

# The impact mechanism of carbon emission reduction performance on financial performance based on carbon neutral targets: Evidence from Chinese energy enterprises

 Boris Ivanovich Sokolov<sup>1</sup>,  Xuyan Jiang<sup>2</sup>,  Xiaowei Ding<sup>3\*</sup>

<sup>1,2,3</sup>Department of Credit Theory and Financial Management, St. Petersburg State University, St. Petersburg, Russia.

\*Corresponding author: Xiaowei Ding (Email: [xiaoweiding06796@gmail.com](mailto:xiaoweiding06796@gmail.com))

## ABSTRACT

**Purpose:** Low-carbon and green technologies are crucial for achieving industrial structure upgrades and significant leaps forward in the development of energy enterprises. Therefore, this paper examines the correlation between carbon emission reduction and financial performance in energy firms.

**Design/Methodology/Approach:** A two-way fixed-effects model is developed using data from 33 Chinese energy-listed companies between 2015 and 2020.

**Findings:** The benchmark regression results show that improving a company's carbon emission reduction performance leads to better financial performance. Moreover, assuming corporate responsibility for reducing emissions can boost companies' reputations and foster better relationships with stakeholders. The trustworthiness of the standard regression outcome is validated through alternative independent variables, reducing time frames, and incorporating previously omitted factors. The results of heterogeneity analyses show that reducing carbon emissions has the same effect on financial performance across all regional characteristics and equity subgroups. Furthermore, the internal transmission mechanism analysis reveals that female leadership positively moderates the effect, while financing constraints negatively moderate the relationship between carbon emission reduction performance and financial performance.

**Conclusion:** Under the national green development strategy of achieving carbon neutrality and carbon peaking, the carbon information disclosure system should be improved by the government; enterprises should implement innovative methods for low-carbon economic management and operation; and regulators should establish effective green regulations, incentives, and constraints. This paper offers a comprehensive guide for energy companies and their stakeholders to reduce carbon emissions, thereby achieving sustainability.

**Keywords:** Carbon emission reduction performance, Female leadership, financial performance, Financing constraints, Heterogeneity analysis, Moderating effect, Two-way fixed effects model.

## 1. INTRODUCTION

As extreme weather events continue to increase globally and environmental issues worsen, the harmful impacts of the greenhouse effect are becoming increasingly significant. Consequently, energy conservation, reducing emissions, and lowering carbon levels have been extensively embraced and universally recognized worldwide as essential strategies to tackle the pressing climate emergency. As the world's highest carbon emitter, China places great emphasis on these measures. In 2020, the Chinese government declared its aim to reach "carbon neutrality" and "carbon peaking," which includes achieving the peak of carbon dioxide emissions by 2030 and striving for carbon neutrality by 2060 (Xue, Zhang, & Zhao, 2021). This announcement represents China's initial response to global climate change and greenhouse gas mitigation, highlighting the country's commitment as a major player in tackling climate challenges. Energy conservation and emissions reduction are crucial in addressing the global

climate change crisis while providing opportunities to implement scientific development, restructure the economy, and transform development methods (Bakhsh, Yin, & Shabir, 2021; Canha, Justino, Gamelas, & Almeida, 2022). Scholars primarily focus on the factors that influence carbon emission reduction performance and its impact on the economy. Macro-economic policies have an impact on the strategic decisions for reducing carbon emissions by microenterprises. Du and Wang (2022), as well as Wang, Lu, and Qiao (2021), provide an example of how the energy-saving and emission reduction policies implemented by the Chinese government can greatly improve carbon emission reduction performance. Additionally, to appraise the carbon efficiency of energy companies, Yuan, Chen, Zhang, and Li (2023) fabricated a carbon efficiency evaluation system for electric industries that incorporates two principal components: carbon administration and carbon reduction of emissions. According to the outcomes, initial emphasis should be given to improving carbon emission reduction efficacy, whereas later stages should focus on emphasizing carbon administration. Energy productivity, utilization of renewable energy technologies, and decarbonization of the energy sector can effectively assist in controlling pollution and reducing carbon emissions (Cattaneo, Jansson, & Ma, 2018; Yue, Huang, & Ren, 2023). The economic impact of reducing carbon emissions has been researched mainly in terms of its effect on financial performance. According to Kim and Kim (2022), performance in carbon emission reduction can considerably increase the percentage of a company's foreign sales.

