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RESEARCH ARTICLE

How Environmental Leadership Promote Technological Innovation in Resource-Based Enterprises: The Role of Green Investment and Government Subsidy

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ABSTRACT Technological innovation represents the core driving force for the green development of resource-based enterprises. How to effectively promote enterprises' technological innovation has received considerable attention in academia and practice. However, most of existing studies have been focused on the influence of industrial level or organizational level, the impact of leadership has received little attention. Therefore, this study explores the impact of environmental leadership, which focuses on environmental protection and sustainable development, on technological innovation. Using Stata 18 software, this study analyzes 170 resource-based enterprises listed on the Shenzhen and Shanghai A-share stock markets, for the time periods spanning from 2013 to 2022. The results indicate a positive impact of environmental leadership on technological innovation, with green investment mediating the relationship between environmental leadership and technological innovation. However, the moderating effect of government subsidies between environmental leadership and green investment is not significant. Our findings offer a better understanding of technological innovation in resource-based enterprises by considering the influence factors from both internal and external pespectives, especially the critical role of leader. Therefore, this study contributes to the literature on leadership theory and technological innovation theory.

INDEX TERMS Green investment, technological innovation, environmental leadership, government subsidy, resource-based enterprises.

I. INTRODUCTION

Resource-based enterprises, as an integral part of China's real economy, are playing an imperative and strategic role in the national economic system [1]. In nature, these enterprises rely on the exploitation of natural resources as the mainstay, with subsequent processing as a secondary function, while primarily relying on resource consumption for growth and development [2]. Owing to their excessive dependence on resources, resource-based enterprises pose great challenges to green development in China such as a single style of industrial structure, excessive resource extraction, and severe ecological damage [3]. Consistent with China's commitment to the green development strategy, a large number of resource-based enterprises have established strategic development goals centered on technological support, green orientation, and innovation-driven approaches [4]. Meanwhile, technological innovation with prominent characteristics including high efficiency, circularity, and low carbon emissions serves as the key force for breaking the bottleneck of green development in resource-based enterprises and realizing sustainable development [5], [6], [7]. As a result, both academia and industry are involved in extensive research on how to support technological innovation in resource-based enterprises while

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facilitating their green development and identifying the influencing factors and mechanisms of technological innovation in resource-based enterprises [8], [9].

Noticeably, technological innovation represents a complex system that depends on both the internal management and external environment [10]. Previous research has found that various factors, including market structure, environmental regulations, regional digitalization level, and business environment effectively impact technological innovation [11], [12], [13], [14]. From an internal perspective, although present research studies have pointed out a significant effect of green awareness and incentive mechanisms of top management teams on technological innovation in resource-based enterprises [15], [16], there is a limited investigation of leaders' influence on technological innovation in proposed enterprises from the leadership perspective. Leadership theories indicate that leadership is a major antecedent of technological innovation [17], such as digital leadership, strategic leadership, transformational leadership, and ethical leadership [18], [19], [20], [21]. Therefore, leadership is the vital driving force for technological innovation. As compared to other industries, resource-based enterprises are characterized by more significant ecological pollution and environmental damage. Particularly, the leadership capabilities in ecological civilization construction are crucial in the current context of green development strategy in China. Accordingly, CEOs, as vital decision-makers in enterprises, not only exert a substantial impact on strategic choices but also respond to internal and external environments due to their personal traits. With the development of leadership theory, extant literature has concluded that environmental leadership demonstrates a significant effect on innovation performance [22]. Besides, technology theories emphasize that innovation depends on the combined effect of internal (i.e. human resource, corporate governance, innovation input) and external factors (i.e. market environment, government policies) [23]. Consequently, this study aims to integrate both external and internal factors that affect technological innovation while exploring the influential mechanisms of environmental leadership on technological innovation in resource-based enterprises.

Specifically, environmental leadership originates from research on sustainable development and emphasizes the direct responsibility of leaders in making organizations adapt to ecological expectations and social values [24]. Furthermore, environmental leader not only provide specialized environmental services, but also orient all practices within the organization towards green development; thereby, actively mobilizing employees to participate in such initiatives [25]. At the same time, the values of ecological protection and sustainable development constitute the core driving force behind the green behavior of environmental leadership. Further, these values exert a substantial influence on the operational and investment decisions of a company. Thus, environmental leadership shows more willingness to supplement green investments, in order to attain ecological management and conservation goals. Besides this, present research on green investment illuminates two major types of behaviors, namely: active behavior in terms of corporate sustainable development and passive behavior based on the government ecological regulations [26]. Explicitly, environmental leadership is beneficial for promoting proactive green investment behavior in business firms.

The essence of green investment requires making investments based on the principles of sustainable development. The notion of green investment encompasses improved production techniques, employment of clean production technologies and new production processes, procurement of eco-friendly equipment, and investment in green technological R&D [27]. In comparison to traditional investment, green investment presents a process of integrating production investment with ecological governance, in order to develop green productivity. Additionally, green investment facilitates new combinations of production elements; consequently, creating novel production functions and promoting technological innovation [28], [29]. Therefore, this study will examine the mediating role of green investment in the relationship between environmental leadership and technological innovation in resource-based enterprises. Though green investment is advantageous for improving the ecological environment, the investment behavior may include diverting different resources from normal production materials; hence, resulting in social welfare outweighing economic benefits [30]. Since resource-based enterprises have a high dependence on resources, such enterprises need to incur higher costs to reduce pollution and improve ecological governance. Hence, resource-based enterprises may lack the motivation for green investment due to associated cost considerations. As a consequence, the government authorities play a critical role in boosting green investment among resource-based enterprises [31]. For instance, government subsidy, as a conventional means of incentivizing innovation and investment, can assist in eradicating the financial constraints of resource-based firms; thereby, stimulating their green investment [32]. Based on this, this paper also explores the moderating role of government subsidies.

