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Research on the Impact of Corporate ESG Performance on Sustained Innovation in the VUCA Context: Evidence from China

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Abstract: In recent years, corporate innovation has faced growing pressures from macroeconomic fluctuations and intensifying industry competition, making the maintenance of uninterrupted innovation increasingly crucial. This study selected Chinese listed firms from 2015 to 2022 as samples and adopted a panel fixed-effect model to examine the impact of corporate ESG performance on sustained innovation, with particular attention to external environmental pressures, including macroeconomic uncertainty, industry competition, and market attention. The results demonstrate that corporate ESG performance significantly promotes corporate sustained innovation. Mechanism analyses indicate that from the dual perspectives of resource effects and governance effects, ESG performance primarily enhances sustained innovation by increasing investment in R&D funding and personnel, as well as avoiding managerial myopia. Specifically, macroeconomic uncertainty dampens the positive effect of ESG performance, whereas, under industry competitive and market scrutiny pressures, the beneficial impact of ESG performance on sustained innovation becomes more evident. The research findings expand the internal drivers for sustained innovation, enrich the study of economic consequences of ESG performance, and clarify the differentiated moderating effects of various external pressures under VUCA scenarios. By integrating internal drivers and external complex environments, the paper offers practical insights for firms to leverage ESG practices for innovation resilience and long-term growth, particularly under dynamic market conditions.

Keywords: ESG performance; sustained innovation; resource effect; governance effect; VUCA

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1. Introduction

China is currently undergoing unprecedented transformations unseen in a century, with profound shifts occurring both domestically and internationally. Against the backdrop of anti-globalization trends coupled with accelerated socioeconomic transformation and industrial upgrading, the VUCA (Volatility, Uncertainty, Complexity, and Ambiguity) characteristics of China's domestic business environment have become increasingly pronounced. In this context, innovation serves as a strategic pillar for enhancing national competitiveness and driving high-quality economic development.

The technological innovation faces inherent challenges, including high investment requirements, elevated risks, and long-lagged return periods. Enterprises are more prone to having their innovation activities disrupted due to objective factors such as capital

shortages and subjective reasons like managerial myopia in a complex and changing environment [1,2]. Given these barriers, how to help enterprises tackle the challenges of the VUCA environment, overcome the difficulties faced by innovation, and effectively enhance sustained innovation capabilities is a pressing issue for both theoretical and practical circles at present.

ESG (Environmental, Social, and Governance) has become a globally recognized framework for sustainable development, with its influence increasingly shaping corporate strategies worldwide. Prior research highlights several notable trends in ESG adoption and performance across different economic contexts. Globally, ESG performance has shown steady improvement, particularly in high-income countries [3]. In Germany and Austria, over half of listed companies disclose ESG reports, compared to just 5% in newer EU member states like Bulgaria and Croatia. In China, this figure climbed to 45% in 2024. European markets stand out due to their strong ESG performance, which correlates with greater resilience during economic downturns compared to conventional markets [4]. This suggests that robust ESG practices contribute to financial stability. Regulatory measures also play a crucial role in advancing ESG objectives. Studies indicate that mandatory ESG reporting significantly enhances corporate carbon reduction efforts, especially in regions with previously weaker regulatory oversight [5]. Given these findings, experts advocate for a standardized global ESG evaluation system to ensure consistency, comparability, and more effective progress toward sustainable development goals [6].

Existing research has established that ESG performance exerts positive effects on enterprises through its signaling and resource effects [7–9]. In capital markets, ESG performance functions as an information transmission mechanism, enhancing investor confidence [10] while improving corporate access to external financing [11]. Internally, enhanced ESG practices contribute to operational efficiency by refining control processes [12], mitigating agency problems [13], and curbing managerial myopia [14]. The benefits can be translated into concrete economic advantages for enterprises. Better ESG performance leads to multiple economic benefits, including higher profitability [15,16], increased firm value [17], greater cash reserves, more conservative capital structures, as well as lower credit risk [18,19]. These findings confirm that ESG performance serves as both a reliable indicator of corporate quality [20] and an effective driver of sustainable organizational growth [21].

