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Can the Top Management Team's Environmental Attention Promote Corporate Green Innovation?

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Abstract: Enterprise green innovation (GI) is the micro foundation for coping with the challenges of the ecological environment and achieving sustainable development. The top management team's environmental attention (TMTEA) is crucial for guiding environmental strategy and resource investment and promoting enterprise transformation towards sustainable development and GI. Drawing on an attention-based view (ABV) and lifecycle theory, this study analyzes data from 1722 listed companies in China (2010–2021) to examine TMTEA's impact on corporate GI and its regulatory mechanisms. The results show the following: (1) TMTEA promotes enterprise GI, particularly in the growth and decline stages. (2) Government environmental attention negatively moderates TMTEA's influence on corporate GI. (3) Compensation and equity incentives positively moderate the TMTEA–GI relationship. These insights enrich executive attention and GI literature, aiding decision-makers and enterprises in formulating effective GI strategies. Limitations include reliance on Chinese-listed company data, potentially limiting generalizability, and the need for qualitative research to deepen understanding of management processes and governance mechanisms.

Keywords: top management team environmental attention; government attention; executive incentive; green innovation; panel Poisson model

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1. Introduction

With the acceleration of industrialization, urbanization, and globalization, environmental challenges, especially in developing countries like China, have become increasingly prominent (Ali et al., 2023; Hojnik and Ruzzier, 2016; Sherazi et al., 2024) [1–3]. Rising temperatures, escalating wastewater discharge, and depletion of resources pose significant threats to sustainable development (Munawar et al., 2022; Sharif et al., 2023) [4,5]. In response, the Chinese government has issued supportive policies for green and low-carbon technology development (Djibo et al., 2022; Guo et al., 2022) [6,7], aligning with the goal of fostering green, circular, and low-carbon development highlighted in national agendas.

Enterprises are increasingly tasked with greater environmental responsibilities, making green innovation (GI) a critical pathway for achieving sustainable development (Brío and Junquera, 2003; Díaz-García et al., 2015; Foxon and Pearson, 2008) [8–10]. The top management team (TMT), having full control over resource allocation, plays a crucial role in coordinating internal environmental management practices. GI's effectiveness relies heavily on the TMT's environmental attention (TMTEA), as per the attention-based view (ABV; Andersén, 2022; Kim et al., 2016; Liao et al., 2021; Ocasio, 1997) [11–14]. TMTEA refers to the degree of attention and behavioral response of top management teams to environmental issues, including their focus on environmental protection and sustainable development, awareness and assessment of environmental impacts, and formulation and implementation of strategies and policies related to environmental protection. Theoretically, TMTEA can influence the organizational values and behavioral patterns internally, driving companies towards environmentally friendly and innovative directions. In our research context, the importance of TMTEA lies in its potential impact on green innovation within

enterprises. Through the attention of top management teams to environmental issues, companies can prioritize environmental innovation and adopt innovative environmental technologies and strategies, thereby promoting the development of green products and green production methods and achieving sustainable development goals. Therefore, understanding and measuring the promoting effect of TMTEA on green innovation within enterprises is crucial for our research.

Moreover, the attention degree and effect of TMTs vary across different enterprise lifecycle stages (Miller and Friesen, 1984) [15]. Enterprises in the growth period exhibit strong innovation willingness and resource abundance, while those in the mature period maintain specific market positions and ample GI resources. Conversely, enterprises in the recession period face limited growth opportunities and TMT attention, impacting their GI development (Dickinson, 2011; Ramzan and Lau, 2023; Yang et al., 2021) [16–18]. Thus, understanding the interplay between TMTEA, enterprise lifecycle, and GI holds practical significance for sustainability.

GI refers to the innovation of novel technologies, products, and business models to respect the interaction between society and the natural environment, minimize the negative impact of human beings on the latter, and provide commercial value to enterprises. Existing research on corporate GI predominantly focuses on external drivers like government regulation, green policies, customer preferences, and supplier relations, neglecting internal management initiatives (Rennings, 2000) [19]. However, while these external factors play a crucial role, relying solely on them has limitations. Improvement in corporate GI often depends on endogenous factors, with TMT exerting significant influence over strategic decisions (Lubatkin et al., 2006) [20]. Scholars have started exploring executive characteristics' role in GI, noting the positive impacts of factors like hometown identity, salary, gender, and position power (Phung et al., 2023; Javed et al., 2023) [21,22]. Additionally, studies have examined personality traits' effects on GI, with findings suggesting positive impacts of traits like arrogance, overconfidence, and perfectionism (Arena et al., 2018) [23]. Despite this, the relationship between executives' cognitive characteristics and GI remains underexplored (Sherazi et al., 2024) [3]. According to the ABV (Kim et al., 2016; Ocasio, 1997; Erhan et al., 2023) [12,14,24] the behavior and decision-making in enterprises are, to some extent, a reflection of the attention allocation of their senior managers. Therefore, the GI activities of enterprises also depend primarily on the attention and cognition of their executives regarding environmental issues (Munawar et al., 2022; Han et al., 2022; Huang et al., 2020; Polas et al., 2021) [4,25–27].

The focused attention principle (Andersén, 2022; Kim et al., 2016; Ocasio, 1997) [11,12,14] of the ABV posits that managers' attention is limited and crucial for determining their enterprise's strategic direction (Erhan et al., 2023; Koryak et al., 2018) [24,28]. TMTEA, reflecting the degree of TMT's attention toward ecological and environmental issues, aligns with this principle. The distribution principle of attention structure (Ocasio, 1997; Fagerlin and Wang, 2020) [14,29] suggests that organizational rules and resources influence decision-makers' attention, impacting problem prioritization and solutions. As an organizational resource linked to top managers, executive incentives may mitigate TMT risk aversion, enhancing their environmental attention and influencing GI. The situational attention principle indicates that decision-makers' attention preferences are influenced by external contexts like government stimuli, particularly environmental attention, potentially promoting GI development (Polas et al., 2021; Chen et al., 2022; Zhao et al., 2023) [27,30,31].

This study utilizes a panel Poisson model to investigate the influence of top management team environmental attention on corporate GI within Chinese-listed companies from 2010 to 2021. It seeks to address the following research questions: Can top management team environmental attention promote corporate GI? How does TMTEA's effect on GI vary across different enterprise lifecycle stages, considering diverse governance environments and resource requirements? Lastly, what are the moderating roles of internal executive incentives and external government environmental attention on the relationship between TMTEA and GI?

This study makes three significant contributions to the literature. Firstly, it sheds light on the influence of TMTEA on enterprise GI, expanding understanding beyond external institutional factors to include internal initiative factors, such as managers' attention, enriching ABV's application. Secondly, incorporating lifecycle theory offers insights into the dynamic relationship between TMTEA and corporate GI across lifecycle stages, addressing a gap in existing literature regarding the time dimension. Thirdly, it considers the contingency effects of external (government environmental attention) and internal (executive incentives) factors on GI, providing a comprehensive understanding of the TMTEA–GI relationship.

The rest of this article is organized as follows: Section 2 elaborates the study's theoretical basis and research hypotheses. Section 3 introduces the data and methods. Section 4 provides the empirical results. Section 5 empirically elaborates on the moderating effect of government environmental attention and executive incentives. In the final section, the paper is summarized.