However, there is still a dearth of comprehensive analysis on the mechanism of reducing carbon emissions and its effect on financial performance. Abbreviations are explained upon first usage. Hence, this study investigates a sample of 33 Chinese energy companies listed from 2015 to 2020. It applies a two-way fixed-effect model to explore the correlation between carbon emission reduction performance and the financial performance of energy firms. The study observes conventional academic formatting and structures with factual and unambiguous titles. The language used is formal, objective, value-neutral, and precise, with the avoidance of colloquial expressions, biased language, and ambiguity. Furthermore, the study aims for clear and logical structure with causal connections between statements, avoiding filler words and mistakes in style guides, grammar, spelling, and punctuation. This paper examines pathways for reducing carbon emissions and their relevance for enabling energy companies to achieve their "dual-carbon" objectives at an earlier stage.

The paper's contributions and innovations are described as follows: Firstly, the paper presents a two-way fixed-effects model, which takes measures for endogeneity into account, to investigate how carbon emission reduction performance affects the financial performance of Chinese energy companies. (2) Various techniques, including substituting the dependent variable, shortening the time period, and introducing omitted variables, have been utilized to verify the stability of the control regression outcomes. (3) This research examines the diverse link between carbon emission performance and financial performance by taking into account the equity nature and regional attributes. (4) The study analyses the internal transmission mechanism by incorporating female leaders and financing constraints as moderating variables and assesses their impact on the correlation between carbon emission performance and financial performance.

## 2. LITERATURE REVIEW AND EMPIRICAL HYPOTHESES

### 2.1. Carbon Emission Reduction Performance and Financial Performance

Amidst the current climate crisis, organizations that cause substantial environmental pollution could face penalties or even closure. The notion of sustainable development stresses the importance of economically, socially, and environmentally balanced advancements (Axon, 2016; Y. Yuan, Zhang, Wang, & Wang, 2022). Institutions bear the responsibility of mitigating harm to the ecosystem, natural habitat, and the welfare of the public. This enhances the company's reputation, establishes a sustainable brand image, and improves its corporate social capital. According to stakeholder theory, prospective investors consider the enterprise's environmental protection practices, carbon emission performance, and low-carbon development prospects, in addition to its profitability (Chen, Mao, & Sun, 2022; Zhu, Du, & Feng, 2023). From a risk perspective, lowering carbon emissions implies reduced energy consumption and savings that mitigate business risks. This influences investor preferences to direct investments towards industry players with enhanced carbon performance, which minimize the resulting investment risks. Moreover, increased public demand for a cleaner environment underpins this shift in investment patterns. Enterprises may be more likely to proactively commit to environmental efforts in response to external pressures. This approach ensures the satisfaction of different stakeholders, reduces conflicts, and promotes

harmonious relationships, which in turn secures their financial and technological support (Çitil et al., 2023). Therefore, we think that improving the carbon emission performance of enterprises can meet the requirements of all stakeholders, improve the working environment of businesses, promote harmony between enterprises and all sectors of society, and ultimately enhance enterprise performance (Cosma, Schwizer, Nobile, & Leopizzi, 2021; Pedron, Macagnan, Simon, & Vancin, 2020). Therefore, this paper presents the following hypothesis:

*H1: The performance of carbon emission reduction has a favourable effect on financial performance.*