II. THEORETICAL BASIS AND HYPOTHESES DEVELOPMENT

A. ENVIRONMENTAL LEADERSHIP AND TECHNOLOGICAL INNOVATION

With the rise of the ecological movement in Western economies, researchers have been analyzing the challenges experienced by organizational leaders in corporate sustainable development while endeavoring to discover the differences between leadership styles in the age of green development and traditional leadership style [33], [34]. In this context, the concept of environmental leadership has emerged over time. On the one hand, the increasingly severe global ecological concerns compel organizations, as foremost contributors to environmental pollution, to take responsibility for resolving environmental matters. In addition, pressures from different stakeholders such as governments, communities,

consumers, and competitors also warrant organizational leaders to actively protect the environment. On the other hand, from the viewpoint of natural resources, ecological factors are integrated into the framework of evaluating an enterprise's competitive [35]. Certainly, the realization of competitive advantage in organizations essentially depends on their management competencies to encourage ecologically sustainable economic practices [36].

Against this backdrop, Brown et al. [37] primarily defined environmental leadership as the ability of organizational leaders to guide proactive changes in organizations. Later, Egri and Frost [38] further pointed out that environmental leadership represents the leaders' aptitude to both influence people and mobilize organizations to attain long-term ecological sustainability visions. Contrary to traditional leadership styles, environmental leadership exhibits three typical characteristics: firstly, environmental leaders highly value and identify with nature. As a consequence, this belief system becomes leaders' behavioral orientation and criteria. Secondly, environmental leaders integrate environmental approaches into business decisions, stakeholder relations, and organizational practices. Finally, these leaders proactively trigger changes in response to existing or potential environmental threats [37].

Technological innovation serves as a key pathway for companies to gain core competitive advantages in the market. In particular, technological innovation involves adopting innovative production methods or business models to improve product quality and develop new products [10]. Owing to the continued deepening of the contradiction between business development and environmental protection, technological innovation plays a critical role in lowering pollution emissions and reducing production costs. Additionally, technological innovation improves the corporate image and develops new markets; thereby, alleviating the conflict between business development and ecological protection [39]. Prominently, resource-based industries such as coal, petrochemicals, and non-ferrous metals depend on natural resources as raw materials in their production processes. Nevertheless, these industries encounter various challenges in terms of high energy consumption and heavy pollution. Meanwhile, the level of process technology, material technology, and processing equipment becomes a significant factor limiting their green development. Simultaneously, technological innovation is the key to minimizing solid waste, reducing exhaust emissions, and mitigating ecological pollution [13].

According to leadership theory, leaders stand as the major driving force for technological innovation in organizations [17]. Consistently, environmental leaders are the creators and disseminators of technological innovation [40]. Accordingly, environmental leadership adheres to the principles of ecological protection and sustainable development; thereby, attempting to neutralize the potential threats and damage to the environment inflicted by business operations. Therefore, technological innovation is regarded as the primary driving force for the green development of resource-based companies. At the same time, environmental leadership supports cooperation related to both internal and external technological innovation in resource-based companies; thus, optimizing production processes, improving production techniques, and eventually accelerating the level of technological innovation in the corporation [41]. In addition to this, leaders with environmental values and skills excel in developing cooperative relationships with different stakeholders to address environmental issues. This contributes to supplementing innovation collaboration among resource-based enterprises and strengthening innovation cooperation between the industrial sector and academic institutions; thereby, establishing a favorable innovation ecosystem. Existing studies reflect that environmental leadership exhibits a positive effect on both green technological innovation and proactive ecological innovation in companies [42], [43]. Based on this, Hypothesis 1 is postulated in this study as follows:

H1: Environmental leadership has a significant positive impact on technological innovation in resource-based enterprises.

B. ENVIRONMENTAL LEADERSHIP AND GREEN INVESTMENT

Emerging from the environmental protection movement in the last century, green investment presents a new investment model that ensures sustainable development by focusing on ecological protection, resource conservation, and the development of a circular economy [27]. Generally, green investment refers to investments made by companies to reduce pollution and eventually protect the environment. This involves expenses related to environmental pollution control, procurement of environmental equipment, and R&D of green technologies [30]. Past research studies report that government environmental regulations, corporate competitive strategies, and corporate social responsibility are the vital factors that drive organizations to engage in green investment activities [44], [45], [46]. Nonetheless, the aforementioned studies have primarily focused on the organizational level while ignoring the significant influence of the leaders' role. In business practices, CEOs or chairpersons play imperative roles in investment decision-making; consequently, the leaders' values inevitably reflect in their decision-making processes [47], [48].