2. Theoretical Analysis and Research Hypotheses

2.1. The Impact of TMTEA on Corporate GI

The ABV suggests that organizational behavior is influenced by how enterprises direct and distribute the attention of their decision-makers (Kim et al., 2016; Ocasio, 1997; Erhan et al., 2023) [12,14,24]. The attention of the TMT significantly impacts organizational choices and performance, reflecting executive values, thinking patterns, and ideologies (Fagerlin and Wang, 2020; Attah-Boakye et al., 2021; Vardarsuyu et al., 2023) [29,32,33]. Limited human cognitive capacity necessitates focused attention, wherein managers prioritize specific fields for processing valuable information. TMTEA, as a decision on corporate environmental strategy, influences the choice and effectiveness of corporate GI.

Firstly, TMTEA directly impacts resource selection and sustainable development policy formulation for enterprise GI (Munawar et al., 2022; Ocasio, 1997; Polas et al., 2021) [4,14,27]. TMTs focusing more on environmental issues are inclined to enhance environmental protection measures and actively implement GI strategies. Increased environmental attention prompts the allocation and deployment of green resources, investment in green technology, and recruitment of green human resources, fostering GI management practices across institutions and policies.

Secondly, heightened environmental attention by the TMT facilitates the identification of business opportunities and new stimulating factors for GI (Munawar et al., 2022; Andersén, 2022; Momayez et al., 2023; Tang et al., 2024) [4,11,34,35]. Managers' varying attention allocations lead to diverse understandings of environmental signals within complex organizations. TMTs with great environmental attention tend to perceive policy regulation and green demand as development opportunities, facilitating the capture of incentive factors for new enterprise GI and organization of innovation resources.

Thirdly, organizational culture and values. The environmental concerns of top management teams can shape the organizational culture and core values of a company, thereby influencing employee behavior and decision-making. When environmental awareness is integrated into the corporate culture, employees are more likely to incorporate environmental principles into their work and actively engage in green innovation practices. Therefore, TMTEA can promote environmental behavior among employees and drive the implementation and development of green innovation by shaping a positive organizational culture and values.

Fourthly, stakeholder pressure and recognition. The environmental concerns of top management teams often receive attention and recognition from various stakeholders, such as governments, social organizations, and consumers (Sherazi et al., 2024 Munawar et al., 2022; Kim et al., 2016; Erhan et al., 2023) [3,4,12,24]. This recognition and support can motivate companies to more actively engage in green innovation to meet the expectations and demands of stakeholders, enhancing the company's corporate social responsibility

image. Therefore, TMTEA, by addressing stakeholder pressure and recognition, drives companies to take more green innovation initiatives to earn social acceptance and support.

Fifthly, technological innovation and industrial upgrading. The environmental concerns of top management teams can promote technological innovation and industrial upgrading, providing more opportunities for green innovation for companies (Polas et al., 2021; Momayez et al., 2023; Tang et al., 2024) [27,34,35]. Driven by environmental pressures and market demands, companies may increase their research and investment in green technologies and innovations to meet market demands and enhance competitiveness. Therefore, TMTEA can provide more opportunities for green innovation by promoting technological innovation and industrial upgrading, thereby driving the implementation and development of green innovation initiatives.

Therefore, we propose the following:

H1. *TMTEA can significantly promote GI.*

2.2. The Impact of Enterprise Lifecycle on TMTEA and Corporate GI

The top management team faces different challenges and opportunities at various stages of the company's lifecycle, leading to varying decision-making approaches. During the growth phase, the focus may lie on market expansion, resource allocation, and capital acquisition to support rapid company growth. As the company matures, decisions may shift towards maintaining market position, enhancing product efficiency, and diversifying business operations to sustain profitability and competitive advantage. In contrast, urgent measures such as business restructuring, resource optimization, and market repositioning in the decline phase may be necessary to address market challenges and seek sustainable development paths. Overall, decisions made by the top management team aim to align with the unique characteristics of each stage in the company's lifecycle, supporting long-term development goals and ensuring sustained competitive advantage and profitability.

2.2.1. Growth Period

According to the enterprise lifecycle theory (Miller and Friesen, 1984) [15], firms evolve through dynamic growth stages, each impacting TMTEA's role in corporate GI differently. During the growth phase, companies bolster competitiveness through substantial investments, such as R&D, product promotion, and production capacity expansion (Zhao et al., 2023) [31]. Initially, TMTEA's approach to environmental concerns might be limited. However, as firms invest in R&D, they develop practical green technologies, expanding market presence and share. Environmental focus enables TMTs to pinpoint high-value projects, meet investor and consumer demands, and achieve GI with adaptability. TMTs maintain entrepreneurial zeal despite emerging agency issues, prioritizing reputation over immediate financial rewards and deriving satisfaction from the innovation journey. With dedicated environmental attention, successful green technology innovations shape enterprise reputation positively and contribute to long-term growth and sustainability.

Therefore, we propose the following:

H2a. *In the growth period of an enterprise, TMTEA is positively related to GI.*

2.2.2. Mature Period

In the mature stage of a firm's lifecycle, it reaches its maximum scale, employee value, and internal governance efficiency (Zhao et al., 2023) [31]. Fortified by a robust resource base and capabilities, mature enterprises adeptly meet green consumer demands, fostering sustainable development. With stable profitability and ample cash flow, directing attention toward the ecological environment enables investment in GI using internal funds (Zhao et al., 2023) [31]. TMTEA steers corporate capital towards green initiatives, supported by accumulated expertise and reduced risks associated with established technology tracks. Strengthening TMT's focus on green development and the environment further enhances

resource allocation, driving GI efforts. Consequently, mature firms in this stage are well-positioned to leverage their financial stability and accumulated knowledge to propel sustainable growth through GI.

Therefore, we propose the following:

H2b. *In the mature period of an enterprise, TMTEA is positively related to GI.*

2.2.3. Recession Period

Enterprises in recessions often encounter challenges like low product yields, rigid institutional processes, and declining market shares (Zhao et al., 2023) [31]. The inability to keep up with new product development paces and increased market competition leads to reduced sales, profits, and cash flow issues. Financial constraints limit their ability to consider relevant policies and undertake high-risk GI activities, eroding confidence among external investors and exacerbating funding constraints (Dickinson, 2011) [16].

Some firms may resort to "coping" GI activities during recessions, focusing on maintaining market value without substantial R&D investments (Zhao et al., 2023) [31]. With a risk-averse stance, TMTs prioritize conservative strategies over high-uncertainty GI initiatives, preferring routine production and operation activities. Reduced innovation capabilities hinder TMT attention from translating into actionable behaviors as firms struggle with outdated technology, declining R&D capabilities, and talent drain (Ramzan and Lau, 2023; Yang et al., 2021) [17,18].

In summary, recession-hit firms lack the financial means, motivation, and capability to invest in GI activities. Despite TMT's attention to environmental concerns, GI is unlikely to be significantly impacted during recessions.

