

HOW CORPORATE GOVERNANCE MECHANISMS RESTRAIN SULFUR DIOXIDE EMISSIONS: EVIDENCE FROM CHINESE LISTED FIRMS

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Abstract: *There has been a noticeable and widespread trend toward a decrease in corporate environmental emissions. Thus far, the majority of these initiatives have prioritized carbon dioxide (CO₂) over sulfur dioxide (SO₂). The media's growing focus on CO₂ and the rising number of acid rain episodes in various parts of China have raised awareness of the issue among Chinese citizens. This study looks at a number of corporate governance mechanisms and assessed elements that work well to lower corporate CO₂ emissions. Regression analysis was conducted using panel data analysis and the Pooled Ordinary Least Square (OLS) approach. Based on a sample of 381 Chinese listed companies in various industries, the results confirmed several conjectures on the connections between corporate governance practices and CO₂ emissions. The findings also offer fresh perspectives on CO₂ emissions, a dangerous and harmful industrial pollutant, and the corporate governance mechanism framework. Additionally, the goal of this study is to provide some corporate-level insights so that relevant parties, such as managers, investors, and regulators, could monitor, manage, and limit this dangerous emission. Furthermore, the theoretical framework and prospective research agenda were discussed.*

Keywords: *Board of Directors, Chinese listed firms, Corporate Governance, Environmental Management, Sulfur Dioxide Emission*

Introduction

China's rapid industrialization has led to surging pollutant emissions from companies, creating major environmental and health hazards that threaten sustainable development. Along with carbon, sulfur dioxide (SO₂) is a critical air pollutant of concern. Analysis of data from NASA's Aura satellite in the journal *Scientific Reports* shows that China's sulfur dioxide emissions hit a peak of about 37 million tons in 2007 but have since fallen steadily year-over-year to around 8 million tons by 2016. This downward trend in SO₂ reflects progress in China's efforts to reduce emissions of this harmful pollutant. However, more work remains to curb SO₂ and other emissions to protect the environment and public health as industrial activity continues to expand. China's efforts to reduce SO₂ emissions and improve the nature environment are strongly tied to the creation and enhancement of pertinent laws, rules, and regulations, and most crucially, compliance by enterprises (Zhang, 2021). Since the air pollution emission of enterprises is mainly through coal burning in the process of power generation, how enterprises use emission performance indicators as well as establish emission control and distribution model matters, indicating that internal corporate governance has a great impact on environmental pollution (Chi, 2021).

Currently, there is a growing volume of literature investigating the relationship between corporate governance and sustainability (Elsayih et al., 2021). Evidence from Australia suggests that firms with higher board independence and an environment committee show enhanced corporate environmental performance (CEP) (Elsayih et al., 2021). A global business study shows that the establishment of sustainability committees, board independence, and board size are strongly associated with increased waste production. According to another research of multinational corporations, staggered boards worsen the agency problem and ultimately result in excessive amount of carbon emissions. (Tanthanongsakkun et al., 2022). Most of current studies focus on carbon emission especially in the form of carbon dioxide and waste management while SO₂ is somehow ignored in the study of corporate environmental emissions. Despite being members of the same chemical family of dioxide, carbon dioxide (CO₂) and sulfur dioxide (SO₂) differ greatly in their molecular properties. In terms of emissions, fossil fuels and volcanic eruptions are the main sources of SO₂ in the atmosphere, SO₂ is less common than CO₂. According to Employee Assistance Programs of the US, SO₂ is the leading cause of acid rain, and high concentrations have been recorded in the vicinity of large industrial facilities (2018). More significantly, there are multiple detrimental impacts of SO₂ emissions on human health. The US Center for Disease Control and Prevention (CDC) claimed that exposure to SO₂ will irritate the eyes, nose, and throat and damage the respiratory system while CO₂ is harmless to people (2019). We believe SO₂ is relatively ignored when considering environmental emissions. In this study, we focused on the emission of SO₂.