Green investment places environmental protection as its top priority whereas such investment is aligned with the value system advocated by environmental leaders. Noticeably, developing green investment is a necessary approach for resource-based companies not only to transform their economic growth patterns but also to realize sustainable development. The environmental leaders are more focused on investments associated with resource efficiency, environmental conservation, and the environmental industry when making investment decisions; thus, attempting to stimulate the strategic goal of sustainable development for resource-based

companies [40]. Meanwhile, leaders with environmental skills excel in effectively transmitting their environmental management ideologies to subordinates during decision-making, which is conducive to lowering potential obstacles in green investment, bolstering an organizational culture of green development, and facilitating the attainment of consensus for green investment [43]. Based on this, Hypothesis 2 is postulated in this study as follows:

H2: Environmental leadership has a significant positive impact on green investment in resource-based enterprises.

C. GREEN INVESTMENT AND TECHNOLOGICAL INNOVATION

Investment is a central driver of innovation in companies, while green investment as a new investment approach, requires higher technological standards, as compared to the traditional investment models [27]. On the one hand, unlike traditional investment models, green investment in resource-based companies emphasizes the integration of production investment with environmental governance and resource conservation. Furthermore, the focus of investments shifts towards green technologies such as new materials, renewable energy, low-carbon environmental technologies, and clean production [8]. Resultantly, innovation is facilitated in terms of novel product design, service offerings, and new production processes for resource-based enterprises. On the other hand, green investment ensures a reduction in ecologically detrimental inputs for resource-based companies within the constraints of limited resources; hence, accelerating the shift from conventional production technologies to eco-friendly alternatives [45].

In addition to this, resource-based theory suggests that a corporate competitive advantage originates from its unique resources [49], whereas technological innovation is also affected by the abundance of company resources. Moreover, corporations can execute green acquisition to trigger the synergistic influences of technological innovation, which enable them to obtain green resources from the acquired enterprises. Evidently, green merger and acquisition as a special investment mode within green investment, can assist resource-based enterprises in overcoming the bottleneck of independent innovation and obtaining a technological innovation advantage through resource integration and arrangement [50]. Therefore, this study proposes H3 as follows:

H3: Green investment has a significant positive effect on technological innovation in resource-based enterprises.

D. THE MEDIATING ROLE OF GREEN INVESTMENT

Studies on leadership theory reveal that individual traits of leaders exert a significant influence on their management philosophies and decision-making, which eventually impacts organizational performance [51]. Against the backdrop of China's green development strategy, resource-based companies are facing the arduous task of transformation and upgrading. How to reduce environmental pollution, improve resource utilization, and achieve sustainable development through technological innovation are strategic issues that every business leader must consider in their investment and management decisions. Parallel to this, environmental leadership entails integrating environmental protection and green development concepts into business decision-making [24]. At the same time, environmental leadership guides companies to allocate more resources to investments that favor environmental protection and resource conservation, thus, optimizing the green investment behavior of resource-based enterprises [40]. Reportedly, existing innovation theories suggest that investment is a strategic factor in promoting innovation [52]. Through green investment, resource-based enterprises can achieve process optimization, attain technological upgrading, and gain more opportunities and resources for technological innovation, thus enhancing their technological innovation. Based on this, hypothesis H4 is proposed as follows:

H4: Green investment mediates the relationship between environmental leadership and technological innovation.

E. THE MODERATING ROLE OF GOVERNMENT SUBSIDY

Although environmental leadership demonstrates a positive influence on green investment, green investment still entails a high level of risks and potential uncertainties. Besides, the government plays a decisive role in extending avenues for green investment and mitigating financial pressures on the corporate sector [31]. Extant literature concludes that negative incentives such as environmental protection taxes, government environmental regulations, and environmental consultations have a positive or ''U-shaped'' impact on green investment, and positive incentives such as government subsidies and tax benefits have a positive impact on green investment [26], [31], [32]. Evidently, government policy direction demonstrates a significant impact on companies' decisions related to green investment.

Government subsidy, commonly utilized as positive incentives, consists of tax exemptions, government procurement, fiscal subsidies, and government investments. Principally, government subsidies intervene or guide corporate business investment by providing appropriate financial support [32]. When a company receives a government subsidy, it demonstrates the government's emphasis on green development, and the company receives financial support from the state; thereby, aligning business investment direction with the strategic plans for national industrial development. Besides this, state subsidy also resolves the possible concern of information asymmetry between enterprises, investors, and financial institutions; resultantly, expanding the companies' financing channels and alleviating the pressure of green investment [53].

However, green investment is influenced by multiple internal and external factors such as policies, markets, and the company itself [27]. Present studies have mostly assumed the impact of a certain external or internal factor on green

investment while neglecting the combined effects of internal and external factors. In specific, environmental leadership, as a significant internal factor affecting green investment, is inevitably influenced by external policy factors. Meanwhile, green investment in resource-based enterprises, such as coal, petroleum, and non-ferrous metals, is characterized by high costs and long cycles [54]. Further, financial pressure serves as a barrier to environmental leaders making green investment decisions. When the government provides certain financial subsidy, it can reduce the decision-making pressure on environmental leaders for green investment and increase the likelihood of engaging in green investment under external support conditions. Based on this, this study proposes H5 as below:

H5: Government subsidy positively moderates the relationship between environmental leadership and green investment, that is, environmental leadership is more effective in promoting green investment when resource-based enterprises obtain government subsidy.