Therefore, we propose the following:

H2c. *In the recession period of an enterprise, TMTEA has no impact on enterprise GI.*

2.3. The Moderating Effect of Government Environmental Attention

Government environmental attention refers to the government's focus on environmental issues, influencing the execution of environmental policies. This attention is a critical external stimulus for enterprises, impacting TMTs across various aspects. Firstly, heightened government attention prompts firms to delve deeper into GI through increased subsidies and tax incentives (Djibo et al., 2022) [6]. Consequently, resource allocation shifts towards green technology innovation, bolstered by stakeholder and resource dependence theories. Secondly, government attention, acting as external pressure, promotes environmental responsibilities through regulations, enhancing TMT sustainability. This fosters long-term investment in GI. Additionally, persistent government focus reduces TMT's short-sightedness, fostering transparent objectives and sustainable development. Moreover, it boosts public awareness, spurring green consumption and shaping consumer demand for green products (Chen et al., 2022) [30]. Consequently, TMTs prioritize green technology development to meet consumer expectations and maintain an environmental reputation. Lastly, the synergy between government attention and TMTEA amplifies overall GI, enhancing environmental performance and driving sustainable development goals (Chen et al., 2022) [30]. Thus, TMTs actively pursue environmental performance to align with government objectives, utilizing GI for sustainable development.

Therefore, we propose the following:

H3. *The positive impact of TMTEA on corporate GI is more significant when government environmental attention is high.*

2.4. The Moderating Effect of Executive Incentive

The distribution principle of attention structure underscores how rules and private resources influence managers' attention allocation. Executive incentives, like compensation

and equity incentives, enable TMTs to pursue long-term, uncertain ideas. Optimal contract theory suggests that these incentives align executive and shareholder interests, reducing agency costs and promoting GI. Compensation incentives reduce management's risk aversion, fostering an 'innovation compensation effect' and enhancing executives' sense of identity with the enterprise.

In contrast, equity incentives promote long-term motivation, aligning shareholder and executive interests (Hossain et al., 2022) [36]. By delaying incentives, equity incentives deter seeking quick success, encouraging TMTs to engage more in environmental issues and expand environmental investment. Moreover, equity incentives signal to the market the excellence of corporate investment projects, easing financing constraints and supporting GI (Hossain et al., 2022) [36].

Therefore, we propose the following:

H4a. *The positive impact of TMTEA on corporate GI is more significant for companies with high compensation incentives*.

H4b. *The positive impact of TMTEA on corporate GI is more significant for companies with high equity incentives*.

3. Data and Methods

3.1. Sample

A-share listed companies in China's Shanghai and Shenzhen Stock Exchanges from 2010 to 2021 are selected as the research objects. According to the following principles, the samples were screened: first, any samples with missing variables were removed; second, due to the unique financial structure of the monetary and financial services industry, such samples were removed; third, abnormal enterprise samples such as ST were eliminated; and fourth, Winsorization was applied to all continuous variables. After data filtering, the sample contained 32,005 observations. Since the panel Poisson model is used in this paper, the model automatically eliminated any enterprise samples with zero results (Chen et al., 2022) [30]. In addition, the enterprise samples with only one value in all observation years were eliminated. Therefore, the final sample consists of 1722 companies and 14,921 effective observations, which are included in the Poisson analysis. The unbalanced panel data were obtained after data processing.

3.2. Measurement of Variables

3.2.1. Dependent Variable

Our dependent variable is GI. The patent application data of the sample enterprises from 2010 to 2021 are collected, following Liao et al. (2021) [13]. Then, the Python tool (The version is 3.9.16) and Excel software (Microsoft® Excel® 2019MSO) are used to match the IPC classification number of the World Intellectual Property Organization to obtain the enterprises' annual number of green patents. Considering the reliability and timeliness of data, this study focuses on innovation managers' innovation. Green patent technology can act on firms when applying for it, so the application data of green patents are considered appropriate. Drawing on Chen et al. (2022) [30], we use the number of green patent applications as a measure of GI.

3.2.2. Independent Variable

Our independent variable is TMTEA; as text analysis can effectively measure managers' attention (Liao et al., 2021) [13], it is often used in panel data studies. Among the various textual content published by listed companies, the annual report shows the investment and attention thereof toward environmental problems (Liao et al., 2021) [13]; thus, it is selected as the object of text analysis. Attention is mapped to each text, and the presentation of the ecological environment description in the annual report exhibits the attention focus of the TMT. Referring to certain scholars (Qiu et al., 2022) [37], this study uses the artificial

intelligence financial data platform Wingo database to measure TMTEA. The measurement steps are as follows:

First, articles measuring environmental attention were searched, the keywords are marked and compared, and then the reports of 50 companies in the past three years are intensively read. Based on previous literature and annual reports, this study extracts and summarizes the seed words for TMTEA, including environmental protection, emission reduction, energy saving, green, ecology, and pollution.

Second, through the Wingo similar word database, similar words are obtained. Specifically, the above six seed words are imported into the Chinese-listed company text database of the Wingo financial text data platform. The top 30 words with the highest similarity to each seed word are taken as the results of the similar word set of the word, and the similarity and word frequency of each similar word are generated.

Third, artificial screening is performed to form a theoretical keyword vocabulary: remove similar words unrelated to environmental issues, remove similar words with word frequency less than 100, delete duplicate similar words, and retain similar words with similar meanings but higher word frequency. To ensure the validity of the vocabulary, 150 annual reports are randomly selected for secondary verification. The final keyword vocabulary is shown in Table 1.

Table 1. TMTEA keywords.

Seed Word	Theoretical Keywords
Environmental protection	Environmental governance, environmental pollution, pollution control, safety production, environmental protection, energy conservation, energy, sewage, water resources protection, health
Emission reduction	Pollutant emissions, nitrogen oxides, sulfur dioxide, zero emissions, greenhouse gases, pollution control
Energy saving	Environmental protection, emission reduction, consumption reduction, intelligence, frequency conversion, high-performance, noise reduction, power saving, water saving, fuel saving, energy consumption, energy efficiency, lightweight, new energy steam, lighting
Green	Environmentally friendly, clean, ecological, low-carbon, high-quality, efficient, garden-style, concept, new, circular economy
Ecology	Water environment, soil, grassland, ocean, landscape, green, beautiful, wetland, water system, saline–alkali land, livable, vegetation, wisdom
Pollution	Wastewater, emissions, harmful, odor, waste gas, dust, waste, leakage, damage, odor, three wastes, soil erosion, harm, unorganized emissions, haze, dust, odor, toxic

Fourth, according to the keyword vocabulary, the TMTEA of each sample enterprise is measured. Specifically, the keyword vocabulary is imported into the text database of Chinese-listed companies in Wingo, and the word frequency of each word is counted to obtain the word frequency of TMTEA from 2010 to 2021. Finally, the natural logarithm one plus the sum of word frequency is used to measure TMTEA.

3.2.3. Enterprise Lifecycle

Enterprises in different lifecycles have different resource endowments and development goals, whereby they have different needs for capital and innovation. The measurement of the enterprise lifecycle includes the single factor method (Wang, 2022) [38], aggregative indicator method (Xue and Zhang, 2022) [39], and cash flow model method (Yang and Deng, 2023) [40]. Referring to previous scholars (Dickinson, 2011; Yang and Deng, 2023) [16,40], this study adopts the cash flow model method, which can not only avoid the influence of industry differences but also prevent the subjective judgment of researchers (Ramzan and Lau, 2023) [17]. We divide the sample into three stages, as shown in Table 2.

Table 2. Enterprise lifecycle identification.