## *2.2. Moderating Effects of Female Leadership and Financing Constraints*

With the rapid expansion of industry, environmental pollution has become increasingly severe. The effective execution of environmental governance is a concern for stakeholders. According to ecofeminist theory, it has been suggested that women are better equipped to be in harmony with nature and accept responsibility (W. Du, Li, Fan, & Liang, 2023; Villalba-Ríos, Barroso-Castro, Vecino-Gravel, & Villegas-Periñan, 2023). Enterprises must prioritize fulfilling social responsibilities while also pursuing economic benefits through scientific and technological innovation. As a result, in the event of severe pollution, female leaders are more inclined to increase investments in environmental measures and assume social responsibility (Cosma et al., 2021; Ding et al., 2023). Additionally, women's tendency to collaborate enables them to build more innovative teams. Furthermore, women have an innate intuition that enables them to anticipate and adapt to changes in trends more effectively. Moreover, they often take the lead in continuous learning and implementing new knowledge and technology (Ebenstein, Fan, Greenstone, He, & Zhou, 2017). Hence, female leaders hold a vital responsibility in supervising boardroom procedures and preventing self-serving behaviour. Furthermore, besides promoting collaboration and decreasing management expenses for internal departments and external firms, the bond that female leaders have with other women additionally improves team cohesion and overall efficiency (Gangadharan, Jain, Maitra, & Vecci, 2019). As a result, it is more probable that female leaders will support corporate carbon reduction initiatives. Based on this assumption, this research presents the following hypothesis:

*H2 (a): Female leadership has a positive moderating effect on the relationship between carbon emission reduction performance and financial performance.*

Reducing carbon emissions by businesses is crucial to attaining the "double carbon" goal. Using a fixed effect model, Naeem and Li (2019) discovered that the reduction of carbon emissions by enterprises can effectively decrease the financial constraints' intensity. Innovation is a significant factor in decreasing carbon emissions. The effective deployment of new technologies and processes is a vital component of carbon reduction initiatives. Innovation is characterized by high levels of risk, capital intensity, and prolonged cycles. Investment and financing are integral to enterprises' day-to-day operations. The existence of information asymmetry, principal-agent concerns, and transaction costs means that internal and external capital cannot be fully replaced, resulting in financial constraints (Cao, Xu, He, & Xu, 2020; Imran, Hayat, Saeed, Sattar, & Wahab, 2023). When companies are unable to obtain financial aid from external credit institutions, they face more severe financing constraints. According to Liu, Wang, Du, Chen, and Li (2023), financing limitations have a dual-threshold effect on knowledge accumulation with regards to the growth of logistics companies, initially increasing before declining due to a suppressive effect. Inadequate private financing options in China have led to the emergence of state-owned banks as the primary lending institutions for enterprises. Small and medium-sized enterprises, due to their size and restricted credit worthiness, face more severe financial constraints. In conclusion, we propose the following hypothesis:

*H2 (b): Financial constraints have a positive moderating effect on the relationship between carbon emission reduction performance and financial performance.*

## **3. VARIABLES SETTING AND DESCRIPTION**

### *3.1. Data Sources*

For the purpose of investigating the impact of carbon emission reduction performance on corporate financial performance, a sample of 198 observations was obtained from Chinese energy-listed firms between 2015 and 2020. Data regarding corporate carbon emissions were sourced from the Carbon Emissions Trading Network (<http://www.tanpaifang.com>), while all other remaining data were obtained from the China Stock Market & Accounting Research Database (CSMAR).

### 3.2. Explained Variable

This paper takes financial performance as an explained variable and uses operating profit margin to measure corporate financial performance.

### 3.3. Explanatory Variable

This paper takes corporate carbon emission reduction performance as an explanatory variable. Revenue earned per unit of carbon emissions is used as a measure of carbon emission performance where carbon emissions include coal, coke, crude oil, petrol, paraffin, diesel, fuel, and natural gas. The larger the value of the enterprise carbon emission performance indicator, the better the carbon emission performance.

### 3.4. Moderating Variables

This paper employs the ratio of female regulation to total regulation as the measure of female leadership. Additionally, corporate financing constraints are assessed using the SA index method proposed by [Hadlock and Pierce \(2010\)](#).