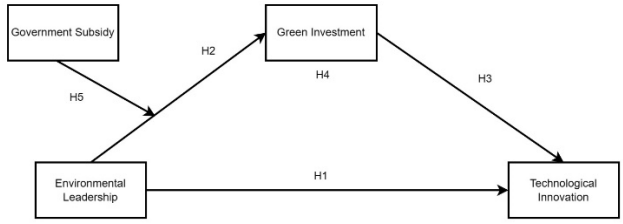

FIGURE 1. Conceptual model.

III. RESEARCH DESIGN

A. RESEARCH SAMPLE AND DATA COLLECTION

Referring to Ruan et al. [55], this study defines resource-based enterprises as corporations and business firms that primarily engage in the development and processing of energy and mineral resources. Such corporations rely on exclusive access to resources, in order to attain a competitive advantage; thereby, optimizing their operational performance. Aligned with the proposed definition, the resource-based enterprises identified in this study primarily include industries involved in coal mining and washing, crude petroleum and natural gas extraction, ferrous metal ore mining and dressing, non-ferrous metal ore mining and dressing, non-metallic mineral ore mining and dressing, petroleum, coal, and other fuel processing, chemical raw materials and chemical product manufacturing, as well as the manufacturing of chemical raw materials and chemical products. Additionally, given that the electricity, heat production, and supply industry also rely on energy and mineral resources, therefore these sectors are included in the study sample. Accordingly, the names and codes of specific industries are illustrated in Table 1.

To ensure data quality and the validity of conclusions, companies with ST* status, abnormal business operations, and severe data missing samples were excluded. Ultimately, a sample of 170 resource-based listed enterprises, represented by Hengbang Co., Taigang Stainless Steel Co., and Shandong Iron & Steel Co., was adopted as the research subjects. Moreover, the observation period ranges from 2013 to 2022. The data structure of this study is a balanced panel.

TABLE 1. Industry codes and names for resource-based enterprises.

Industry of Enterprise	Code	Industry
Mining and Washing Industry	B06	Coal Mining and Washing
	B07	Crude Petroleum and Natural Gas Extraction
	B08	Ferrous Metal Ore Mining and Dressing
	B09	Non-Ferrous Metal Ore Mining and Dressing
	B10	Non-Metallic Mineral Ore Mining and Dressing
Primary Processing Industry	C25	Petroleum, Coal, and Other Fuel Processing
	C26	Chemical Raw Materials and Chemical Product Manufacturing
	C30	Non-Metallic Mineral Product Manufacturing
	C31	Ferrous Metal Smelting and Rolling Processing
	C32	Non-Ferrous Metal Smelting and Rolling Processing
	C33	Metal Product Manufacturing
	D44	Electricity, Heat Production, and Supply

Notably, the research data on environmental leadership was extracted from the annual reports, ESG reports, and environmental responsibility reports of the selected sample of listed companies. While the government subsidy data was derived from the CSMAR (Guotai An) database. Similarly, green investment data was gathered from the annual reports of listed companies, whereas the data on technological innovation was obtained from the CNRDS (China Research Data Services Platform) database. Finally, statistical analysis and processing were conducted using Stata18 software after completing the data collection process.

B. MEASUREMENT

(1) Explanatory Variable: Environmental Leadership (EL). Past studies have most often measured environmental leadership using research questionnaire assessments, which involve self-report by leaders or evaluations from subordinates regarding their supervisors' environmental leadership. However, in terms of publicly listed enterprises, regular reports such as annual reports, ESG reports, and environmental responsibility reports offer a more specific and extensive presentation of the corporation's business philosophy, organizational structure, and financial performance. Particularly, the proposed reports provide an objective and comprehensive understanding of how leaders in the company execute and implement the approaches of green development in investment, strategic management, production management, and employee management practices. Therefore, it is both feasible and rational to measure the environmental leadership of

TABLE 2. The keyword dictionary for environmental leadership.

Items	Keyword Dictionary
The leaders within the company inspire a shared vision of the organization as environmentally sustainable, creating or maintaining green values throughout the company.	Sustainable Development, Green Development, Environmental Health and Safety, Green and Low-Carbon, Green Business, Environmental Protection Philosophy
The leaders within the company utilize well-developed approaches to environmental management which generally center around a program customized to the company's specific business and market.	Establishment of an Energy Management Team, Clean Production, Environmental Management System, Environmental Management Policies, Environmental Management Framework, Environmental Technology, Transformation, Green Transformation, Environmental Management Department
The leaders within the company create partnerships with the company's stakeholders to solve environmental problems and to accomplish environmental goals.	Engaging in Environmental Communication with Stakeholders, Local Ecological and Environmental Authorities, Suppliers, Customers, Higher-Level Units, Neighboring Companies, Surrounding Residents, Employees, Government Agencies, Regulatory Bodies, Investment Institutions, and Shareholders
The leaders within the company can take on the responsibility of environmental education with the intent of engaging employees in environmental management initiatives.	Promotional Training, Environmental Emergency Drills, Environmental Education, Environmental Training, Environmental Awareness Campaigns

the company by extracting information on leaders' environmental philosophies, green management, and green behaviors from the regularly published reports of listed enterprises.