	Growth Period		Mature Period	Decline Period				
	Startup Period	Growth Period		Fluctuation Period			Elimination Period	
Net operating cash flow	-	+	+	-	+	+	-	-
Net investment cash flow	-	-	-	-	+	+	+	+
Net fundraising cash flow	+	+	-	-	+	-	+	-

3.2.4. Regulating Variable

To a certain extent, local government work reports reflect government attention allocation. Therefore, based on government work reports, this study uses the logarithm of the total frequency of environmental-related keywords in provincial annual government work reports to measure government environmental attention (Chen et al., 2022) [30]. Similar to measuring TMTEA, the relevant words in the report are processed through Wingo. The measurement steps are as follows:

First, based on the literature and the government work reports from the past three years, the seed words for government environmental attention are refined and summarized, including environmental protection, emission reduction, energy conservation, green, ecology, and pollution.

Second, similar words of the above seed words are obtained through the Wingo similar word database. Specifically, the above six seed words are imported into the Chinese government text database of the text structure financial text data platform. The top 30 words with the highest similarity to each seed word are taken as the results of the similar word set of the word, and the similarity and word frequency of each similar word are generated.

Third, artificial screening is performed to form a theoretical keyword vocabulary: we remove similar words unrelated to environmental issues, remove similar words with word frequency less than 100, delete duplicate similar words, and retain similar words with similar meanings but higher word frequency. Fifty government work reports are randomly selected for secondary verification, and the final keyword vocabulary is shown in Table 3.

Table 3. Government environmental attention keywords.

Seed Word	Theoretical Keywords
Environmental protection	Weak links, protection, geological disaster prevention and control, environmental protection, environmental protection work, environmental management, environmental monitoring, environmental construction, environmental problems, environmental quality, environmental governance, ecological, environmental protection, ecological environment protection, ecological construction, ecological civilization construction, soil and water conservation, water resources protection, resource protection, resource conservation
Emission reduction	Ammonia nitrogen, standard discharge, sulfur dioxide, energy saving, emission reduction, emission, total emission control, coal combustion, water pollution prevention and control, desulfurization, denitrification, deadline management, reduction, one control and two standards, pollution control, total control
Energy saving	Dust removal, high energy-consuming industries, energy consumption, contract energy management, environmental protection and energy saving, emission reduction, building energy saving, consumption reduction, energy-saving products, energy-saving work, energy saving and environmental protection, energy-saving technology, energy saving and consumption reduction, water saving, energy efficiency, mandatory, clean production
Green	Low-carbon, clean, green products, green low-carbon, green development, green economy, green food, beautiful, clean, clean energy, mountainous, ecological, ecological, ecological, pastoral, circular, organic agriculture, landscaping, intelligent agriculture.
Ecology	Green, green ecology, ecological protection, ecological development, ecological environment, ecological landscape, ecological corridor, ecological tourism, ecological agriculture, ecological area, ecological circle, ecological wetland, ecological civilization, ecological system, ecological livable, wetland, water town, original ecology, natural ecology.
Pollution	Waste gas, dust, industrial pollution, industrial pollution sources, environmental pollution, volatile organic compounds, motor vehicle exhaust pollution, straw burning, air pollution, nonpoint source pollution, agricultural nonpoint source pollution, scattered pollution, water pollution, pollution prevention and control, pollutants, pollutant discharge, serious pollution, pollution sources, pollution control, soot, noise pollution, key sewage, heavy metal, heavy metal pollution

Fourth, according to the keyword vocabulary, government environmental attention is measured. The keyword vocabulary is imported into the Chinese government text database of the text structure financial text data platform, and the word frequency of each word is counted. The natural logarithm one is added to the sum of word frequency to measure government environmental attention.

Executive incentives include compensation and equity incentives. The proxy variable of compensation incentives is the total salary of senior managers, and the natural logarithm

processes it. In addition, the proxy variable of equity incentives is the number of shares held by senior managers, and the natural logarithm processes it.

3.2.5. Control Variables

We control for firm age, firm size, R&D intensity, equity concentration, total assets net profit margin (ROA), total operating income fixed assets ratio, and asset–liability ratio. These control variables are usually adopted in research on corporate GI (Guo et al., 2022; Zhao et al., 2023; Momayez et al., 2023; Jiang et al., 2023) [7,31,34,41]. The variable names and descriptions are shown in Table 4.

Table 4. Variable names and descriptions.

Variable Name		Symbol	Variable Description	Data Sources
Green innovation		GI	Number of green patent applications	Chinese Research Data Services (CNRDS)
Top management team environmental attention		TMTEA	The sum of eco-environment-related word frequencies in the company's annual report plus the natural logarithm of 1	Wingo database
Government environmental attention		GEA	The sum of eco-environment-related word frequencies in the local government work report plus the natural logarithm of 1	Wingo database
Executive incentive	Salary incentives	SalInc	Total executive compensation plus the natural logarithm of 1	China Stock Market and Accounting Research (CSMAR)
	Equity incentive	EquInc	The total number of senior management holdings plus the natural logarithm of 1	
Controlled variable	Firm age	Age	The number of years of establishment of the enterprise in the reporting period plus the natural logarithm of 1	
	Firm size	Size	Total assets of the business plus the natural log of 1	
	R&D intensity	RD	The proportion of net intangible assets to total assets	
	Equity concentration	Equity	The sum of the shares held by the top 10 shareholders	
	Return on total assets	Roa	Net profit/total assets × 100%	
	Operation revenue	Revenue	Business revenue plus the natural logarithm of 1	
	Fixed assets ratio	Fixed	Fixed assets/total assets × 100%	
	Asset–liability ratio	AssLia	Total liabilities/total assets × 100%	

3.3. Model Design

3.3.1. Baseline Model

Since our dependent variable is measured via the number of green patents, it will have many 0 values and the characteristics of nonnegative integers. Therefore, the Poisson model is appropriate (Chen et al., 2022; Xiang et al., 2020) [30,42]. Assuming that the individual effect is related to GI (Chen et al., 2015) [43], we choose the fixed-effect Poisson regression model. To test the impact of TMTEA on GI, the Poisson model used in this study is shown in Equation (1):

$$E(GI_{it}|x_{it},\eta_i) = exp\left(\alpha \times TMTEA_{it} + \sum_{i=1}^{k}\beta_i \times x_{it} + \eta_i + \varepsilon_{it}\right), \quad (1)$$

where GI_{it} represents the number of green patent applications of company I in year t, $TMTEA_{it}$ represents the TMT environmental attention of company i in year t, $I \times x_{it}$ is the selected control variable, I_i represents the fixed effect of the company, and ε_{it} represents the disturbance term.

3.3.2. Regulating Model

To test the moderating effect of government environmental attention and executive incentives, the Poisson model used in this study is shown in Formulas (2)–(4):

$$E(GI_{it}|x_{it}, \eta_i) = exp\left(\alpha \times TMTEA_{it} + \alpha_2 GEA_{it} + \alpha_3 TMTEA_{it} \times GEA_{it} + \sum_{i=1}^{k} \beta_i \times x_{it} + \eta_i + \varepsilon_{it}\right), \quad (2)$$

$$E(GI_{it}|x_{it}, \eta_i) = exp\left(\alpha \times TMTEA_{it} + \alpha_2 SalInc_{it} + \alpha_3 TMTEA_{it} \times SalInc_{it} + \sum_{i=1}^{k} \beta_i \times x_{it} + \eta_i + \varepsilon_{it}\right), \quad (3)$$

$$E(GI_{it}|x_{it}, \eta_i) = exp\left(\alpha \times TMTEA_{it} + \alpha_2 EquInc_{it} + \alpha_3 TMTEA_{it} \times EquInc_{it} + \sum_{i=1}^{k} \beta_i \times x_{it} + \eta_i + \varepsilon_{it}\right), \quad (4)$$

where GEA_{it} represents the proxy variable of government environmental attention, $SalInc_{it}$ represents the proxy variable of compensation incentives, and $EquInc_{it}$ represents the proxy variable of equity incentives.