Empirical studies provide scholarly evidence indicating that ESG performance significantly enhances corporate innovation, such as improving the overall quality of innovation [22] and green innovation performance [23,24]. However, existing research has largely overlooked how firms sustain their innovation behaviors over extended periods without disruption, particularly in an uncertain environment. This oversight is noteworthy because corporate innovation is inherently a multifaceted, long-term activity deeply influenced by external factors. Environmental uncertainty significantly affects companies' innovation attitudes and resource allocation capabilities, thereby constraining innovation investment [25]. On the other hand, sustained innovation itself serves as a crucial strategy for navigating such uncertainty, enabling firms to build competitive advantages and ensure long-term viability [26].

Consequently, we examine how ESG performance influences corporate sustained innovation by constructing a comprehensive dataset of China's listed companies from 2015 to 2022. Our analysis incorporates external environmental pressures through three key dimensions of the VUCA context: macroeconomic uncertainty, industry competition, and market attention. We aim to identify the logic through which corporate ESG performance promotes innovation decisions while revealing how these relationships manifest under different stress conditions. We have found that ESG performance significantly enhances corporate

sustained innovation. Increasing innovation resources and mitigating managerial myopia are the influencing mechanisms. Further research reveals that macroeconomic uncertainty weakens the promoting effect; however, under the influence of industry competition and market attention, the positive impact of ESG performance on corporate sustained innovation becomes more evident. By investigating ESG factors as internal drivers of sustained innovation, our study not only extends existing innovation research but also provides targeted decision-making insights for sustained innovation in challenging environments.

The ESG concept mandates enterprises to prioritize not only economic interests but also environmental protection, social responsibility, and corporate governance, aligning with the high-quality development concept advocated by the Chinese government. Guided by the leading "dual-carbon" goals, Chinese enterprises have actively participated in ESG activities and consistently pursued innovation, providing excellent samples for our research. Furthermore, in the absence of a unified standard for ESG information disclosure, the existence of multiple ESG rating agencies in China enables cross-validation in this study.

This paper contributes to four strands of the literature. First, this study expands the understanding of firms' sustained innovation by examining ESG performance as an internal driver. Previous studies have identified the mismatch between long-term returns and short-term investments as a major constraint on innovation continuity. Taking ESG performance as the starting point, we attempt to bridge the gap between short-term investments and long-term returns, internal investments and external feedback, as well as operational performance and non-operational gains, thereby uncovering new internal drivers of sustained innovation within the enterprise.

Second, this paper enriches the research on the economic consequences of ESG performance. Building upon the existing literature that has validated the impact of ESG performance on corporate financing, investment, and market value, it further explores its facilitating role in corporate sustained innovation and examines the underlying mechanisms. This provides a basis for identifying the influence of ESG performance on businesses.

Third, this paper deepens the research on contextual influences by clarifying how different VUCA factors moderate ESG's impact on sustained innovation. While existing studies often treat environmental uncertainty as a single dimension, we systematically distinguish between macro-level, meso-level, and micro-level environmental factors. This bridges the gap between internal innovation drivers and external pressures, offering new insights into corporate decision-making under environmental uncertainty.

Fourth, this study significantly advances the theoretical understanding of corporate sustained innovation by applying the VUCA framework to analyze ESG's impacts. Unlike conventional innovation studies, which often focus on short-term results, our research is centered on sustained innovation. This paper also clarified the difference between sustained innovation and continuous innovation. To test how enterprises can achieve long-term, uninterrupted innovation, we have introduced various external pressures. The findings provide valuable evidence and countermeasures for establishing and improving the ESG information disclosure system, enhancing corporate sustained innovation levels, and achieving high-quality economic development.

The remainder of the paper is arranged as follows. Section 2 presents the theoretical analysis and research hypotheses. Section 3 details the empirical methodology and data. Section 4 presents empirical results and the robustness test. Section 5 conducts further analysis examining the moderating effects of VUCA factors. Section 6 concludes with practical implications.

2. Theoretical Analysis and Hypothesis

2.1. Theoretical Analysis and Literature Review

The ESG concept has attracted considerable and ongoing scholarly interest globally in recent years. Current studies have theoretically analyzed how ESG performance influences corporate sustainability and investigated its connection to enterprise innovation.