Firstly, this study referred to the definition of Dechant and Altman [24] and the questionnaire items in Xu et al. [51] to perform translations between Chinese and English, in order to determine the final measurement items in Chinese. Thereafter, the research team reviewed the annual reports, ESG reports, and environmental responsibility reports of various listed enterprises, in order to recognize keywords that aligned with the meaning of the measurement items. Meanwhile, the below keywords were modified accordingly, after being reviewed by two experts; thus, resulting in the final keyword dictionary for scaling environmental leadership. Lastly, ATLAS.ti text analysis software was employed to analyze 2258 reports from 170 enterprises, where the frequency of occurrence of keywords associated with environmental leadership was quantified by the authors. Categorically, a higher frequency of occurrence of keywords related to environmental leadership connotes a higher level of environmental leadership among the company leaders. Correspondingly, Table 2 populates the detailed keyword dictionary for environmental leadership.

(2) Dependent Variable: Technological Innovation (TI). Existing research primarily uses measures of innovation inputs or outputs to evaluate technological innovation in companies. The former most often utilizes R&D investments, while the latter generally adopts indicators such as the number of patent applications and granted patents. Nevertheless, certain literature argues that R&D activities are characterized by uncertainty and high failure rates; thus, making innovation output measures more intuitive for measuring the level of technological innovation in companies [56]. Therefore, referring to the methodology of Hu et al. [9], this study adopts the number of patent applications as a measure of technological innovation, with the specific data extracted from the CNRDS (China Research Data Services Platform) database.

(3) Mediating variable: Green investment (GI). In order to measure the green investment, the annual reports of listed companies were manually collected and examined by the researchers. Furthermore, investment expenditure items related to environmental governance, green production, and other relevant aspects were aggregated from the annex notes of ongoing projects. This included expenses on desulfurization, denitrification, wastewater treatment, waste gas and residue treatment, and clean production, among others. Afterward, the sum of these items offered the data on green investment for each company in a given year.

(4) Moderating variable: Government subsidy (GS). In this study, we adopted the approach of Liu et al. [57], where a value of 1 is assigned when an enterprise receives government subsidies, and 0 otherwise.

Three control variables were included in this study, namely: asset-liability ratio, return on net assets, and cash flow ratio. Correspondingly, the symbols and measurement methods for each variable are depicted in Table 3.

C. MODELING

This study involves the testing of direct effects, mediating effects, and moderating effects. Therefore, following the testing methods of Hayes and Preacher [58], the following models are constructed, as shown in equations (1) - (5).

Equation (1) tests the impact of environmental leadership on technological innovation; equation (2) tests the impact of environmental leadership on green investment; equation (3) tests the impact of green investment on technological innovation; equation (4) tests the mediating role of green invest-ment between environmental leadership and technological innovation; equation (5) tests the moderating effect of gov-ernment subsidies on the relationship between environmental leadership and green investment.

$$\mathrm{TI}_{i,t} = \alpha_0 + \beta_0 \mathrm{EL}_{i,t} + \gamma \sum \mathrm{controls}_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$\mathrm{GI}_{i,t} = \alpha_1 + \beta_1 \mathrm{EL}_{i,t} + \gamma \sum \mathrm{controls}_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$\mathrm{TI}_{i,t} = \alpha_2 + \delta_1 \mathrm{GI}_{i,t} + \gamma \sum \mathrm{controls}_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$\mathrm{TI}_{i,t} = \alpha_3 + \beta_2 \mathrm{EL}_{i,t} + \delta_2 \mathrm{GI}_{i,t} + \gamma \sum \mathrm{controls}_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$\mathbf{GI_{i,t}} = \boldsymbol{\alpha_4} + \boldsymbol{\beta_3 \mathrm{EL}_{i,t}} + \boldsymbol{\theta \mathrm{GS}_{i,t}} + \boldsymbol{\varphi \mathrm{EL}_{i,t} \times \mathrm{GS}_{i,t}} + \boldsymbol{\gamma} \sum \mathbf{controls_{i,t}} + \boldsymbol{\varepsilon_{i,t}} \quad (5)$$

TABLE 3. Definition table of each variable.

	Variables	Symbols	Variable Interpretation
Dependent variable	Technological innovation	TI	Log (Patent application count plus 1)
Independent variable	Environmental leadership	EL	Log (Frequency of environmental leadership dimension keywords appearing in annual reports and other reports plus 1)
Mediating variable	Green investment	GI	log (Summation of relevant investment expenditure items in the ongoing projects' annex notes plus 1)
Moderating variable	Government subsidy	GS	Value of 1 if the company receives government subsidies, and 0 otherwise
Control variable	Asset-liability ratio	Lev	The total debt at the end of the year divided by the total assets at the end of the year
	Return on equity	ROE	Net profit divided by the average shareholder's equity
	Cash flow ratio	Cashflow	Net cash flow from operating activities divided by total assets

TABLE 4. The descriptive statistics.

Variable	N	Mean	p50	SD	Min	Max
TI	1700	3.193	3.296	1.568	0	8.737
EL	1700	1.340	1.386	1.014	0	4.419
GI	1700	16.99	16.96	2.447	7.139	27.06
GS	1700	0.810	1	0.392	0	1
Lev	1700	0.492	0.503	0.204	0.0150	1.111
ROE	1700	0.0490	0.0580	0.205	-4.320	1.536
Cashflow	1700	0.0640	0.0610	0.0660	-0.248	0.406

IV. DATA ANALYSIS AND RESULTS

A. DESCRIPTIVE STATISTICS AND CORRELATION ANALYSIS

The mean, medians, standard deviations, minimum values, and maximum values of each variable are presented in Table 4. Further, the results of correlation analysis and multicollinearity test are shown in Table 5. From Tables 4 and 5, it is evident that there exists a positive correlation between environmental leadership and technological innovation. In addition, a positive correlation is documented between environmental leadership and green investment, as well as between green investment and technological innovation. Moreover, government subsidy is positively correlated with environmental leadership. Prominently, the descriptive statistics and correlation analysis provide preliminary evidence to support the postulated hypotheses whereas the multicollinearity test reveals that the variance inflation factors (VIF) are all below 10. This indicates the absence of multicollinearity issues among the variables; thus, validating the suitability of regression analysis for the study model.