### 3.5. Control Variables

To account for the effect of various factors on financial performance, this study incorporates asset turnover ratio, debt ratio, ratio of shareholding of the largest shareholder, firm size, and nature of equity as control variables ([Ding et al., 2023](#); [Feng et al., 2023](#)). [Table 1](#) presents detailed descriptions and settings of these variables.

**Table 1.** Definition of variables and description analysis.

Category of variables	Specific indicator	Sign	Variable description	Data source	Mean	Min.	Max.
Dependent variable	Financial performance	FP	Ratio of net profit to operating income	CSMAR database	0.215	-0.239	4.162
Independent variable	Carbon emission reduction performance	CERP	Carbon emission reduction performance	CETN database	-0.949	-9.767	1.656
Moderating variables	Female leadership	Fem	Ratio of female regulation to total regulation	CSMAR database	0.114	0.000	0.381
	Financing constraints	Sa	Financing constraint index		-3.69	-4.43	-2.188
Control variables	Total assets turnover ratio	Atr	Operating income to total assets		0.378	0.022	1.433
	Leverage	Lev	Debt to assets ratio		0.577	0.200	0.863
	Ratio of shares held by the largest shareholder	Sfs	Ratio of number of shares held by the largest shareholder to total number of shares		46.640	12.12	86.350
	Firm size	Size	Natural logarithm of total assets		24.410	21.11	28.640
	Property of ownership	State	State-owned enterprises assigned 1, otherwise 0		0.934	0.000	1.000

### 3.6. Model Construction

To investigate the direct impact of reducing carbon emissions on the financial performance, we have constructed a two-way fixed effects model as shown in [Equation 1](#).

$$FP_{it} = \alpha_0 + \alpha_1 CERP_{it} + \alpha_2 Controls_{it} + \text{Fixed effects} + \varepsilon_{it} \quad (1)$$

We employ the interaction term form to investigate if there is variance in the relationship between carbon emission reduction performance and financial performance among subgroups categorized by equity nature and regional characteristics (Reg). State-owned enterprises are assigned as 1, otherwise 0, while eastern enterprises are assigned as 1, otherwise 0, as depicted in Equations 2-3.

$$FP_{it} = \beta_0 + \beta_1 CERP_{it} + \beta_2 State_{it} + \beta_3 CERP_{it} * State_{it} + \beta_4 Controls_{it} + Fixedeffects + \varepsilon_{it} \quad (2)$$

$$FP_{it} = \gamma_0 + \gamma_1 CERP_{it} + \gamma_2 Reg_{it} + \gamma_3 CERP_{it} * Reg_{it} + \gamma_4 Controls_{it} + Fixedeffects + \varepsilon_{it} \quad (3)$$

We also utilize the interaction term format to examine the moderating impacts of female leadership and financing constraints on the correlation between carbon emission reduction performance and financial performance, as shown in Equations 4-5.

$$FP_{it} = \kappa_0 + \kappa_1 CERP_{it} + \kappa_2 Fem_{it} + \kappa_3 CERP_{it} * Fem_{it} + \kappa_4 Controls_{it} + Fixedeffects + \varepsilon_{it} \quad (4)$$

$$FP_{it} = \eta_0 + \eta_1 CERP_{it} + \eta_2 Sa_{it} + \eta_3 CERP_{it} * Sa_{it} + \eta_4 Controls_{it} + Fixedeffects + \varepsilon_{it} \quad (5)$$

Where, i represents firms; t represents years;  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\kappa$  and  $\eta$  represent variable coefficients; Controls represent the control variables set, Fixed-effects represent time and entity fixed effects and  $\varepsilon_{it}$  represents the residual.