Stakeholder theory suggests companies should address all stakeholders' interests for sustainable development. The ESG concept operationalizes it by balancing environmental, social, and governance responsibilities, thereby effectively safeguarding the interests of various stakeholders. Firms with strong ESG performance can better align stakeholder interests, gain broader support, and effectively drive innovation [27]. By reducing information asymmetry between managers and investors [28], ESG mitigates managerial risk aversion and encourages greater tolerance for innovation failures. This facilitates increased resource allocation to R&D activities while countering short-termism, thereby fostering innovation. Studies show the ESG performance correlates with higher patent output [22], demonstrating its role in sustained innovation.

Signaling theory suggests that "signals" play a vital role in mitigating information asymmetry and bridging information gaps. In this context, strong ESG performance serves as a credible positive signal, demonstrating a firm's environmental consciousness, social responsibility commitment, governance improvements, and dedication to sustainable development [29]. Innovation emerges as a measurable manifestation of ESG performance. Externally, ESG performance favors gaining more attention and trust of stakeholders, facilitating conditions such as reducing financing risk premiums, breaking down implicit barriers, and obtaining support for innovative resources [30]. Internally, positive external feedback also helps enterprises enhance their optimistic expectations, fostering a virtuous cycle of improving ESG performance → reducing information asymmetry → gaining recognition and support → engaging in innovation.

Reputation theory suggests that good ESG performance helps maintain and enhance corporate reputation, which in turn supports innovation through improved resource access and risk mitigation. First, by demonstrating ESG performance, companies establish a positive public image that attracts stakeholder support, facilitating resource acquisition from investors, consumers, and other channels. Second, corporate reputation significantly impacts the talent market by strengthening employee belonging, identification, and loyalty. Studies show that reputation particularly influences high-quality innovative talent [31], making its positive effect on sustained innovation more pronounced. Finally, reputation provides a certain insurance effect that can soften the consequences of corporate missteps [32], creating a more tolerant environment for ongoing innovation efforts.

2.2. Research Hypotheses

Due to demanding substantial and sustained resource investments, innovation activities are particularly vulnerable to disruption when external environmental pressures create resource constraints. Sustained innovation refers to the ability of enterprises to maintain the coherence and stability of innovation activities over the long term, preventing interruptions caused by changes in the external environment [26]. Existing research focuses on how to increase innovation output, with less attention given to sustaining it amid various unfavorable environmental constraints. Drawing from a series of studies on corporate innovation, we have identified resource constraints and managerial myopia as pivotal barriers to innovation. We also find that ESG performance can assist enterprises in acquiring innovation resources through the resource effect and mitigating managerial myopia via the governance effect, thereby effectively addressing the challenges faced by enterprises in sustained innovation.

Research confirms that the resource effect of ESG performance enables firms to secure essential innovation resources through multiple channels. ESG-oriented firms gain preferential access to government-supported resources, including R&D-specific funding [33], tax incentives [34], and other policy benefits that directly support innovation activities. Beyond public funding, ESG performance generates capital market advantages through improved investor confidence. The transparency and risk management derived from strong ESG practices enable firms to obtain equity investments and debt financing at more favorable terms [35], while also facilitating extended trade credit from suppliers. This comprehensive financial support system ensures sustained resource availability for innovation initiatives.

The resource effect extends to human capital acquisition and retention. Empirical studies demonstrate that such firms attract R&D professionals more effectively [36] due to their demonstrated social responsibility and superior governance standards. Wu et al. [37] and Zuo et al. [38] further establish that these firms achieve higher levels of employee satisfaction and organizational identification, while Jin et al.'s [39] findings confirm significantly lower turnover rates among technical staff. Additionally, such enterprises often prioritize employee training and the enhancement of knowledge and skills, providing more learning opportunities for employees and improving their ability to engage in innovative activities.

Extensive research confirms that ESG performance exerts governance effects that effectively mitigate principal-agent problems in innovation activities. Amore et al. [40] provide empirical evidence that managerial risk aversion and career concerns frequently inhibit sustained innovation investment. ESG performance addresses these challenges by monitoring, motivating, and constraining management behavior [41]. Firstly, ESG performance enhances organizational transparency, enabling stakeholders to better monitor managerial decisions and risk management practices, thereby facilitating the effective allocation of resources toward sustained innovation. Secondly, the governance dimension of ESG performance facilitates incentive alignment [42], structurally connecting executive rewards to long-term value creation metrics. Lastly, reputation and image attract greater external attention, creating accountability pressures that curb speculative innovation behaviors.