Another issue is that most of the studies do not include Chinese firms as subjects of their studies, although China has the highest carbon emissions in the world with more than 11 billion tons of CO₂ in 2020 (Worldmeters, n.d.). Chinese firm data is strictly protected and hard to access by oversea scholars. However, this does not mean the findings and theories generated and established in foreign research cannot be applied in the Chinese business environment and adjacent corporation and operational context. There indeed is a potential gap between studies conducted in firms outside China and Chinese firms. Chinese firms have created Western-style oversight mechanisms and corporate governance, but this function remains weak (Kang et al., 2008). According to the World Economic Forum, China ranked 102 in terms of the gender gap, suggesting a severe gender inequality situation (2021). Additionally, only 13% of directors on the board are Female in China according to Credit Suisse (2021). Males dominate Chinese

board members. Another notable cultural attribute is the widespread credentialism in China. Chinese boards generally prefer managers with academic backgrounds and degree holders to those with degrees from regional universities. The uniqueness of China's corporate governance system offers useful insights into the relationship between environmental emissions and governance practices. Examining this issue in the context of Chinese companies can shed light on how governance mechanisms influence pollutant outputs in an emerging economy with its own institutional norms.

Industrialization has led to a high level of pollution, especially of highly polluting compounds such as SO₂, which raised great concern among stakeholders regarding CSR (i.e., Corporate social responsibility) compliance and ESG (i.e., Environment, Social, and Governance) results. At the same time, it caused a dilemma among managers about whether pollution control can increase corporate value and performance or increase costs and undermine competitiveness. Undoubtedly, balancing emissions and returns becomes an important corporate governance issue. Hence, we proposed to study how Chinese corporate governance mechanisms affect SO₂ emissions with the aim of encouraging companies to reduce SO₂ and including other pollutant emissions by changing their governance structures.

Literature Review and Hypothesis Development

Agency Theory

According to agency theory, agents always aim to maximize their benefits. As a result, agents may not always be able to satisfy shareholders (Masulis et al., 2009). In addition, it also shows that agents rarely sacrifice unnecessary costs to pursue social responsibility, so they would not put much effort into controlling environmental emissions. However, considerable corporate governance plays a prominent role in minimizing the conflicts between agents and shareholders (Guthrie & Parker, 1990). Strong corporate governance mechanisms tend to align the management and shareholders' interest, which thereby reduces agency conflicts between them. Additionally, agency theory suggests that the monitoring role of board members is contingent on the board members' responsibilities. Independent board members involved in fiduciary duties are more alert to corporate issues and more willing to exercise monitoring functions. Agency theory contends that the owners or shareholders are responsible for the actions of the company, while the directors and managers are true personnel monitoring daily operations, which gives rise to a vacuum of accountability when tracing back to the responsibility of sustainability. Another issue regarding the agency is the externalization of the environment and social integrity. The assumption that shareholders are profit-oriented pushes out all those externalities onto people around the firm in the community (Krüger, 2015). Convincing the shareholders to act on environmental issues gets difficult based on this condition.

Corporate Governance and Environmental Management

There is abundant foreign research investigating the relations between corporate governance and environmental emissions. A study focused on listed firms in Turkey found that the corporate governance mechanism did have some positive impact on reducing CO₂ emissions (Kılıç & Kuzey, 2019). Evidence from Australia shows that effective and proper corporate governance mechanisms and most components in corporate governance mechanisms can better achieve carbon performance (Elsayih et al., 2021). Another research that studied the US firm's pollutant performance suggests that well-governed firm attempts to project a positive image by increasing their pollutant performance and frequent CSR promotions. Additionally, studies in

Southeast Asia have found that most corporate governance elements facilitate the management to monitor, control, and promote environmental sustainability on a firm-wide level (Liu, 2018). To sum up, multiple studies conducted on foreign firms have suggested the corporate governance mechanism has a direct or indirect impact on corporate environmental emissions. We want to delve into this relationship and examine whether this kind of relationship is still valid in the context of Chinese-listed firms and SO₂.

Hypotheses Development

Board Size

Studies by some scholars indicate that board size is negatively related to corporate performance, and firms with smaller boards tend to be more risk-taking (Eisenberg et al., 2008). Cheng (2008) further suggests that there exists an inverse relationship between board size and R&D expense, which means enterprises with small-sized boards, would spend more money on improving technology to reduce emissions during production. Based on agency theory, large boards are often less effective in communication and decision-making, which highly affects firms' environmental performance (Jensen, 1993). Larger committees may not be able to implement an acceptable environmental agenda because of their lack of coordination and enforcement (Goodstein et al., 1994). However, Chinese firms with smaller-sized boards are identified as companies with more conservative traits. This conclusion was inconsistent with the previous research, which shows the negative relationship between board size and firm value transcends different corporate governance systems. As environmental emissions control needs high coordination and strong monitoring, the first hypothesis is as follows:

H1: Board size is positively associated with corporate SO₂ emissions.

