianjin-Hebei region under the carbon neutrality goal——An empirical analysis based on quantile regression and VAR model. *Resource Development and Market, 37*, 1025–1031.

Zhou, J., & Han, Y. (2016). Regional differences and driving factors of China's carbon emission intensity—based on 1995-2013
Empirical analysis of inter-provincial panel data. *Financial Theory Research, 1*, 18–26.

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