Existing research has also examined the dark side of ESG as a cost burden for firm performance through resource consumption and the expansion of agency conflicts [43]; ESG practices consume resources in accordance with stringent regulations, laws, and auditing practices, suggesting that ESG practices may impose cost burdens by consuming firm resources and crowding out other critical investments [44], thereby raising doubts about the relationship between ESG performance and sustained innovation. Moreover, ESG policies may inadvertently encourage firms to focus on short-term regulatory compliance at the expense of long-term strategic innovation, which could weaken market adaptability and systemic resilience [45]. However, we contend that ESG facilitates access to incremental external resources rather than merely reallocating internal funds among competing projects. Through its dual resource and governance effects, ESG systematically reduces barriers to sustained innovation. The resource effect ensures stable financial, human, and institutional capital, while the governance effect alleviates short-term managerial biases in resource allocation. By simultaneously addressing input constraints and decision-making distortions, ESG enables firms to sustain innovation continuity even under external pressures, ultimately fostering long-term technological progress and competitive resilience.

Therefore, the following hypothesis is proposed:

H1: *Good ESG performance can enhance corporate sustained innovation.*

3. Research Design

3.1. Sampling and Data Collection

We select China's A-share companies listed on the Shanghai and Shenzhen stock exchanges from 2015 to 2022 as the initial sample. The study begins in 2015, as China implemented its "strictest-ever" Environmental Protection Law in that year, compelling enterprises to prioritize environmental and social responsibilities. In the same year, the OECD revised its Principles of Corporate Governance, recommending that listed companies actively adopt and disclose ESG reports, which had a profound impact on corporate ESG practices.

This paper excludes ST, *ST, and PT firms, as they face special treatment due to poor performance or other risks. The listed financial companies are also excluded due to their unique business models, which may render their data incomparable. Additionally, companies with unavailable data despite efforts to obtain them are removed. The samples with missing data were excluded, and the main continuous variables were shrink-tailed at the 1% level in order to exclude the influence of outliers.

The final main regression test included 19,084 data. The ESG data of enterprises are obtained from the WIND database. The innovation patent and internet search index data are from the "Innovation Patent Research" and "Internet Search Index" databases of the Chinese Research Data Services Platform (CNRDS), respectively. The data on management myopia are from the WinGo financial text database. The remaining financial data are obtained from the China Stock Market and Accounting Research Database (CSMAR). Stata17 measurement software (developed by StataCorp LLC, based in College Station, TX, USA) and Excel tools were used to analyze and organize the data.

3.2. Research Methodology

To account for unobserved heterogeneity, we construct a fixed effects model that controls for both industry-specific characteristics and temporal variations. To ensure the robustness of our findings, we implement a comprehensive strategy involving the substitution of both independent and dependent variables (e.g., ESG Score and sustained innovation). Furthermore, we address potential endogeneity concerns through multiple econometric techniques, including (1) two-way fixed effects estimation, (2) clustered-robust standard errors, (3) instrumental variable (IV) approaches, and (4) propensity score matching (PSM). This multi-methodological framework enhances the reliability and validity of our empirical results.

We construct the model as follows:

$$LnPat_{it+1} = \alpha_0 + \alpha_1 ESG_{it} + \alpha_2 Control_{it} + Ind_i + Year_t + \varepsilon_{it} \quad (1)$$

Model (1) to verify the relationship between the ESG performance and corporate sustained innovation. $LnPat_{it+1}$ represents the sustained innovation of company i in $t+1$ year. ESG_{it} represents the ESG performance of company i in the t period; $Control_{it}$ represents all control variables; Ind_i represents the industry fixed effect; $Year_t$ represents the annual fixed effect; and ε_{it} represents the error.