4. Results

4.1. Descriptive Statistics and Correlation Analysis

Table 5 reports the descriptive statistical analysis results and Pearson correlation coefficient matrix of the main variables. Hence, the range of GI among listed companies is 0~933, and the average is 1.73 (sd. = 13.91). This shows that the overall level of GI is low and that the GIs of various companies significantly differ. The range of TMTEA is 0.69~5.49, and the average value is 3.36 (sd. = 1.07), indicating that the TMT of each enterprise allocates a different attention level to the environment. The mean value of government environmental attention is 4.15 (sd. = 0.3), indicating that the overall difference in the government environmental attention of the sample companies is not significant; furthermore, TMTEA is more dispersed than government environmental attention. The average value of equity incentives is 10.82 (sd. = 7.34), the change interval is 0~19.78, the average value of compensation incentives is 14.91 (sd. = 0.81), and the change interval is 12.86~17.05, demonstrating that the dispersion degree of equity incentives is greater than that of compensation incentives. The average size is 22.12, the average R&D intensity is 0.05, the average ownership concentration of the sample companies is 59.06, the average ROA is 0.04, the average total operating income is 21.44, the average fixed asset ratio is 0.21, and the average asset–liability ratio is 0.42. In summary, TMTEA is positively correlated with the enterprise GI index, i.e., when the environmental attention value of the TMT is high, the GI value of the enterprise is relatively high. In addition, as Table 6 shows, a single variable's variance inflation factor (VIF) is less than 6, and the average VIF of the main variables is 1.94, indicating no multicollinearity problems.

Table 5. Descriptive statistics and correlation coefficients of core variables.

Variable	Mean	Sd	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13
GI	1.73	13.91	0	933	1												
TMTEA	3.36	1.07	0.69	5.49	0.106 ***	1											
Age	2.92	0.34	0.69	4.17	0.017 ***	0.190 ***	1										
Size	22.12	1.30	19.69	26.11	0.181 ***	0.256 ***	0.210 ***	1									
RD	0.05	0.05	0	0.31	−0.002	0.068 ***	0.015 ***	0.021 ***	1								
Equity	59.06	15.35	23.16	90.31	0.025 ***	0.052 ***	−0.219 ***	0.086 ***	−0.009	1							
Roa	0.04	0.06	−0.25	0.20	0.010 *	−0.019 ***	−0.119 ***	−0.045 ***	−0.047 ***	0.256 ***	1						
Revenue	21.44	1.46	18.19	25.53	0.172 ***	0.235 ***	0.176 ***	0.889 ***	−0.008	0.101 ***	0.05 ***	1					
Fixed	0.21	0.16	0.002	0.69	0.010 *	0.101 ***	0.023 ***	0.113 ***	0.113 ***	−0.006	−0.078 ***	0.134 ***	1				
AssLia	0.42	0.21	0.05	0.89	0.059 ***	0.047 ***	0.209 ***	0.498 ***	0.008	−0.143 ***	−0.363 ***	0.489 ***	0.105 ***	1			
GEA	4.15	0.30	3.14	4.68	0.020 ***	0.160 ***	0.085 ***	0.015 ***	−0.003	0.037 ***	0.006	0.017 ***	−0.035 ***	−0.022 ***	1		
EquInc	10.82	7.34	0	19.78	0.027 ***	0.156 ***	−0.119 ***	−0.116 ***	−0.084 ***	0.025 ***	0.133 ***	−0.089 ***	−0.177 ***	−0.225 ***	0.108 ***	1	
SalInc	14.91	0.81	12.86	17.05	0.124 ***	0.279 ***	0.165 ***	0.495 ***	−0.047 ***	0.084 ***	0.151 ***	0.488 ***	−0.090 ***	0.121 ***	0.108 ***	0.165 ***	1

Note: *, *** indicate statistical significance at the 10% and 1% levels, respectively.

Table 6. VIF test of major variables.

Variable	VIF
TMTEA	1.22
Age	1.19
Size	5.29
RD	1.03
Equity	1.16
Roa	1.35
Revenue	5.31
Fixed	1.1
AssLia	1.75
GEA	1.05
EquInc	1.2
SalInc	1.57
Mean VIF	1.94

4.2. Results of Baseline Regression

We first examine the impact of TMTEA on GI. As shown in Table 7, column (1) shows the results of the fixed-effect Poisson regression. The regression coefficient between TMTEA and GI is 0.097 ($p < 0.01$). Hence, when the environmental attention score of the TMT of the listed company increases by 1 point, the corporate GI increases by an average of $e^{0.097}$ points, or approximately 1.102 points. The time fixed effect is added to column (2), column (3) has no fixed effect, and the TMTEA coefficient in column (2) and column (3) is significantly similar to that in column (1). These results show that TMTEA significantly improves the level of GI. Therefore, H1 is verified.

Table 7. Results of baseline regression.

	GI		
Variable	**(1)**	**(2)**	**(3)**
TMTEA	0.097 ***	0.043 ***	0.141 ***
	(0.010)	(0.011)	(0.01)
Age	1.275 ***	−0.367 ***	0.990 ***
	(0.045)	(0.1)	(0.042)
Size	0.429 ***	0.306 ***	0.483 ***
	(0.024)	(0.025)	(0.023)
RD	0.618 ***	0.770 ***	0.604 ***
	(0.228)	(0.24)	(0.224)
Equity	0.017 ***	0.009 ***	0.015 ***
	(0.000)	(0.001)	(0.001)
Roa	−0.679 ***	−0.597 ***	−0.821 ***
	(0.143)	(0.145)	(0.141)
Revenue	0.070 ***	0.162 ***	0.059 ***
	(0.021)	(0.022)	(0.02)
Fixed	−0.321 **	−0.575 ***	−0.429 ***
	(0.082)	(0.084)	(0.079)
AssLia	−1.177 ***	−1.005 ***	−1.159 ***
	(0.071)	(0.075)	(0.07)
Firm FE	Yes	Yes	No
Year FE	No	Yes	No
Log likelihood	−29,787.295	−27,989.712	−39,256.251
Wald Chi2	8359.44	11,913.35	8586.53
Observations	14,921	14,921	32,002
Number of ID	1722	1722	4422

Note: Standard errors in parentheses. **, *** indicate statistical significance at the 5%, and 1% levels, respectively.

4.3. Enterprise Lifecycle Test

Since top managers adjust their attention according to different stages in enterprise development, we assume that the relationship between TMTEA and GI differs in these distinct lifecycles. Columns (1), (2), and (3) in Table 8 report the results of the impact of TMTEA on corporate GI during the growth, maturity, and recession periods. The TMTEA coefficient in the growth period is positive and statistically significant at the critical level of 1%, indicating a positive relationship between TMTEA and corporate GI in the growth period. Hence, TMTEA can significantly promote GI, and H2a is verified. In addition, the TMTEA coefficient during the mature period was positive but not significant. Therefore, H2b is not supported; this may be because mature companies tend to have stable business models and market positions, and they are more inclined to prioritize resources to existing businesses and profits rather than invest in new, riskier GI projects. At the same time, executive performance evaluations may rely more on short-term financial metrics than long-term innovation and sustainability metrics.