Board Independence

Literature suggests that independent directors positively affect firm performance because they are committed to monitoring management activities, enhancing disclosure quality, and developing sustainable practices (Muniandy & Hillier, 2015). Independent directors are more concerned about environmental policies and practices as they know these kinds of actions improve firms' reputations in the eyes of stakeholders (Jo & Harjoto, 2011). More importantly, behaving in an environmentally friendly way helps maintain their standing in the market (Toms, 2002). According to a study on independent directors in China (Liu et al., 2015), a positive relationship between board independence and firm value could be found in China, especially in government-controlled firms. Therefore, we proposed the second hypothesis:

H2: Board independence is negatively associated with corporate SO₂ emissions.

Female Chairperson

Female directors are considered more ethical in business practices than their counterparts, male directors, and therefore reduce environmental violations (Liu, 2018). Females as chairpersons could take different leadership approaches on boards. Female chairpersons contribute to the information symmetry on boards and all aligning board members together (Abad et al., 2017). Female chairpersons are good at communicating on the board and have a large motivation for sharing (Chen et al., 2016). As a result, the reduction of SO₂ emission considering the female chairperson may suggest that female chairpersons have adopted a high-level stakeholder orientation and assume more environmental responsibility in business practices. They may also indulge the board with greener motivation and high environmental awareness. This study argues

that due to the stakeholder orientation and female green nature, female chairpersons can bring advancement and improvements to the board, which includes the decrease of SO₂ emissions. Hence, we formulate the following hypothesis:

H3: The presence of a female chairperson is negatively associated with corporate SO₂ emission.

The Educational Attainment of The Chairperson

The upper echelons theory states that the education and age of the top executives can predict the organizational outcome, strategic decision, and corporate performance level (Hambrick & Mason, 1984b). Education background has always been an indicator of human capital in corporations (Barro & Lee, 2013a). A bachelor's degree bears more value and recognition than a high school degree since this credential is deemed as a proxy of an individual's intelligence and competence. High levels of education contribute to the ability to tolerate ambiguity, boundary spanning, and demonstration of the ability for integrative complexity, which suggests a high-level ability of information processing (Dollinger, 1984).

We argue that due to educational attainment and process, chairpersons with higher education degrees are likely to develop a strong awareness of the environment and sustainability, a prominent level of information processing ability, and intellectual ability, which eventually leads to their role of promoting environmental sustainability on the board. Hence, we formulate the following hypothesis:

H4: The education attainment of the chairperson is negatively associated with corporate SO₂ emission.

