

The Impact of Internal Control Effectiveness on Green Innovation in Heavily Polluting Industries

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Abstract

With the carbon peak and carbon neutrality imperative as the overarching policy, as well as green development being elevated to national strategies, high-emission industries are facing mounting pressure to transform. Focusing on heavily polluting A-share listed firms in China across the years 2011 through 2023, the present study empirically assesses the contribution of internal control mechanism effectiveness to organizational environmental eco-innovation and deciphers the associated causal logic. The evidence indicates that superior internal control yields a significant and positive influence on propelling green innovation within these high-emission enterprises. This conclusion remains robust after tests for multicollinearity and heteroscedasticity. This study contributes to the body of knowledge on the antecedents of corporate green innovation from an internal governance perspective, but also provides practical guidance for heavily polluting enterprises to enhance green innovation capabilities and achieve sustainable development by optimizing their internal control systems.

Keywords

Heavily Polluting Industries; Internal Control Effectiveness; Green Innovation; R&D Investment; Sustainable Development.

1. Introduction

Ever since the dawn of industrialisation, an extensive development pattern has delivered rapid GDP growth but has simultaneously caused unsustainable resource depletion and ongoing environmental degradation. The economic growth and the conservation of the ecosystem have become such an important global dilemma that needs to be resolved. It is against this backdrop that China, the second-largest economy in the world, has been a leader in promoting a green development paradigm that views a good ecological environment as priceless wealth, and has made the dual carbon goals of peaking carbon emissions and achieving carbon neutrality a national policy. It is on this background that the green transformation and sustainable development of heavily polluting industries which are the major contributors to environmental pollution is urgently needed.

Enterprises are the main actors in green innovation, and their internal governance mechanisms are crucial to the success of innovation activities. Internal control is a fundamental institutional structure of corporate governance, which is designed to promote efficiency in operations, reliability in financial reporting, and legal and regulatory compliance. However, as for the relationship between internal control and innovation, the academic community maintains two opposing perspectives: the inhibition theory and the promotion theory. [1][2]The former believes that high internal control suffocates innovative spirit, and the latter opines that a high-quality internal control ensures a stable institutional environment in which innovation thrives. The available literature tends to examine the dichotomy of the nexus between internal control and R&D spending, or the direct relationship between green innovation and R&D investment.

Research integrating all three dimensions to extensively examine how internal control effectiveness in highly polluting industries influences green innovation remains scarce.

To address this gap in the literature, our research uses a group of highly polluting domestic A-share publicly traded companies in China between 2011- 2023 and conducts empirical research to identify the effects of internal control effectiveness on green innovative performances of firms. Theoretically, this research elucidates the underlying processes between internal control, the amount of spending on research and development and eco-innovation to the existing system of determinants of corporate green innovation. In practical terms, it offers an evidentiary support and policy implications that can be used to ensure that the high-emission firms have improved internal control, strategic allocation of resources towards green innovation and finally have a dual dividend of both the economic and environmental benefits.

2. Literature Review and Research Hypothesis

2.1. Economic Consequences of Internal Control

The extant literature extensively discusses the economic ramifications of internal control. Strong internal control has the potential to improve the quality of accounting information (Fang Hongxing & Zhang Zhiping, 2012)[3], minimize the cost of corporate financing and maximize internal resource allocation. Furthermore, good internal control is able to limit the short-sightedness of managers, over-investment or under-investment, thus enhancing efficiency in operations. However, academia has not reached a consensus regarding the link between internal control and innovation.

2.2. Drivers of Green Innovation

Studies on determinants of green technology innovation are broadly categorized as external or internal dimensions. External factors mainly include environmental regulations (Deng Yuping et al., 2021)[4], media attention (Chen Yunping et al., 2023)[5], and market competition; internal factors focus on executive team characteristics, corporate governance structure, and R&D investment (Geng Hejiang, 2020)[6]. Although fruitful, there are relatively few studies using internal control, a fundamental institutional arrangement, as the core explanatory variable.