## 4. RESULT

### 4.1. Benchmark Regression

To estimate the direct impact of carbon emission reduction performance on financial performance, this paper gradually introduces time-fixed effects and entity fixed effects in the regression model. The results are shown in Table 2. The estimation results of not introducing fixed effects, introducing time fixed effects, entity-fixed effects and two-way fixed effects are shown sequentially in models (1)-(4). All model results show that carbon emission reduction performance is significantly and positively related to financial performance at the 10% level. Therefore, H1 is fully supported. Energy companies that actively reduce carbon emissions can establish a positive reputation for environmentally-friendly practices and earn the support of stakeholders (Lee & Lee, 2022). This can lead to improved access to key resources that are essential for business activities and the development of unique competitive advantages, resulting in greater economic benefits. Therefore, improving the performance of carbon emission reduction can have a positive impact on financial performance. Meanwhile, debt ratio is significantly negatively related to financial performance in all models. Corporate managers must ensure reasonable control of liabilities to safeguard the corporate financial security.

Table 2. Direct effect of carbon emission reduction performance on financial performance.

Dep. variable	Model (1)	Model (2)	Model (3)	Model (4)
	FP			
CERP	0.006* (1.71)	0.007* (1.82)	0.007* (1.80)	0.007* (1.91)
Atr	-0.028 (-0.39)	-0.084 (-1.09)	-0.002 (-0.03)	-0.062 (-0.81)
Lev	-0.619*** (-3.65)	-0.617*** (-3.61)	-0.532*** (-3.00)	-0.467** (-2.48)
Sfs	-0.003 (-1.03)	-0.003 (-1.03)	-0.004 (-1.09)	-0.005 (-1.41)
Size	0.047 (1.29)	0.013 (0.27)	0.038 (0.85)	-0.044 (-0.60)
State	-0.068 (-0.74)	-0.075 (-0.81)	-0.076 (-0.81)	-0.083 (-0.88)
Intercept	-0.354 (-0.41)	0.484 (0.43)	-0.111 (-0.10)	1.900 (1.08)
Fixed_time	No	Yes	No	Yes
Fixed_entity	No	No	Yes	Yes
Observations	198	198	198	198
R-squared	0.137	0.159	0.985	0.986

Note: \*, \*\*, \*\*\* Significant at 10%, 5% and 1% confidence levels, respectively, with t-stats in parentheses.

#### 4.2. Robustness Test

We use the methods of replacing the dependent variable, shortening the time windows, and adding omitted variables to verify the reliability of the benchmark regression results in Table 3. In model (1), we use fixed asset margin as a proxy variable for financial performance. It shows that carbon emission reduction performance significantly and positively affects financial performance at the 10% level. In 2018, a series of measures to protect the environment, such as an environmental protection tax, were implemented, so we set the time windows to 2019-2020. Model (2) shows that carbon emission reduction performance significantly and positively affects financial performance at the 1% level. In model (3), we add female leadership, financing constraints, and regional characteristics to the set of control variables. The result shows that carbon emission reduction performance significantly contributes to financial performance at the 10% level. Therefore, we assessed the dependability of the benchmark regression outcomes by substituting the dependent variable, decreasing the time frame, and including previously omitted variables.

**Table 3.** Results of robustness test.

Dep. variable	Model (1)	Model (2)	Model (3)
	FP		
CERP	0.005* (1.67)	0.034*** (5.30)	0.007* (1.75)
Control variables	Yes	Yes	Yes
Intercept	0.492 (0.36)	0.346 (0.14)	-1.869 (-0.56)
Fixed_time	Yes	Yes	Yes
Fixed_entity	Yes	Yes	Yes
Observations	198	66	198
R-squared	0.894	0.997	0.986

Note: \*, \*\*\* Significant at 10% and 1% confidence levels, respectively, with t-stats in parentheses.

#### 4.3. Heterogeneity Analysis

To determine whether the relationship between carbon emission performance and financial performance varies across equity nature and regional characteristic subgroups, this paper gradually introduces time-fixed effects and entity fixed-effects into the regression model. The estimation results are presented in Table 4. Models (1)-(3) indicate that the coefficient of the interaction term between carbon emission reduction performance and equity nature is positive but not statistically significant. Models (4)-(6) indicate that the coefficient of the interaction term between carbon emission reduction performance and regional characteristics is negative but insignificant. Therefore, the relationship between carbon emission reduction performance and financial performance is not heterogeneous among the equity nature and regional characteristics subgroups.