3.3. Variable Measurement

3.3.1. Dependent Variable

Sustained Innovation (*LnPat*). We measure the corporate sustained innovation by the following formula.

$$LnPat_t = Ln[\frac{Pat_t + Pat_{t-1}}{Pat_{t-1} + Pat_{t-2}} \times (Pat_t + Pat_{t-1}) + 1] \quad (2)$$

Pat_t, Pat_{t-1}, and Pat_{t-2} are patent application volumes of enterprises in periods t, $t-1$, and $t-2$, respectively. This indicator is taken to its natural logarithm. The primary considerations for selecting this indicator are as follows: patent technology can potentially impact a business during the application process, so patent application data are more stable, reliable, and timely compared to grant data. Furthermore, this paper not only considers the patent applications of listed companies themselves but also includes those of their joint ventures, associates, and subsidiaries. Compared to smaller enterprises, those with larger innovation scales may find it more difficult to sustain innovation. Therefore, in order to mitigate the impact of innovation scale, we multiply the patent application by its year-on-year growth rate. We measure innovation using firms' all patents rather than only invention patents for two key reasons. This comprehensive approach more accurately reflects a firm's overall innovation capacity since different patent types capture distinct aspects of technological and operational innovation that would otherwise be missed. On the other hand, our study focuses on sustained innovation, which requires consistent inventive activity over time rather than occasional breakthroughs in specific areas. By including all patent types, we better capture both the breadth and persistence of innovation, which is particularly important when examining long-term innovation patterns in volatile business environments.

3.3.2. Independent Variable

ESG Performance (*ESG*). China's ESG rating systems include SynTao Green Finance, Rankins, Hua Zheng ESG rating system, etc. Hua Zheng ESG rating takes into account China's basic national conditions and capital market status, such as targeted poverty alleviation and regulatory penalties imposed by the China Securities Regulatory Commission (CSRC). This gives it advantages in terms of localization and breadth of coverage. Hua Zheng ESG ratings are broader in scope than other rating systems, including three first-level indicators, namely, environment (E), society (S), and governance (G), and 16 second-level indicators, such as environmental pollution, supply chains, social contribution, and governance risk. In addition, there are 44 third-level indicators, such as carbon emission reduction routes, water consumption, renewable energy, and solvency, and more than 70 fourth-level indicators as well as more than 300 underlying data indicators. In contrast to conventional rating frameworks, the Hua Zheng ESG rating exhibits a higher frequency of updates, typically occurring on a quarterly basis. Therefore, we draw on the research of Deng et al. [46] and assess ESG rating using the HuaZheng ESG Rating, which is divided into nine levels, from low to high. We assign them values from nine to one sequentially, with a higher value indicating better ESG performance.

3.3.3. Control Variable

Regarding the control variables, following prior research (e.g., [47,48]), we account for the company characteristics and factors that impact patent development, including $Size_{it}$, the total assets of the firm in year t and take the natural logarithm. Age_{it}, the number of years the firm has been established in year t, is expressed as the difference between the current year and the birth year. TQ_{it}, the Tobin's Q ratio of the firm in year t, is expressed as the ratio of the sum of the market value of equity and debt to the book value of total assets. Ato_{it}, divide the i company's total revenue by its average total assets in year t. $Board_{it}$, the number of directors in a board and take the natural logarithm. PPE_{it}, the percentage of fixed assets in a company's total assets.

The main variables definition are shown in Table 1 and the definition and measurement of all variables can be found in Appendix A.

Table 1. Variable names and definitions.

Variables' Type	Variable Name	Variable Symbol	Variable Definition
Explained variable	Sustained Innovation	LnPat	Ln [(2-year CAGR of patents) × ($patents_t$ + $patents_{t-1}$) + 1]
Explanatory variable	ESG performance	ESG	Scoring based on Hua Zheng ESG ratings
Control variable	Firm size	$Size_{it}$	Ln (the total assets of the firm in year t)
	Firm age	Age_{it}	the number of years the firm has been established in year *t*
	TobinQ	TQ_{it}	the Tobin's Q ratio of the firm in year t
	Total asset turnover	Ato_{it}	the *i* company's total revenue/its average total assets in year *t*
	Board size	$Board_{it}$	Ln (Number of board of directors)
	Fixed assets ratio	PPE_{it}	percentage of fixed assets in a company's total assets