Table 8. Enterprise life cycle test.

	GI		
Variable	**(1)**	**(2)**	**(3)**
TMTEA	0.179 ***	0.011	0.163 ***
	(0.018)	(0.018)	(0.028)
Age	0.825 ***	1.486 ***	1.091 ***
	(0.08)	(0.077)	(0.197)
Size	0.289 ***	0.736 ***	0.954 ***
	(0.039)	(0.045)	(0.119)
RD	0.637 **	−1.46 ***	−1.568
	(0.298)	(0.553)	(1.209)
Equity	0.013 ***	0.025 ***	0.012 ***
	(0.001)	(0.002)	(0.003)
Roa	−1.259 ***	−1.698 ***	0.654
	(0.243)	(0.278)	(0.43)
Revenue	0.102 ***	0.085 *	0.112
	(0.033)	(0.046)	(0.072)
Fixed	−0.276 **	−0.811 ***	−0.201
	(0.126)	(0.154)	(0.462)
AssLia	−0.943 ***	−1.645 ***	−2.044 ***
	(0.108)	(0.144)	(0.264)
FE	Yes	Yes	Yes
Log likelihood	−11,707.903	−8029.155	−2274.0412
Wald Chi2	2478.45	4156.10	530.96
Observations	6115	3775	1215
Number of ID	1185	824	361

Note: Standard errors in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Finally, these results show that although an enterprise is in a recession, the TMTEA coefficient is still positive ($p < 0.01$), indicating that TMTEA still positively and significantly impacts GI in such a recession. Accordingly, H2c is not supported; this may be due to the TMT's consideration of cost savings and risk aversion. On the one hand, in their recession period, enterprises face cost pressures. TMTs can improve energy efficiency (Khan et al., 2023) [44] and reduce greenhouse gas emissions (Jiang et al., 2023) [45] by focusing on the ecological environment and GI and reducing pollution, thereby reducing production costs and enhancing the competitiveness of their companies. On the other hand, during the recession period, business operations enter a trough; if companies cannot adapt to environmental changes, they may go bankrupt. TMTEA and corporate GI thus help companies reduce environmental risks (Javed et al., 2023) [22] and sustainability

risks (Jiang et al., 2023; Wei et al., 2023) [41,46], enabling them to obtain opportunities for regeneration and extend their life.

4.4. Robustness Test

4.4.1. Replacing the Core Independent Variable

In the robustness test, we chose senior executives' average years of education as an alternative core independent variable, i.e., TMTEA1. This is because there is a potential link between education level and environmental awareness, and executives with longer years of education are more likely to be exposed to environmental protection and sustainable development, so they pay more attention to environmental issues in their business operations. In addition, highly educated executives may be more inclined to think long-term, which includes an emphasis on GI. Since a direct measure of an executive's concern for the environment can be somewhat subjective, years of education can serve as an indirect, more accessible, and quantifiable proxy variable. Previous research (Safford and Hamilton, 2012) [47] has also shown that education level predicts people's perceptions of environmental issues. Similarly, TMTEA1 is included in the fixed-effect Poisson model. Column (1) in Table 9 reports the robustness test results that replace the core independent variable, wherein TMTEA1 still positively affects GI ($p < 0.01$).

Table 9. Robustness test.

	GI	GI1	GI2	GI
Variable	**(1)**	**(2)**	**(3)**	**(4)**
TMTEA		0.131 ***	0.047 ***	0.253 ***
		(0.014)	(0.015)	(0.02)
TMTEA1	0.089 ***			
	(0.007)			
Control var	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes
Log likelihood	−29,662.541	−18,235.053	−17,196.889	−16,812.294
Wald Chi2	8437.67	5060.33	3448.03	766.90
Observations	14,842	12,064	12,055	14,921
Number of ID	1698	1364	1378	1722

Note: Standard errors in parentheses. *** indicate statistical significance at the 1% levels.

4.4.2. Replacing the Dependent Variable

To ensure robustness, we use the number of green invention patent applications and green practical patent applications to measure the GI of enterprises. The corresponding regression results are reported in columns (2) and (3) in Table 9. TMTEA is thus positively correlated with GI ($p < 0.01$), consistent with the above result.

4.4.3. Replacing the Regression Model

Finally, we use panel negative binomial regression to replace the Poisson model. Panel negative binomial regression is often used to deal with discrete count data, which can better deal with zero expansion problems and heteroscedasticity. From column (4) of Table 9, the impact of TMTEA is positive ($p < 0.01$), which indicates that TMTEA can still promote the GI of enterprises by panel negative binomial regression.

4.4.4. Endogeneity Test

There may be a reverse causal relationship between TMTEA and GI. To solve the endogeneity problems in the above research model, we first use the instrumental variable regression model of the Poisson distribution and introduce public environmental attention (PEA) as the instrumental variable. Concerning the literature, we use the Baidu Annual Search Index to measure the PEA of the provinces where listed companies were located from 2010 to 2021 (Liu et al., 2023) [48], taking environmental pollution as a keyword. We

find a strong correlation between PEA and TMTEA, but PEA has less effect on enterprise GI. The explained variable of the first stage is TMTEA, and the explanatory variable is the instrumental variable PEA. Therefore, the predictive variable of TMTEA (P_TMTEA) is obtained. Then, the relationship between P_TMTEA and GI is further explored.

In column (2) of Table 10, the estimated coefficient is positive ($p < 0.01$), indicating that TMTEA has a positive and significant impact on corporate GI. In addition, we conducted lag treatment for the independent variables, and the regression results were reported in column (3). The coefficient is positive ($p < 0.01$). Finally, we used PSM for the test. Samples were divided according to the median of TMTEA. Samples with TMTEA values above or equal to the median were used as the experimental group, and samples with TMTEA values below the median were used as the control group. We used the kernel matching method, and column (4) reports the estimated results of the treatment effect, with a positive coefficient ($p < 0.01$), indicating that after controlling for other variables, a high level of TMTEA was positively correlated with GI, and the influence was significant. Similar results are obtained by replacing the matching method with nearest neighbor matching and radius matching. Therefore, the above results further support hypothesis H1.

Table 10. Results of endogeneity test.

	First Stage	**Second Stage**	**Lagged Treatment**	**PSM-Kernel**
	TMTEA	**GI**	**GI**	**GI**
Variable	**(1)**	**(2)**	**(3)**	**(4)**
PEA	0.0005 ***			
	(0.000)			
P_TMTEA		4.56 ***		
		(0.495)		
L.TMTEA			0.108 ***	
			(−0.011)	
high_TMTEA				2.215 ***
				(−0.16)
Control var	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes
Log likelihood	−39,644.003	−29,790.887	−25,472.974	-
Wald Chi2	2563.70	8188.06	6235.31	-
Observations	31,439	14,921	12,261	32,002
Number of ID	3859	1722	1518	-

Note: Standard errors in parentheses. *** indicate statistical significance at the 1% levels.