B. DIRECT EFFECTS ANALYSIS

Column (1) of Table 6 shows regression results for the linear relationship between environmental leadership and technological innovation. Accordingly, the regression coefficient for environmental leadership stands at 0.062, which is statistically significant at the 5% level of statistical significance. This implies a positive and significant correlation between environmental leadership and technological innovation, providing support for H1 that posits the role of environmental leadership in boosting technological innovation.

C. MEDIATION EFFECTS ANALYSIS

The regression results for the relationship between environmental leadership and green investment are exhibited in Column (2) of Table 6. Reportedly, the regression coefficient for environmental leadership is documented to be 0.107, which is significant at the 5% level of statistical significance. This confirms a positive correlation between environmental leadership and green investment; hence, offering support for H2 which holds that environmental leadership promotes green investment.

Afterward, Column (3) of Table 6 presents the regression outcomes for the relationship between green investment and technological innovation. The regression coefficient for green investment is reported to be 0.177, with a 1% level of statistical significance. This reveals a positive correlation between green investment and technological innovation; thereby, confirming that green investment plays a role in promoting technological advancement. As a result, Hypothesis 3 is also supported in this study.

Subsequently, Column (4) of Table 6 represents the regression results after including green investment as a mediating variable. Evidently, the derived results show that the coefficient for environmental leadership is recorded to be 0.056, at a 5% level of significance; consequently, reflecting a positive correlation. Further, the coefficient

TABLE 5. The results of the correlation analysis and multicollinearity test.

	TI	EL	GI	GS	Lev	ROE	Cashflow	VIF
TI	1							
EL	0.049**	1						1.01
GI	0.314***	0.076***	1					1.19
GS	-0.057**	0.060**	0.041*	1				1.01
Lev	0.168***	0.064***	0.328***	0.070***	1			1.21
ROE	0.087***	-0.0260	0.084***	-0.00700	-0.222***	1		1.18
Cashflow	0.147***	0.0140	0.177***	0.045*	-0.058**	0.314***	1	1.14

Notes: * Indicates significance at the 0.1 level, ** indicates significance at the 0.05 level, and *** indicates significance at the 0.01 level. Similarly, for the rest of the analysis.

TABLE 6. The regression result.

Variable	(1)	(2)	(3)	(4)	(5)
	TI	GI	TI	TI	GI
EL	0.062**	0.107**		0.056**	0.129**
	(0.026)	(0.043)		(0.026)	(0.054)
GI			0.177***	0.055***	
			(0.016)	(0.015)	
GS					0.034
					(0.110)
c_EL×c_GS					0.046
					(0.108)
Lev	-0.601**	1.358***	0.782***	-0.675***	4.310***
	(0.256)	(0.425)	(0.193)	(0.256)	(0.275)
ROE	-0.045	0.578***	0.424**	-0.077	1.375***
	(0.134)	(0.222)	(0.190)	(0.133)	(0.287)
Cashflow	2.077***	0.518	1.987***	2.049***	5.935***
	(0.438)	(0.728)	(0.578)	(0.436)	(0.868)
_cons	3.275***	16.118***	-0.349	2.395***	14.231***
	(0.140)	(0.233)	(0.252)	(0.284)	(0.175)
N	1700	1700	1700	1700	1700
r2_a	-0.085	-0.098	0.122	-0.077	0.157

TABLE 7. The regression results (a lagged one-period).

Variable	(1)	(2)	(3)	(4)	(5)
	TI	GI	TI	TI	GI
EL	0.061**	0.117***		0.054**	0.118***
	(0.027)	(0.045)		(0.027)	(0.045)
GI			0.033**	0.031*	
			(0.017)	(0.017)	
GS					0.007
					(0.100)
c_EL×c_GS					0.080
					(0.085)
Lev	-0.552**	1.128**	-0.616**	-0.611**	1.122**
	(0.272)	(0.459)	(0.271)	(0.271)	(0.460)
ROE	-0.014	0.516**	-0.036	-0.031	0.522**
	(0.132)	(0.224)	(0.132)	(0.132)	(0.224)
Cashflow	1.766***	0.716	1.729***	1.728***	0.704
	(0.461)	(0.780)	(0.460)	(0.460)	(0.781)
_cons	0.029	16.091***	2.225***	2.187***	16.086***
	(0.027)	(0.260)	(0.357)	(0.357)	(0.264)
N	1530	1530	1530	1530	1530
r2_a	-0.104	-0.110	-0.097	-0.095	-0.111

for green investment stands at 0.055, with a 1% level of statistical significance. Hence, green investment mediates the relationship between environmental leadership and technological innovation. Consequently, this implies that environmental leadership accelerates green investment in resource-based enterprises, which in turn enhances technological innovation. Based on this, H4 is validated in this study.