2.3. Internal Control and Green Innovation: Promotion vs. Inhibition

Regarding the connection between internal control and innovation, there exists a debate between "inhibition theory" and "promotion theory."

Inhibition theory argues that overly strict internal control constrains management's autonomy and innovative spirit. Ribstein et al. (2002) [2] point out that strict internal control makes executives overly cautious about high-risk, long-term innovation projects, thus cutting investment. Yao et al. (2023) [7] found an inverted U-shaped relationship between internal control and corporate innovation, meaning moderate internal control promotes innovation, but excessive internal control inhibits innovative vitality.

Promotion theory argues that high-quality internal control provides a stable institutional environment for corporate innovation. Li et al. (2017)[8] suggest that internal control encourages enterprises to optimize innovation decisions by reallocating resources from exploratory to routine innovation. An empirical investigation by Xu Hongfeng (2021)[9] reveals that internal control quality exhibits a strong positive relationship with the scale and performance of corporate innovation. For industries characterized by high technological uncertainty, large capital demands and complex risks, industrial green innovation demands a robust, standardized internal framework to cut trial-and-error expenses and ensure sustained resource allocation. Based on this, the hypothesis below is proposed in the current research:

H1: *Ceteris paribus*, high-quality internal control significantly promotes green innovation in heavily polluting enterprises.

3. Research Design

3.1. Sample Selection and Data Sources

The present study constructs its sample with China's mainland-listed firms within heavy-pollution sectors spanning the period running from 2011 to 2023 as the preliminary estimation sample. According to the CSRC industry classification, heavily polluting industries are defined based on relevant environmental protection department regulations. The original data are screened in line with the filtering criteria below: (1) removing ST and *ST firms; (2) deleting financial and insurance companies; (3) filtering out companies that have significant gaps in key financial data. This gives a final sample of 8,478 entity-year data points. Winsorization is done at the 1st and 99th percentiles of all continuous variables to reduce the influence of extreme values.

The three sources used to gather the data are (1) National intellectual property records on green patents available via the State Intellectual Property Office (SIPO); (2) Internal control information available in the DIB Internal Control and Risk Management Database; and (3) Corporate financial and governance information available in CSMAR.

3.2. Variable Definitions and Measurement

3.2.1. Dependent Variable: Green Innovation (Gi)

This paper (following Li Qingyuan et al., 2020) [10] determines the level of green innovation with the help of the natural logarithm of the sum of the number of green utility model patent applications and the number of green invention patent applications that the firm has registered during the current year. Compared to granted patents, patent application volume is a closer proxy to current innovation efforts in a company.

3.2.2. Independent Variable: Internal Control Effectiveness (IC)

The current investigation employs a log-transformed value for the DIB Internal Control Rating for Chinese listed corporations to gauge the firm's internal control effectiveness. This index is constructed from five dimensions: the control environment, risk identification and assessment, control operations, information and communication, and monitoring activities, thus providing an objective measure of internal control effectiveness. A higher IC score denotes stronger internal control performance.

3.2.3. Control Variables

Following established practices in the literature, the present study controls for the variables listed below: enterprise scale (Size), debt ratio (Lev), net profit margin (ROA), return on equity (ROE), cash flow (Cashflow), growth rate (Growth), the ratio of outside board members (Indep), CEO-chairman dual role (Dual), ownership concentration of the largest shareholder (Top1), market Q ratio (TobinQ), and a state equity indicator (SOE). Furthermore, year and industry dummies (Year, Ind) are added to absorb time as well as industry fixed impacts. The table below outlines the variable definitions.