**Table 4.** Results of heterogeneity analysis.

Dep. variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
	FP					
CEPI	-0.004 (-0.31)	-0.002 (-0.18)	-0.005 (-0.39)	0.012* (1.86)	0.013** (2.14)	0.013** (2.05)
State	-0.077 (-0.83)	-0.078 (-0.84)	-0.086 (-0.92)			
CEPI*State	0.012 (0.84)	0.010 (0.69)	0.013 (0.94)			
Reg				-0.227 (-1.17)	0.232* (1.83)	0.176 (1.28)
CEPI*Reg				-0.008 (-1.01)	-0.010 (-1.32)	-0.009 (-1.13)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes

Dep. variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
	FP					
Intercept	0.475 (0.42)	-0.178 (-0.16)	1.880 (1.07)	0.131 (0.12)	-0.552 (-0.50)	1.661 (0.92)
Fixed_time	Yes	No	Yes	Yes	No	Yes
Fixed_entity	No	Yes	Yes	No	Yes	Yes
Observations	198	198	198	198	198	198
R-squared	0.146	0.985	0.986	0.181	0.985	0.986

Note: \*, \*\*, \*\*\* Significant at 10%, 5% and 1% confidence levels, respectively, with t-stats in parentheses.

#### 4.4. Moderating Effects Analysis

This paper examines the relationship between carbon emission reduction performance and financial performance, using female leadership and financing constraints as moderating variables. Table 5 presents the results of the stepwise regression method, which sequentially introduces time fixed effects, entity fixed effects, and two-way fixed effects. Models (1)-(3) demonstrate that female leadership significantly contributes to the effect of carbon emission reduction performance on financial performance at the 1% level. Models (4) and (6) demonstrate that financing constraints hinder the influence of carbon emission reduction performance on financial performance at the 5% level. Model (5) indicates that the adverse moderating effect of financing constraints is significant at the 1% level. Hence, both H2 (a) and H2 (b) are fully supported.

Table 5. Results of moderating effects analysis.

Dep. variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
	FP					
CEPI	-0.023*** (-2.66)	-0.023*** (-2.81)	-0.023*** (-2.73)	-0.058** (-2.14)	-0.063** (-2.43)	-0.057** (-2.17)
Fem	0.483** (2.52)	0.369** (1.99)	0.327* (1.71)			
CEPI*Fem	0.161*** (3.98)	0.159*** (4.09)	0.156*** (4.01)			
Sa				-0.678*** (-2.66)	-0.245* (-1.84)	-0.467 (-1.40)
CEPI*Sa				-0.018** (-2.39)	-0.019*** (-2.72)	-0.017** (-2.44)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	0.039 (0.04)	-0.225 (-0.21)	1.140 (0.65)	-5.709** (-2.25)	0.005 (0.00)	-2.044 (-0.62)
Fixed_time	Yes	No	Yes	Yes	No	Yes
Fixed_entity	No	Yes	Yes	No	Yes	Yes
Observations	198	198	198	198	198	198
R-squared	0.278	0.986	0.987	0.268	0.986	0.987

Note: \*, \*\*, \*\*\* Significant at 10%, 5% and 1% confidence levels, respectively, with t-stats in parentheses.

## 5. DISCUSSION

We demonstrate that improving carbon emission reduction promotes corporate financial performance using a two-way fixed effects model. We also analyse the heterogeneity of this relationship in regards to equity and regional characteristics. Furthermore, we explore the internal transmission mechanism between carbon emission reduction and corporate financial performance. Although we have gathered vital insights, there remain a few unresolved matters warranting further discussion.

(1) The correlation between corporate carbon emission reduction performance and financial performance does not vary based on equity or regional groupings. The most effective way for China's economy to change from a basic model to an intensive one is through the national initiative known as the green development strategy.