Research Framework

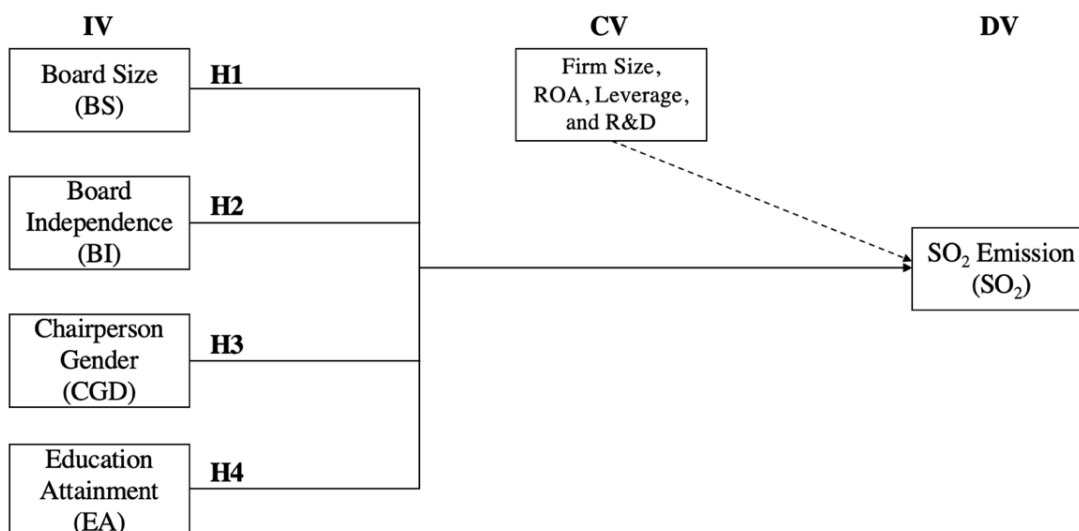


Figure 1 Research Framework

Research Method

Measurement

Table 1 Summary of Variables

Variable	Measure	Type	Source
SO ₂ Emission (SO ₂)	Real SO ₂ emissions for a company during a fiscal year	IV, Ratio	CSMAR
Board Size (BS)	Total number of directors' board members	DV, Ratio	RESSET
Board Independence (BI)	The proportion of a board's independent directors	DV, Ratio	RESSET
Chairperson's Gender (CGD)	The factual gender of the chairperson	DV, Categorical	RESSET
Education Attainment (EA)	The chairperson's greatest educational qualification	DV, Categorical	RESSET
Firm Size (FS)	A company's total revenue for a certain fiscal year	CV, Nominal	RESSET
Return on Assets (ROA)	Net income/Total assets	CV, Ratio	RESSET
Leverage (LEV)	Total debt/Total assets	CV, Ratio	RESSET
Research & Development (R&D)	R&D expense/Total revenue	CV, Ratio	RESSET

Model Construction and Hypotheses Testing

As there are different samples in different years, we use pooled OLS to control different firm-level characteristics (e.g., industry effect, country effect, etc.) Our four model is as follows:

$$\text{Model 1: } SO2_{i,t} = b_0 + \beta_1 BS_{i,t} + \sum \beta_n \text{Controls} + \varepsilon_{i,t} \quad (1)$$

$$\text{Model 2: } SO2_{i,t} = b_0 + \beta_1 BI_{i,t} + \sum \beta_n \text{Controls} + \varepsilon_{i,t} \quad (2)$$

$$\text{Model 3: } SO2_{i,t} = b_0 + \beta_1 BGD_{i,t} + \sum \beta_n \text{Controls} + \varepsilon_{i,t} \quad (3)$$

$$\text{Model 4: } SO2_{i,t} = b_0 + \beta_1 EA_{i,t} + \sum \beta_n \text{Controls} + \varepsilon_{i,t} \quad (4)$$

Data Analysis and Findings

Descriptive Analysis

Table 2 Descriptive Statistics of Variables

	N	Min.	Max.	Mean	Std. Deviation
SO2	1143	0.001	106,700.000	1,085.581	6,559.542
BS	1143	5.000	19.000	11.819	3.716
BI	1143	0.133	0.667	0.392	0.121
CGD	1143	0.000	1.000	0.258	0.438
EA	1143	0.000	1.000	0.570	0.495
FS	1143	184.965	2,516,810.000	26,217.154	125,757.245
ROA	1143	-0.008	0.005	0.001	0.001

LEV	1143	0.051	1.698	0.445	0.208
R&D	1143	0.000	0.385	0.027	0.028

FS is measured in million.

- (1) **SO₂ emissions (SO₂):** SO₂ varies significantly amongst companies, with a maximum of 106,700.000 and a minimum of 0.001. Some companies emit huge amounts of SO₂ while others emit almost no SO₂ in their production and business process. The mean value is around 1,085.581, indicating that most enterprises are in heavy-pollution industries.
- (2) **Board size (BS):** The number of people on the board is relatively certain, with a maximum of 19, a minimum of 5, and a mean of 11.819, which is in line with the requirements of Chins Securities Regulatory Commission (CSRC).
- (3) **Board Independence (BI):** There is little difference in the proportion of independent board directors, with a maximum of 0.667, a minimum of 0.133, and a mean of 0.392. This indicates that the proportion of independent directors in most companies exceeds one-third, but only a few exceed one-half, which meets the basic requirement stipulated by CSRC but is much lower than that of Western countries.
- (4) **Chairperson's gender (CGD):** The minimum of 0 refers to all males, and the maximum of 1 refers to all females. The mean of 0.258 shows that most of the chairpersons are male, indicating women's voice, influence, and participation in the company are not enough.
- (5) **Education attainment (EA):** The minimum of 0 refers to the degree bellowing the master's degree, and the maximum of 1 refers to the master's degree and above. The mean of 0.570 shows that more than half of the chairpersons are highly educated in the master of Ph.D.