Table 1. Variable Definitions

Variable Type	Variable Name	Symbol	Description
Dependent	Green Innovation	Gi	Total number of green utility model patent applications + green invention patent applications (log)
Independent	Internal Control Quality	IC	DIB Internal Control Index (log)
Control	Firm Size	Size	Natural log of total assets at year-end
	Leverage	Lev	Total liabilities / Total assets
	Profitability	ROA	Net profit / Average total assets
	Return on Equity	ROE	Net profit / Average equity × 100%
	Cash Flow Ratio	Cashflow	Operating cash flow / Total assets
	Firm Growth	Growth	(Current year revenue / Prior year revenue) - 1
	Independent Director Ratio	Indep	Number of independent directors / Total directors
	CEO Duality	Dual	1 if Chairman and CEO are the same person, else 0
	Ownership Concentration	Top1	Shares held by largest shareholder / Total shares
	Tobin's Q	TobinQ	(Market value of tradable shares + non-tradable shares × net assets per share + book value of liabilities) / Total assets
	Ownership Nature	SOE	1 if state-owned enterprise, else 0

3.3. Econometric Model Construction

In order to verify hypothesis H1, this paper constructs the baseline regression specification presented below:

$$Gi_{i,t} = \alpha_0 + \alpha_1 IC_{i,t} + \sum \alpha_k Controls_{i,t} + \sum Ind + \sum Year + \varepsilon_{i,t}$$

Where $Gi_{i,t}$ is the dependent variable, $IC_{i,t}$ is the core independent variable, $Controls$ represents all control variables, Ind and $Year$ control for industry and year fixed effects respectively, and $\varepsilon_{i,t}$ is the random error term.

4. Empirical Results and Analysis

4.1. Descriptive Statistics and Diagnostic Tests

4.1.1. Descriptive Statistics

Table 2 details the descriptive statistics for the main variables. The green innovation index (Gi) averages 0.223 (SD = 0.664) and ranges from 0 to 5.677, highlighting both the generally low green innovation intensity among heavily polluting enterprises and the wide variation across

firms. Internal control quality (IC) yields a mean of 6.245 and a standard deviation of 1.192, with a range spanning 0 to 6.724, suggesting that while internal control is acceptable on average, there is considerable dispersion among firms. All other control variables demonstrate distributions that are well within standard bounds.

Table 2. Descriptive Analysis

Var Name	Observations	Mean	SD	Min	Max	Median
Gi	8478	0.223	0.664	0.000	5.677	0.000
IC	8478	6.245	1.192	0.000	6.724	6.492
Size	8478	22.497	1.386	20.064	26.444	22.248
Lev	8478	0.442	0.201	0.059	0.925	0.442
ROA	8478	0.038	0.060	-0.184	0.222	0.035
ROE	8478	0.056	0.141	-0.701	0.414	0.065
Cashflow	8478	0.058	0.064	-0.120	0.243	0.056
Growth	8478	0.146	0.380	-0.467	2.428	0.078
Indep	8478	37.289	5.332	16.670	66.670	33.330
Dual	8478	0.236	0.425	0.000	1.000	0.000
Top1	8478	0.350	0.151	0.091	0.765	0.327
TobinQ	8478	1.770	1.058	0.811	7.059	1.431
SOE	8478	0.435	0.496	0.000	1.000	0.000

4.1.2. Multicollinearity Test

To mitigate the risk of biased estimates of the regression coefficients because of the high linear correlation among the explanatory variables, this study uses the variance inflation factor (VIF) to diagnose multicollinearity. Table 3 reports the results, showing that all VIFs are well below the threshold of 10, with the highest VIF at 6.60 and a mean VIF of 2.15. Therefore, the model does not suffer from serious multicollinearity.

Table 3. Multicollinearity Test

Variable	VIF	1/VIF
IC	1.18	0.850
Size	1.87	0.535
Lev	2.69	0.372
ROA	6.60	0.151
ROE	5.53	0.181
Cashflow	1.32	0.757
Growth	1.12	0.891
Indep	1.16	0.860
Dual	1.20	0.831
Top1	1.47	0.681
TobinQ	1.31	0.766
SOE	1.01	0.985
Mean VIF	2.15	

4.1.3. Heteroscedasticity Test

To detect potential heteroscedasticity, we conduct the White test to assess if the model exhibits heteroscedasticity. The null hypothesis posits homoscedasticity. The diagnostic results are reported in Table 4, where the chi-square statistic equals 1142.97, yielding a corresponding p-value of 0.0000. This result decisively rejects the null hypothesis of homoscedasticity,

indicating that the regression model suffers from heteroscedasticity. To ensure valid estimation results, this paper uniformly uses heteroscedasticity-robust standard errors for t-value correction in subsequent regressions.