D. MODERATION EFFECTS ANALYSIS

Specifically, Column (5) of Table 6 introduces the interaction term between decentralized environmental leadership and

TABLE 8. The regression results (shortened time).

Variable	(1)	(2)	(3)	(4)	(5)
	TI	GI	TI	TI	GI
EL	0.058*	0.129**		0.056*	0.095
	(0.033)	(0.060)		(0.033)	(0.077)
GI			0.066***	0.064***	
			(0.021)	(0.021)	
GS					0.041
					(0.157)
c_EL×c_GS					0.045
					(0.155)
Lev	0.489	0.885	0.416	0.432	4.173***
	(0.403)	(0.738)	(0.401)	(0.401)	(0.399)
ROE	-0.002	0.105	-0.006	-0.008	1.099***
	(0.150)	(0.274)	(0.149)	(0.149)	(0.374)
Cashflow	2.175***	-1.032	2.255***	2.241***	4.150***
	(0.604)	(1.106)	(0.601)	(0.600)	(1.276)
_cons	0.489	16.581***	2.087***	2.057***	14.612***
	(0.403)	(0.386)	(0.405)	(0.405)	(0.255)
N	848	848	848	848	848
r2_a	-0.226	-0.244	-0.213	-0.211	0.124

government subsidy, in order to analyze the moderating influence of government subsidy. The relevant results highlight the regression coefficient for the interaction term; indicating that the moderation effect stands at 0.046. However, the proposed moderation effect is not statistically significant; thus, failing to support Hypothesis 5. The insignificant moderation effect of government subsidy may be attributed to the possibility that government subsidy crowds out a portion of the companies' internal green investments, as a result, the substitution phenomenon takes place where companies reduce their own green investments in response to receiving government subsidies.

V. ROBUSTNESS CHECK

A. ENDOGENEITY TEST

Owing to the possible lagged effects of environmental leadership and green investment on technological innovation, a lagged one-period treatment is implemented for the explanatory variable, mediating variable, moderating variable, and control variables. Specifically, regression of t-1 environmental leadership and green investment on t period technological innovation in order to mitigate possible reverse causality bias. Meanwhile, the regression results are presented in Table 7. Prominently, the findings are consistent with the hypotheses put forward in the previous sections; hence, further validating the reliability of proposed hypotheses in this study.

B. SHORTENED TIME WINDOW

In this study, a shortened time window of the most recent five years (2018-2022) is employed to re-examine the afore-mentioned relationships through regression analysis. The regression results are exhibited in Table 8. Consistently, the conclusions are aligned with the previous tests, therefore, this study once again validates all presented hypotheses.

VI. CONCLUSION AND IMPLICATIONS

A. CONCLUSION

(1) Environmental leadership promotes technological innovation in resource-based enterprises. Leadership with environmental orientation and capability, as a critical internal motivation, accelerates enterprises' technological innovation. Specifically, leaders driven by core values of environmental protection and green development, advocate changing production methods through technological innovation to reduce environmental pollution and ecological destruction. Moreover, the core value of environmental leaders is derived from a new ecological paradigm, which prompts leaders to pursuit economic growth from the viewpoint of technological progress [25]. Environmental leadership possesses a transformational mindset and drives organizational changes, creating an open and inclusive climate for technological innovation. In the same vein, environmental leadership not only stresses cooperation with stakeholders but also enhances technological collaboration among enterprises; consequently, offering a favorable atmosphere for technological innovation in resource-based enterprises.

(2) Environmental leadership has a significant positive influence on green investment in resource-based enterprises. Environmental leadership has different value criterion systems of decision making when facing environmental issues and social environmental pressure. Environmental leaders who believe and persist ecological sustainable economic development are inclined to practice more green activities by considering economic and ecological benefits. For resource-based enterprises, the annual reports, ESG reports, sustainability reports demonstrate that green investment has become an important part of business management. The amount of funds injected into green technology, green production, green merger and acquisition presents an increasing trend in the enterprise which the level of environmental leadership is high.

(3) Green investment positively and significantly impacts on technological innovation in resource-based enterprises. Nowadays, technological innovation is an essential path to deal with environmental issues for resource-based enterprises. Whatever green product innovation or green process innovation cannot achieve without enterprise investment. Through green investment, not only the funding for technological innovation is guaranteed, but also the pressure on talents for technological innovation can be alleviated. Meanwhile, green investment is a beneficial way to integrate resource among enterprises, the speed and efficiency of technological innovation can be improved.

(4) Green investment plays a positive mediating role in the relationship between environmental leadership and technological innovation. Certainly, environmental leadership values the unity of economic, social benefits, and ecological benefits in their investment decisions [25]. Similarly, these leaders are more capable of devising investment plans, consistent with the principles of green development, aligned with the business nature and market of a certain enterprise. Resultantly, such leaders possess higher motivation for green investment, as compared to leaders with lower environmental leadership. Owing to the high-tech attributes of low-carbon, energy efficiency, and environmental protection, green investments improve production processes, product transformation, and technological advancements through investments in eco-friendly, energy-efficient, and clean production projects.