4. Empirical Analysis

4.1. Descriptive Statistics

Table 2 presents the statistical properties of the principal variables. The mean value of corporate sustained innovation in China measures 4.279 with a standard deviation of 1.612. The maximum value reaches 11.76 while the minimum registers at 0, with the former being nearly three times the mean value. This implies that, overall, the sustained innovation of the sampled enterprises is relatively low. Moreover, the substantial variation in innovation levels reveals significant disparities across firms, suggesting that their eagerness to engage in sustained innovation activities requires enhancement. These findings justify the importance of investigating both internal drivers and external environmental factors that influence innovation sustainability. The average ESG score across companies is 4.152, with values ranging from a minimum of 1 to a maximum of 8. This distribution highlights significant room for improvement in corporate ESG practices. The number of companies disclosing ESG information in China has shown consistent growth, alongside an upward trend in average ESG scores. This pattern aligns with developments in other major economies, including the EU and the UK. However, due to the absence of globally standardized ESG disclosure guidelines, the comparability of related evaluation results remains limited. The descriptive statistics for these principal variables demonstrate consistency with the established literature, thereby supporting the validity of our dataset.

Table 2. Descriptive statistics.

Variable	Obs	Min	P25	P50	Mean	P75	Max	Sd.
ESG	19,084	1.000	3.000	4.000	4.114	5.000	8.000	1.120
LnPat	19,084	0.000	3.326	4.348	4.279	5.290	11.760	1.612
Size	19,084	20.160	21.510	22.230	22.400	23.090	26.270	1.245
Age	19,084	2.303	2.833	3.045	3.005	3.219	3.555	0.272
TQ	19,084	0.834	1.262	1.687	2.119	2.451	8.545	1.358
Ato	19,084	0.089	0.376	0.548	0.624	0.768	2.331	0.380
Board	19,084	1.609	1.946	2.197	2.106	2.197	2.639	0.194
PPE	19,084	0.004	0.091	0.173	0.201	0.282	0.638	0.141
Lev	19,084	0.069	0.271	0.416	0.423	0.561	0.891	0.192

4.2. Correlation Test

Table 3 presents the results of the Pearson correlation test. All correlation coefficients among the variables are less than 1, with the majority falling below 0.5. This indicates the absence of severe multicollinearity among the variables. ESG performance is positively correlated with corporate sustained innovation, and this correlation is significant at the 1% level, thus providing preliminary validation for Hypothesis 1. Moreover, most of the control variables exhibit significant correlations with both the explanatory and non-explanatory variables. Furthermore, the Variance Inflation Factor (VIF) values for all variables are less than 10, with an average VIF of 1.35, indicating that the variable selection is relatively reasonable.

Table 3. Correlation analysis.

	LnPat	ESG	Size	Age	TQ	Ato	Board	PPE	Lev
LnPat	1								
ESG	0.208 ***	1							
Size	0.460 ***	0.222 ***	1						
Age	−0.017 **	0.000	0.147 ***	1					
TQ	−0.145 ***	−0.055 ***	−0.365 ***	−0.111 ***	1				
Ato	0.091 ***	0.058 ***	0.100 ***	0.042 ***	−0.020 ***	1			
Board	0.118 ***	0.050 ***	0.269 ***	0.095 ***	−0.109 ***	0.022 ***	1		
PPE	−0.006	−0.016 **	0.096 ***	0.035 ***	−0.097 ***	0.032 ***	0.100 ***	1	
Lev	0.210 ***	−0.079 ***	0.480 ***	0.124 ***	−0.298 ***	0.149 ***	0.124 ***	0.073 ***	1

Note: *** $p < 0.01$, ** $p < 0.05$.

4.3. Baseline Regression Results

Table 4 presents the baseline regression results examining the relationship between ESG performance and sustained innovation. Column (1) includes only industry and year fixed effects, whereas Column (2) additionally incorporates firm-level control variables. The coefficients of ESG performance (*ESG*) on sustained innovation (*LnPat*) are 0.318 and 0.136 in Columns (1) and (2), respectively; both are statistically significant at the 1% level. The coefficient of 0.136 in Column (2) implies that a one standard deviation increase in *ESG* (1.120) corresponds to a 0.152 (0.136 × 1.120) rise in *LnPat*. This incremental effect accounts for approximately 3.55% of the average patent logarithm (4.279%). This demonstrates that ESG performance significantly enhances corporate sustained innovation, thereby supporting Hypothesis 1. Regarding control variables, the regression coefficients are 0.728 for firm size (*Size*) and 0.023 for Tobin's Q (*TQ*); both are significant at the 1% level. These results suggest that larger firms and those with higher market valuations possess greater resource capacity to facilitate sustained innovation activities, a finding that is consistent with previous research conclusions.