Table 4. White's Test

	Coef.
Chi-square test value	1142.97
P-value	0.0000

4.1.4. Model Specification Test

To choose between fixed- and random-effects specifications, this paper performs a Hausman test. The obtained p-value equal to 0.01 rejects the null of random-effects validity ($p < 0.05$). Consequently, the main regressions are based on a two-way fixed-effects design that accounts for industry and time fixed effects.

4.2. Regression Results Analysis

Table 5. Baseline Regression Results

	(1)	(2)
	Gi	Gi
IC	0.025***	0.014***
	(5.61)	(3.05)
Size		0.136***
		(14.63)
Lev		-0.202***
		(-4.71)
ROA		-0.111
		(-0.49)
ROE		-0.017
		(-0.20)
Cashflow		0.334***
		(3.12)
Growth		-0.031*
		(-1.78)
Indep		0.001
		(0.73)
Dual		-0.034**
		(-2.40)
Top1		0.215***
		(4.37)
TobinQ		0.035***
		(4.88)
SOE		0.077***
		(4.96)
_cons	0.065**	-3.056***
	(2.32)	(-14.08)
N	8478	8478
R ²	0.113	0.173
Adj. R ²	0.11	0.17

*Note: t-statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The regression estimates for Model (1) are reported in Table 5. The univariate regression in Column (1) yields an IC coefficient of 0.025, which is statistically positive at the 1% threshold. Moving to Column (2), with all control variables and industry-year fixed effects included, IC's coefficient stands at 0.014 and continues to be positive at the 1% significance level. These findings suggest that, having accounted for other influencing factors and adjusting for heteroscedasticity, internal control quality continues to exert a significantly positive influence on green innovation, lending support to hypothesis H1.

5. Conclusion and Implications

5.1. Research Conclusion

To quantitatively estimate the effect of the internal control effectiveness on green patenting, the article relies on a sample of A-share listed companies in the high-emissions sectors during 2011-2023. We conclude that strong internal control has a significantly positively impact on green patenting among high-polluting businesses. This result is obtained when multicollinearity and heteroscedasticity are taken into account. A well-organized internal control system is not only effective in the disciplined distribution of resources but also provides a stable institutional environment and monitoring protection of the high-risk, long-horizon green innovation projects, further enhancing the green innovative capacity of the firm.

5.2. Policy Implications

Based on the empirical results, we suggest the following implications:

First, on the side of the firm, there should be a strong focus on developing and upgrading internal control architectures by transforming them from a passive compliance tool to an active strategic resource. It is urgent in the case of enterprises in pollution-intensive sectors, in particular, to coordinate the clean innovation goals with the internal control mechanisms and to apply risk management and process monitoring to protect green R&D programs, thereby facilitating green transformation.

Second, internal control has efficiency-enhancing effects that should be included in the R&D budgeting at the managerial level to avoid wasteful investment. Through a well-developed internal control system, the managers will be able to properly screen, assess and monitor the green innovation projects and hence maximize the efficiency of the R&D inputs and at the same time, ensure both economic and environmental benefits.

5.3. Research Limitations

There are some limitations to this study. First, the use of the number of patent applications to determine green innovation, although logical, overlooks the quality of patents and the effectiveness of commercialization. Second, the long input-output cycle of green innovation may introduce time lags into the data. To address these issues, better indicators (e.g. green patent citations, green total factor productivity) and dynamic panel models could reduce these concerns in future work to understand more about the impact of internal control on corporate environmental innovation.

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