Correlation Analysis

Table 3 Pearson Correlation Coefficients

	SO ₂	BS	BI	CGD	EA	FS	ROA	LEV	R&D
SO ₂	1								
BS	0.160**	1							
BI	-0.050**	-0.341**	1						
CGD	-0.072*	-0.164**	0.484**	1					
EA	-0.096	0.056	0.058	0.234**	1				
FS	0.844**	0.156**	-0.031	-0.056	0.117**	1			
ROA	-0.041	-0.102**	-0.026	-0.045	-0.091**	-0.013	1		
LEV	0.100**	0.250**	-0.050	-0.015	0.125**	0.075*	-0.369**	1	
R&D	-0.087**	-0.139**	0.067*	0.063*	0.016	-0.074*	0.000	-0.128**	1

** . Correlation is significant at the 0.01 level.

* . Correlation is significant at the 0.05 level.

Table 3, shows that the dependent variable (SO₂) has a significant correlation with the main independent variables, board size (BS), board independence (BI), and chairperson's gender (CGD). However, there is one exception, that SO₂ is not significantly correlated with the educational attainment of the chairperson. Looking at the symbols of coefficients between SO₂ corporate governance indicators, we can also make a preliminary inference that the results are consistent with our hypotheses.

Regression Analysis and Interpretation

In all four models, the F-value of around 570 at the 1% significance level indicates that the linear relationship is significant and can be modeled, and the R-squared of about 0.71 suggests that the independent variables explain 71% variation of the dependent variable, showing overall goodness of fit of the model.

For the impact of independent variable BS on the SO₂, the results showed a substantial positive correlation between the two, with a coefficient of 0.219 at the 1% significance level. The higher the number of directors on the board, the higher the SO₂ emissions. Hence, our hypothesis 1 is supported by the data.

On the impact of independent variable BI on the SO₂, the results showed a substantial negative correlation between the two, with a coefficient of -0.122 at the 1% significance level, indicating that the amount of SO₂ emissions decreases with the percentage of independent directors on the board. In conclusion, hypothesis 2 is supported by the data.

On the impact of independent variable CGD on the SO₂, the results showed a substantial negative correlation between the two, with a coefficient of -0.325 at the 1% significance level, thus implying that the presence of a female chairperson would effectively reduce the SO₂ emissions. Therefore, hypothesis 3 is valid.

On the relationship between independent variable EA and the SO₂, the results yielded a coefficient of -0.007 with a p-value of 0.659, pointing out there is no significant relationship between the two. The educational attainment of a chairperson does not have many impacts on the SO₂ emissions. Hence, hypothesis 4 is invalid.

Results and Discussion

Discussion on Hypotheses

Model 1 suggested that the board size has a positive relationship with Corporate SO₂ emissions. Increasing the Board size is likely to result in a larger amount of corporate SO₂ emissions. The board's ability to implement the strategy is undoubtedly weakened by the larger size since they are hard to communicate and align their different interests toward a single target. A cumbersome and bloated organization is unlikely to be efficient and risk-taking.

The Model 2 confirms that companies where the board of directors has less independence tend to have higher levels of SO₂ emissions. The hypothesis that greater board independence reduces SO₂ emissions is strongly supported. Having more independent directors can effectively curb this pollutant. Independent board members are able to objectively monitor corporate activities like reputation and emissions, without being swayed by close ties between managers and shareholders. Their detached perspective allows them to critically assess performance and strategy, leading to better oversight of environmental impacts. With their commitment to governance, independent directors help rein in harmful SO₂ outputs. This validates that board independence is a key factor in lowering corporate SO₂ emissions. In contrast with the board independence of firms in Western countries like the UK, Chinese board independence is far behind, which is consistent with the transparency and corruption level of these two different regions (Wu & Tang, 2019). China has a long history of nepotism and bureaucratism, making the practice of appointing those whom you trust very popular among Chinese corporations (Wang, 2013). These business practices are more prevalent in well-established and traditional

companies with few innovations and a lack of creative strategy and mindset. These companies and businesses with high emissions have a lot in common (IEA, 2020). The low board independence is affected by the whole environment of China, which is not an incidental phenomenon.