Eastern and state-owned enterprises possess sophisticated technology and ample capital, drawing in highly skilled professionals to carry out eco-friendly manufacturing processes and improve their industrial structures (Lu & Lian, 2012). This, in turn, leads to a reduction in carbon emissions. Non-eastern regions and non-state-owned enterprises have limited access to capital and technology due to their geographical location and the nature of their businesses. To redress the imbalance in the development of enterprises across regions and different sectors, the central government is extending more favourable financial subsidies and tax exemptions to these entities (Boukattaya & Omri, 2021). This support will provide them with the necessary financial, technological, and policy support to fulfil their carbon emission reduction objectives. Therefore, businesses with varying backgrounds and geographical locations have incorporated low-carbon green development as a crucial objective in their operational strategies.

(2) Female leadership has no moderating effect on the relationship between carbon emission reduction performance and corporate financial performance. This is because of the increasing role of women in work and family with the rise of feminism in Europe and the United States. Although China has developed rapidly since reform and opening up, traditional and feudal ideas persist. Women continue to face gender discrimination in the workplace and encounter obstacles in attaining leadership roles within enterprises. Furthermore, the significance of female leadership has been diminished due to men holding the majority of corporate leadership positions, with women only being allowed to supervise rather than make substantive decisions on major corporate matters (Hu & Yang, 2021). Carbon emission reduction activities are characterized by high risk, lengthy cycles, and high capital. Their implementation necessitates the mobilization of substantial resources to support them. Additionally, women's inherent caution and sensitivity may impede the introduction of innovative green technologies and high-risk investments (Katmon, Mohamad, Norwani, & Farooque, 2019). In conclusion, it appears that female leaders have a modest effect on the relationship between carbon emission reductions and corporate financial performance. This effect is primarily symbolic, rather than substantive.

## 6. CONCLUSION

### 6.1. Conclusion and Recommendations

Using a sample of energy firms listed from 2015 to 2020, this study examines the effect of decreasing carbon emissions on financial performance by creating a two-way fixed effects model. The results show that the improvement in carbon emission reduction has a positive influence on financial performance, thereby completely supporting H1. Examining the influence of carbon emission reduction performance on financial performance within the context of China's economic system, this analysis considers property rights and regional characteristics. The findings indicate that the relationship between carbon emission reduction performance and financial performance is not heterogeneous across equity types and regional characteristics. The results of the internal transmission mechanism reveal that female leadership has a positive moderating impact, while financing constraints have a negative one. Our study fully supports H2 (a) and H2 (b). Companies are effectively implementing measures to reduce their carbon footprint, enhance their financial performance, and strive towards corporate sustainable development. This paper offers specific recommendations.

(1) The central government ought to hasten the enhancement of a unified carbon trading market and introduce a thorough carbon information disclosure scheme. Along with a unified national management system and settlement system, it is necessary to create a comprehensive policy guideline for companies to disclose carbon information in order to make it easier for investors and the public to get carbon data from companies. This will also help create an open and honest market for trading carbon emission rights (Qu & Cang, 2022). This promotes rational carbon emission pricing in the market and encourages companies to undertake social responsibility proactively. Furthermore, integrating carbon disclosure into the legal regulatory framework improves the equity and transparency of the carbon trading market. This approach also deters listed firms from making deceptive carbon disclosures and assists stakeholders in evaluating the level of low-carbon development of enterprises. In turn, this enables informed investment decisions, leading to better carbon performance across the industry (Lagasio & Cucari, 2019; Shi, Guo, & Chen, 2016).