5. Further Analysis

Column (1) in Table 11 reports the results of the H3 test. We find that government environmental attention significantly negatively regulates the relationship between TMTEA and GI ($\beta = -0.246$, $p < 0.01$). That is, the stronger the government's environmental attention is, the smaller the impact of TMTEA on enterprise GI. This is inconsistent with H3; therefore, H3 is not affirmed. This result may be because the government's focus on the ecological environment may lead to more environmental policy changes and regulatory pressures (Catozzella and Vivarelli, 2016) [49], whereby the TMT may need to spend vast attention and resources to meet the administrative and regulatory requirements and assure environmental compliance rather than engage in GI. Furthermore, columns (2), (3), and (4) concern the moderating effect of government environmental attention on enterprises in different lifecycles. We find that the negative moderating effect of government environmental attention is significant at the levels of 1% in the growth and recession periods of enterprises but that the negative moderating effect of government environmental attention is not significant in the maturity period.

Table 11. Regulating effect.

	GI											
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
TMTEA	0.110 ***	0.205 ***	0.013	0.24 ***	0.059 ***	0.140 ***	−0.043 **	0.116 ***	0.098 ***	0.185 ***	0.007	0.158 ***
	(0.010)	(0.018)	(0.018)	(0.029)	(0.011)	(0.019)	(0.021)	(0.042)	(0.010)	(0.018)	(0.018)	(0.030)
GEA	0.0009	−0.081 *	0.02	0.704 ***								
	(0.026)	(0.042)	(0.043)	(0.112)								
SalInc					−0.063 ***	−0.036	−0.117 ***	−0.207 ***				
					(0.015)	(0.025)	(0.026)	(0.052)				
EquInc									−0.011 ***	−0.006 **	−0.015 ***	−0.038 ***
									(0.002)	(0.003)	(0.003)	(0.007)
TMTEA × GEA	−0.246 ***	−0.334 ***	−0.056	−0.81 ***								
	(0.021)	(0.036)	(0.036)	(0.08)								
TMTEA × SalInc					0.058 ***	00.079 ***	00.078 ***	0.039				
					(0.007)	(0.012)	(0.013)	(0.024)				
TMTEA × EquInc									0.005 ***	0.003 **	0.015 ***	0.006
									(0.001)	(0.002)	(0.002)	(0.004)
Control var	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log likelihood	−29,690.424	−11,635.481	−8027.754	−2216.2229	−29,751.38	−11,687.332	−8006.591	−2266.0261	−29,761.65	−11,704.809	−7985.4583	−2261.1302
Wald Chi2	8560.65	2612.35	4162.73	585.68	8468.52	2529.11	4217.75	541.91	8427.30	2488.88	4239.65	543.64
Observations	14,921	6115	3775	1215	14,921	6115	3775	1215	12,264	6115	3775	1215
Number of ID	1722	1185	824	361	1722	1185	824	361	1519	1185	824	361

Note: Standard errors in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Columns (5) and (9) in Table 11 concern the tests of H4a and H4b. The interaction coefficients of compensation and equity incentives with TMTEA are positive and significant at the 1% level. Therefore, H4a and H4b are both supported. Further, the sample companies are divided according to their development stage to verify the moderating effect of compensation and equity incentives in different enterprise lifecycles. Columns (6), (7), and (8) report on the interactions between compensation incentives and TMTEA in the growth stage, maturity stage, and recession stage of the enterprise, while Columns (10), (11), and (12) in Table 11 report on the interactions between equity incentives and TMTEA in these three development stages. In the stages of growth and maturity, the interaction coefficients of compensation and equity incentives with TMTEA are positive at the level of 1% or 5%, indicating that in this period, both positively regulate the relationship between TMTEA and GI. That is, the compensation and equity incentives allow the TMT to maintain environmental attention, which guarantees the TMT and encourages it to allocate environmental attention toward GI. However, in the recession periods, the interaction coefficients of the two incentive factors with TMTEA are not significant.

Considering the potential for government-led green revolution, the regulatory role of government environmental attention may be significant within state-owned enterprises. Therefore, we further scrutinize state-owned enterprises to provide a more comprehensive analysis. Table 12 reports the moderating effect of government environmental attention in state-owned enterprises. In column (1), it can be observed that within state-owned enterprises, the coefficient of the interaction term is −0. 024, but not significant, further validating that H3 is indeed not supported. Columns (2), (3), and (4) further report the detailed moderation effects of government environmental attention across the lifecycle. It can be seen that the coefficient of the interaction term is significantly negative in the growth and decline phases, but not significant in the maturity phase.

Table 12. State-owned enterprise test.

	GI			
Variable	**(1)**	**(2)**	**(3)**	**(4)**
TMTEA	0.148 ***	0.118 ***	0.114 ***	0.429 ***
	(0.014)	(0.026)	(0.023)	(0.04)
GEA	−0.039	0.063	0.084	0.119
	(0.036)	(0.066)	(0.055)	(0.152)
TMTEA × GEA	−0.024	−0.185 ***	0.066	−0.711 ***
	(0.027)	(0.054)	(0.045)	(0.104)
Control var	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes
Log likelihood	−12,263.038	−4477.1925	−4031.113	−823.7625
Wald Chi2	5119.11	1642.37	2045.17	462.18

Note: Standard errors in parentheses. *** indicate statistical significance at the 1% levels.

Table 13 reports an overview of the results of hypothesis testing in this study.

Table 13. Overview of hypothesis verification results.

Relevant Hypotheses	**Verification Results**
H1. TMTEA can significantly promote GI.	Support
H2a. In the growth period of an enterprise, TMTEA is positively related to GI.	Support
H2b. In the mature period of an enterprise, TMTEA is positively related to GI.	Not verified
H2c. In the recession period of an enterprise, TMTEA has no impact on enterprise GI.	Not verified
H3. The positive impact of TMTEA on corporate GI is more significant when government environmental attention is high.	Not verified
H4a. The positive impact of TMTEA on corporate GI is more significant for companies with high compensation incentives.	Support
H4b. The positive impact of TMTEA on corporate GI is more significant for companies with high equity incentives.	Support

6. Discussion and Conclusions

Based on the ABV and lifecycle theory, this study uses the data of 1722 listed companies in China from 2010 to 2021 to not only test the relationship between TMTEA and GI but also reveal the regulatory mechanism of the internal and external factors. Our research finds that TMTEA has a significant impact on GI. The higher the TMTEA is, the better the GI. Moreover, this positive correlation is significant only during the growth and recession periods. Further analysis shows that government environmental attention has a significant negative moderating effect on the relationship between TMTEA and GI, which is inconsistent with our hypothesis. Our survey also proves that compensation and equity incentives can positively regulate the relationship between TMTEA and GI.

6.1. Discussion

This paper studies the impact of TMTEA on GI and analyzes the mechanism of government environmental attention and executive incentives in the development of enterprise GI.

We can find the following: (1) TMTEA can significantly improve enterprise GI, and this positive relationship still exists in the growth and decline periods. When TMT focuses more on environmental issues, the company's strategic focus, resource allocation, and culture and values are tilted towards GI to achieve environmental goals. This study not only helps to complement the drivers of corporate GI but also provides a new perspective on the micro basis of corporate environmental behavior, adding to the literature on environmental management.

(2) The effect of TMTEA on GI at maturity was not significant, which was inconsistent with our expectations. This result may be due to several factors. First, mature enterprises tend to have established a stable business model and organizational structure. In such an environment, organizational inertia may be strong, and resistance to significant changes, such as GI, may be more pronounced. Even if TMTEA exists, it may be difficult to translate quickly into actual innovative action. Second, TMT will likely focus more on maintaining existing profit models and less on investing in GI, which could affect short-term financial performance. Finally, mature companies typically have a stable market position and customer base and may not feel strongly motivated to seek market advantage or differentiate themselves through GI. It can also be seen that in mature enterprises, even with TMTEA, there are many challenges in translating this attention into concrete GI actions.