Model 3 indicated that having a female chairperson on a company's board of directors has a positive effect on reducing SO₂ emissions. Females have adopted different leadership approaches in the chairperson positions. The result suggests that female leader is generally more likely to indulge the board with motivation for reducing environmental emission and their ability to convince and persuade board member as well as align members' interest towards a greener future. In contrast with Western corporate governance, we can observe that females play a minor role in the leadership of the firm. Fewer than 30% of chairpersons in our selected firms are female. Empowerment of female leaders is not quite common and popular among Chinese firms, especially in those traditional industries like manufacturing and steel. Despite pervasive gender inequality in China's business world that makes it difficult for women to advance, female leaders are still more effective at managing SO₂ emissions than male leaders when they do reach senior positions. Even though institutional barriers create obstacles for women becoming chairperson, those who overcome these challenges to lead companies demonstrate superior governance over environmentally harmful SO₂ outputs. This suggests that increasing female representation in top corporate roles could potentially curb China's SO₂ pollution, even with the gender discrimination that persists in the country's corporate culture. The statistical output concerning educational attainment seems to be inclusive as the p-value of model 4 is not high enough. It is likely that SO₂ is not considered a serious pollutant in the environmental education of these Chinese chairpersons and leaders. Additionally, it is notable that Chinese people become gradually aware of SO₂ in the new millennium (Gao et al., 2009). There are some alternative explanations for this output. It is possible those chairpersons have not received such environmental education, which includes SO₂ as a major source of pollutants in their upbringing. On the other hand, this model also reflects that SO₂ emission still does not catch people's attention, which gives rise to ignorance of such harmful pollutants in educational attainment. There is an observable time lag between the point where Chinese people acknowledge the harmful effects of SO₂ and the point where corporate SO₂ emission begins to pollute and jeopardize the environment and people's health (Wang, 2021).

Limitations of the Study

In terms of time span, industry differences, and variable selection, there are some limitations of this study. Firstly, the data selected is only from 2017 to 2019, without the latest data. This is because the COVID-19 outbreak at the beginning of 2020 caused significant fluctuations in the whole industry, leading many companies' production levels and SO₂ emissions not to reflect normal levels, which makes this data biased and inapplicable to our research. Secondly, our research aims to study corporate governance and SO₂ emissions across all industries in China, lacking a reclassification of some of the most prominent heavy industries. Additionally, we mainly analyzed from the enterprise perspective and ignored how SO₂ is emitted in the business process, and the factors affecting SO₂ generation, such as energy efficiency and industrial material, from a technical perspective. Thirdly, the indicators of corporate governance we chose are widely used in previous studies, which are representative but relatively general. There are some special ones or integrated indexes taking more indicators into account waiting to be discovered and studied.

Suggestions for Future Studies

Firstly, a longer period of emissions and corporate governance mechanism should be chosen, which can increase the robustness and validity of the research. Research based on a dataset of 5 consecutive years uncovers more insight into this relationship and is also more reliable than a 3-year record when predicting the long-term trend of emissions of a corporation.

In addition, studying the emission of SO₂ requires more than one perspective. Our research is based on the corporation perspective, while the in-depth industrial perspective can help better analyze the business process where corporations emit SO₂. Interviewing specialists and practitioners who work in industries heavily emitting SO₂ and have expertise in emission management seems indispensable.

Lastly, using a comprehensive index of corporate governance mechanism is recommended. Due to the time constraint and data availability, some attributes of corporate governance might be ignored. For instance, the gender proportion of the board and the establishment of an environmental committee can affect corporate strategies for reducing environmental emissions.

Conclusion

The corporate governance mechanism has been considered as an effective approach to controlling environmental emissions, especially the major source of climate change and global warming, CO₂. SO₂ is also another conspicuous corporate emission that causes serious environmental deterioration, the amount of which the company intends to control and reduce. This study examines the impact of four prominent corporate governance mechanisms on lowering SO₂ emissions using statistical methods. This research proves that SO₂ can be successfully reduced by several corporate governance mechanism and highlight some shortcomings of Chinese corporate governance mechanism in contrast to Western corporate governance. Gender equality and board independence are two demerits of Chinese corporate governance. Additionally, this research put forward some pertinent approaches to digging deeper into the relationship between corporate governance mechanisms and industrial environmental emissions.

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