(2) Businesses ought to proactively devise strategies for low-carbon transformational development and innovate their low-carbon economic management and operational approaches. They should heighten low-carbon consciousness and cultivate a corporate culture that is both low-carbon and eco-friendly (Viet, Quynh, & Trung,



2020). Whether managers are willing to take up environmental and social responsibility by integrating low-carbon development into the enterprise's management philosophy is crucial to lowering carbon emissions and promoting low-carbon development. Enterprises should integrate low-carbon environmental protection into their development strategy by changing their concept of development, raising awareness, exploring low-carbon economic models, and improving carbon emission reduction performance. In the long term, adopting a low-carbon economy aligns with governmental efforts to save energy and reduce emissions and demonstrates the enterprise's active social responsibility. To promote low-carbon practices and sustainable development in enterprises, it is essential to boost employee engagement and establish a strong green culture. This can improve the ecological image of companies and ultimately achieve long-term sustainability (Xie, Gao, He, & Feng, 2016).

Emphasis should be placed on investing in low-carbon technology and conducting research and development. Improving the level of low-carbon technology is essential for the development of a low-carbon economy by enterprises. Enterprises should combine policy support and low-carbon subsidy investment from the government. They should plan and invest special funds in low-carbon research and development and improve low-carbon technologies to enhance their level (He, Ding, & Yang, 2021). The production process and energy structure should also be improved to increase the efficiency of resource utilisation and reduce losses. To enhance the enterprise's low-carbon competitiveness, they should provide technological support for transformation and development. Simultaneously, enterprises ought to prioritise enhancing global collaboration while assimilating cutting-edge, low-carbon technologies from around the world. Furthermore, they should strive to utilise the Clean Development Mechanism initiative and enhance their own carbon emissions reduction performance to ensure sustainable development.

(3) Local authorities and regulators ought to establish effective green regulations, incentives, and restraint mechanisms. A robust regulatory framework is necessary to encourage enterprises to implement eco-friendly practices. Local authorities and regulators ought to establish explicit environmental regulations to govern the eco-friendly actions of businesses, clearly outline the consequences for non-compliance, and escalate the penalties for exceeding carbon emission thresholds by means of taxation or other sanctions (Zhai & An, 2020). This will encourage enterprises to appreciate the cost of environmental protection violations via substantial fines. To ensure the reliability and authenticity of carbon information disclosed by businesses, the government must enhance the audit and oversight of carbon information published by firms in tandem with fortifying the carbon information disclosure mechanism (Da, Liu, Liu, & Fan, 2021). Relevant governmental departments should devise appropriate policies in accordance with local developmental conditions. Additionally, they must enhance the monitoring and control of government personnel while executing an open and transparent performance assessment system to avoid the inclination towards attaining personal accomplishments by artificially achieving short-term emission reduction targets.

Furthermore, the government should support enterprises in undertaking environmentally sustainable initiatives by increasing incentives for those that embrace green technologies and adopt low-carbon business practices. Export tariff exemptions should be provided for environmentally-friendly products with low energy consumption. Policy preferences, environmental protection subsidies, and credit support should also be given to low-carbon development enterprises (Ding et al., 2023). This will help to ease the financial burden on companies engaged in research and development of low-carbon technologies, as well as equipment procurement. Simultaneously, the development of technology aimed at reducing carbon emissions is bolstered by amplifying investment via specific government funds, recruiting competent personnel, and establishing relevant technological departments to offer technical assistance to businesses and facilitate their technological advancement (Li, Huang, Ren, Chen, & Ning, 2018; S. Wang, Wang, Wang, & Yang, 2020).

## 6.2. Limitations and Future Research Directions

This paper utilises theoretical and empirical research to investigate the influence of carbon emission reduction performance on the financial performance of listed energy companies in China between 2015 and 2020. However, there are certain limitations due to the available data and information. To enhance the robustness of the findings, the study's time frame has been extended. There are significant variations in direct and indirect carbon emissions across industries and enterprises. Thus, evaluating the carbon emissions of diverse sectors remains a critical future research agenda. Furthermore, our future research direction is to investigate whether technological innovation, as

the optimal approach for achieving environmental sustainability, acts as a mediator between carbon emission performance and financial performance.

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#### INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable.

#### TRANSPARENCY

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

#### COMPETING INTERESTS

The authors declare that they have no competing interests.

#### AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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