(3) Government environmental attention negatively regulates the relationship between TMTEA and GI, consistent with the research results that hold negative views on government factors. A study by Catozzella and Vivarelli (2016) [49] found that subsidies negatively correlate with innovation productivity. At the same time, Wu and Hu (2020) [50] also found that the synergistic effect between government subsidies and idle absorption hurts green technology innovation. In addition, a study pointed out that the government's increased attention to environmental issues led to a significant increase in the environmental costs of heavily polluting enterprises, which further reduced their investment in innovation, thus inhibiting the development of GI (Chen et al., 2022) [30]. The negative moderating effect of government attention contradicts our hypothesis, and we attempt to conduct an in-depth analysis of the reasons and implications behind this result. First, when the government pays more attention to environmental protection, it may be accompanied by more stringent environmental regulations and standards. In such cases, companies may need to focus more on complying with existing regulations rather than undertaking additional GI. Second, enterprises may rely on government guidance and incentives, reducing independent GI efforts in the case of high government environmental attention. This can lead to a substitution effect, in which external incentives replace internal incentives for innovation. Third, frequent changes or uncertainty in government environmental policies may cause companies to hesitate in making long-term GI decisions. This uncertainty can curb firms' incentive to innovate because they are unsure which innovations will fit with future policy directions. Fourth, our sample is limited to Chinese-listed companies. Whether the negative adjustment results of government environmental attention apply to unlisted companies,

small enterprises, or companies in different cultural or regulatory contexts needs further consideration in the future. In conclusion, while government environmental attention can help improve corporate environmental standards and environmental awareness, excessive regulation or an uncertain policy environment may inhibit independent GI. This suggests that governments, when formulating environmental policies, need to consider balancing regulation and incentives to promote, rather than inhibit, companies' ability to innovate in a green way. At the same time, it also highlights the need for companies to find a balance between compliance and independent innovation in the face of government environmental policies.

(4) Both compensation incentives and equity incentives positively regulate the relationship between TMTEA and GI, which is consistent with the research results of Jiang et al. (2023) and Jiang et al. (2023) [41,45], indicating that executive incentives can positively regulate the relationship between internal factors and GI. Compensation and equity incentives can align the personal interests of the senior management team with the business's long-term goals, including GI. When managers' income is partly tied directly to their firm's GI performance, they are more motivated to drive those innovations. In addition, the design of incentives can promote the emphasis on GI within the company, thus forming a corporate culture that supports innovation and sustainable development.

6.2. Theoretical Significance

The theoretical significance of this study is manifested in several aspects:

Firstly, it expands the theoretical perspective. This study integrates the enterprise lifecycle theory with environmental management and innovation theories, delving into the impact of TMTEA on corporate GI and distinguishing and analyzing it across different lifecycle stages. This expanded research perspective enriches the existing theoretical frameworks, providing new insights and perspectives for understanding corporate environmental behavior and innovation.

Secondly, it deepens the understanding of the relationship between environmental management and innovation. The study finds that TMTEA has a significant positive impact on corporate GI, highlighting the importance of environmental management for innovation activities. Through in-depth analysis of the mechanisms at different lifecycle stages, it further reveals the inherent connection between environmental management and innovation, which is crucial for promoting sustainable development.

Thirdly, it enhances understanding of the regulatory role of government policies. The study discovers that government environmental attention moderates the relationship between TMTEA and GI differently in various contexts, contributing to a deeper understanding of the mechanisms by which government policies promote environmental management and innovation. This has implications for guiding the effective formulation of environmental and innovation policies by government agencies.

Fourthly, it emphasizes the importance of executive incentive mechanisms. The research demonstrates that executive incentives can actively promote the impact of TMTEA on corporate GI, underscoring the crucial role of executives in environmental management and innovation. This finding provides guidance for enterprises to prioritize the design and implementation of executive incentive mechanisms to sustain their focus and investment in environmental management and innovation.

Lastly, it offers guidance for enterprise management practices. The study provides specific recommendations on how enterprises can conduct environmental management and innovation across different lifecycle stages, aiding them in better understanding and adapting to external environmental changes, thereby enhancing their competitiveness and sustainable development capabilities.

6.3. Management Enlightenment

Enlightenment at the enterprise level: First, strengthen TMTEA. Companies should enhance TMT's awareness and focus on environmental issues through training and internal

communication. At the same time, companies should encourage TMT to integrate environmental attention into daily decision-making and long-term strategic planning. Second, innovation strategies should be adapted to different stages of the enterprise life cycle. During periods of growth and recession, businesses should take full advantage of TMTEA to drive GI. In the mature stage, enterprises should strive to overcome organizational inertia and find new GI opportunities to maintain competitiveness and market position. Third, design an effective incentive mechanism. Companies should design compensation and equity incentive plans linked to GI performance to stimulate the innovation drive of TMT and employees. These incentives should focus on long-term performance to promote sustained GI. Fourth, enterprises should establish and strengthen the internal innovation motivation mechanism to ensure the continuity and effectiveness of GI. This includes fostering innovation in the corporate culture, encouraging employees to develop innovative environmental solutions, and providing the necessary resources and support. Fifth, companies should develop and execute a GI strategy independent of government incentives or regulations. This means that companies are not just responding to government policies but also taking the initiative towards GI based on their own sustainable development goals and competitive advantages in the market. Due to the possibility of frequent changes or uncertainty in government environmental policies, businesses need to maintain a high degree of flexibility and adaptability. This involves staying sensitive to policy changes, adjusting strategies promptly, and preparing to address the potential impacts of policy changes.

Policy-level recommendations: First, there should be a balance between regulation and incentives. Governments should seek a balance between regulation and incentives when formulating environmental policies. On the one hand, there is the need to ensure that companies comply with environmental regulations. On the other hand, incentives (e.g., tax incentives, subsidies) should be provided to encourage companies to engage in GI. Second, policy uncertainty should be reduced. The government should aim to provide a clear and stable environmental policy framework to reduce the uncertainty businesses face. A stable policy environment helps companies make long-term GI investment decisions. Thirdly, environmental awareness and education should be promoted. The government should raise social awareness of environmental issues through public information and education activities. At the same time, the government can support enterprises in upgrading their TMTEA through training and development programs.

6.4. Limitations and Future Research Directions

We consider the study's limitations and the direction of future research from several aspects. First, the study is mainly based on data from Chinese-listed companies, which may limit the generality of its conclusions. Future studies could be expanded to more countries and regions and private companies to test whether these findings are universal across cultures and economies. Second, quantitative research provides strong evidence for understanding the relationship between TMTEA and GI. However, qualitative research (e.g., case studies, interviews) can provide deeper insights, especially into management decision-making processes and internal governance mechanisms. Finally, verifying mediation effects is an important aspect of future research that can be further refined. The mediation effect analysis helps reveal the internal mechanism and action path between TMTEA and GI. Future research could explore the mediating role of organizational culture, employee engagement, and internal resource allocation between TMTEA and GI. For example, TMTEA may affect a company's GI by shaping an organizational culture that is more supportive of innovation and sustainability, influencing employee engagement and motivation, or changing the allocation of resources (e.g., financial resources, human resources) within the company.

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