(5) There is an inconclusive moderating impact of government subsidy on the relationship between environmental leadership and green investment in resource-based enterprises. There are five possible reasons: Firstly, environmental leadership, as an essential internal driver of green investment, places a greater emphasis on the CSR aspects of investments while attenuating the external influence of economic costs. This occurs under the premise that social and ethical factors act as significant driving forces. Secondly, resource-based enterprises play an imperative role as key implementers of national green development strategies; thus, benefiting from extensive policy support provided by government authorities. In this study, a majority of companies among the 170 samples have received government subsidy, thereby, diminishing the differentiating effect of such subsidies. Additionally, there is a threshold effect of government subsidies on the green investment and innovation output of resource-based enterprises, neither too high nor too low subsidy intensity is conducive to the incentive of enterprise investment behavior [59]. Thirdly, the policies formulated by the government usually have a certain delay effect, and it may take a long time for the government's financial assistance policy to be formulated and implemented, which leads to the stimulus utility for green investment cannot be emerged immediately. Fourthly, much of the information about green investment is confidential, not all the details about green investment are disclosed to the public, which may lead to some data of green investment cannot be available. Fifthly, based on the perspective of enterprise and industrial heterogeneity, different impact of government subsidy on green investment may occur. For instance, the government subsidy effect is more significant in promoting technology-intensive industries, while insignificant in promoting capital-intensive industries and labor-intensive industries [8]. Besides, non-state-owned enterprises is more sensitive to the incentive effect of government subsidy than state-owned enterprises [31].

B. IMPLICATIONS

(1) On the leader level, firstly, leaders in resource-based enterprises need to deepen their knowledge of green development and strengthen their environmental leadership. This can be realized through targeted learning initiatives and educational programs that aim to cultivate leaders' ecological and sustainable development perception and abilities. As a consequence, leaders shall develop a heightened sensitivity towards environmental protection. Secondly, leaders in resource-based enterprises should actively embrace and implement the national strategy for green development. Since a large number of resource-based companies are state-owned enterprises (SOEs), it is imperative to evaluate environmental leadership when selecting and appointing key leaders. Furthermore, the establishment of an evaluation system for environmental performance can serve as an institutional mechanism to stimulate resource-based company leaders to improve their environmental leadership. Thirdly, leaders in resource-based enterprises should enhance their green strategic leadership, such as the ability to form and implement the strategies of green investment and technology innovation.

(2) In the modern landscape of business, it is of vital significance to encourage resource-based companies to be involved in green investment and enhance the level of green investment decision-making. Companies, especially those in resource-based industries, need to prioritize environmental protection and fulfill their ecological responsibilities owing to the increasing stringency of environmental regulations and growing public awareness of environmental issues. Meanwhile, an uplift in the scale of green investment is critical in this regard. While green investment may require financial resources, it can yield substantial improvements in terms of environmental quality and enhance the company's reputation. It is a necessary measure for the sustainable development of resource-based companies. To alleviate financial pressures related to green investment, resource-based enterprises explore diversified channels for green financing, such as green credit, green bonds, green insurance funds, and green trusts. By strengthening their role as decision-makers in investment and technology choices, companies can actively promote the commercialization of green investment projects and establish a virtuous cycle between investment and innovation. In summary, resource-based companies should recognize the importance of environmental

sustainability, embrace green investment opportunities, and proactively undertake environ-mental governance responsibilities. By doing so, they can not only secure their long-term viability but also contribute to a more sustainable future.

(3) On the policymaker level, firstly, environmental incentive policies focused on resource-based industries should be established effectively, such as action plan for improving technological innovation capability of resource-based industries, evaluation of excellent environmental companies and excellent environmental leaders. Second, government subsidy policies should be scientifically established, in order to ensure the positive incentive impact on inspiration of green investment and technological innovation. By leveraging the internal motivation of resource-based companies to invest in green initiatives and technological innovation, governments can effectively guide their actions. This can be achieved through a combination of regional industrial development plans and comprehensive research, which shall help demonstrate the scientific and feasible nature of government incentives. Thirdly, diversifying policy tools play a critical role in improving support policies that promote the green transformation and upgrading of resource-based enterprises. There is a significant need to consider differences in ownership nature, size, and industry characteristics among these companies to enhance the alignment between policies and industrial chains. Additionally, establishing an evaluation system for scientific policy, monitoring the potential effects of policy implementation, and assessing the efficiency of government subsidies is compulsory to avoid the misallocation of different resources.

C. LIMITATIONS AND FUTURE DIRECTION

There are certain limitations associated with this study that warrant further exploration in future studies. Firstly, this study only focuses on resource-based enterprises within the scope of Chinese contest, while overlooking the influence of environmental leadership on technology innovation in other regions and other different industries. Future research could expand the research scope and include other industries such as manufacturing and construction, including the comparative studies between resource-based enterprises and the non-resource-based enterprises. A sequence comparative research among different countries or regions will be conducted, in order to enhance the results' generalizability. Secondly, in this paper, the measurement of variables such as environmental leadership, green investment, technological innovation, and government subsidies solely relied on secondary data. This may not fully reflect the cognitive and behavioral aspects of corporate leaders. Future research could incorporate methods such as questionnaires and interviews to complement secondary data, enabling triangulation of information and providing more reliable and comprehensive guidance for technological innovation among different enterprise.

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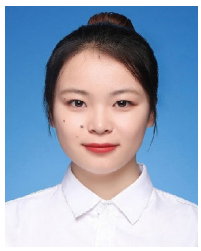

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