We further conducted separate sub-sample analyses for heavily polluting industries and manufacturing firms based on prior research experience [49]. For heavily polluting industries, we believe in stronger ESG performance effects due to their higher environmental sensitivity, and for manufacturing firms, we focused on sustained innovation given its strategic importance in this sector. These targeted examinations allow us to investigate how ESG mechanisms operate differently across critical industry contexts. Our separate analyses of sub-samples from heavily polluting industries and manufacturing companies reveal that ESG performance continues to exert a statistically significant impact on sustained innovation. The findings further demonstrate the broader applicability of ESG performance's positive effects.

Table 4. Baseline regression results.

	LnPat			
	(1)	**(2)**	**(3) Heavily Polluting Industries**	**(4) Manufacturing Companies**
ESG	0.318 ***	0.136 ***	0.124 ***	0.123 ***
	(32.17)	(15.71)	(8.30)	(13.49)
Size		0.728 ***	0.625 ***	0.728 ***
		(72.92)	(36.37)	(70.05)
Age		−0.207 ***	−0.375 ***	−0.184 ***
		(−5.83)	(−5.51)	(−4.89)
TQ		0.023 ***	0.018	0.016 **
		(2.92)	(1.32)	(1.98)
Ato		0.307 ***	0.221 ***	0.375 ***
		(9.58)	(4.87)	(12.66)
Board		0.188 ***	0.366 ***	0.130 **
		(3.81)	(4.28)	(2.51)
PPE		−0.325 ***	−0.371 ***	−0.491 ***
		(−3.98)	(−2.93)	(−5.92)
Lev		−0.181 ***	0.021	0.006
		(−3.00)	(0.20)	(0.09)
_cons	2.973 ***	−12.464 ***	−11.613 ***	−13.159 ***
	(71.00)	(−53.96)	(−25.89)	(−51.41)
Year	YES	YES	Yes	Yes
Industry	YES	YES	Yes	Yes
N	19,084	19,084	5818	14,260
Adj.R^2	0.209	0.440	0.357	0.463

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

4.4. Robustness Test

4.4.1. Alternative of Variables

Following Wang and Zhang [50], the independent variables were re-tested by replacing the Bloomberg ESG score. Furthermore, following Xiao et al. [51], we measure sustained innovation (*LnPat*2) by dividing the increment of intangible assets by the current total assets. We also multiply the two-year chain growth rate of R&D investment by the sum of the current and previous periods' R&D investments to measure sustained innovation. The specific formula is as follows:

$$Lnrd_t = Ln[\frac{rd_t + rd_{t-1}}{rd_{t-1}+rd_{t-2}} \times (rd_t + rd_{t-1}) + 1] \quad (3)$$

$Lnrd_t$ represents the enterprise's sustained innovation in year t, with rd_t, rd_{t-1}, and rd_{t-2} denoting the enterprise's R&D investment in year t, year $t-1$, year $t-2$, respectively.

Table 5 reports the regression results with the alternative variable. Column (1) presents that the regression coefficient of ESG performance on corporate sustained innovation is 0.014 and significant at the 1% level. Hypothesis 1 remains confirmed. Columns (2) and (3) present the results when measuring sustained innovation by the increment in intangible assets and R&D investment, respectively. The regression coefficients are 0.087 and 0.001, respectively; both are significant at the 1% level, thus continuing to support Hypothesis 1.

Table 5. Alternative of the variables test.

	Alternative of Independent Variables	Alternative of Dependent Variables	
	(1) LnPat	**(2) LnPat2**	**(3) Lnrd**
ESG	0.014 ***	0.087 ***	0.001 ***
	(5.68)	(13.42)	(5.40)
Size	0.708 ***	0.949 ***	0.001 ***
	(37.02)	(126.97)	(6.86)
Age	−0.140 **	−0.265 ***	−0.003 ***
	(−2.18)	(−11.08)	(−5.46)
TQ	0.007	0.092 ***	−0.000
	(0.66)	(14.63)	(−1.48)
Ato	0.463 ***	0.601 ***	−0.000
	(8.90)	(22.24)	(−0.55)
Board	0.229 ***	0.055	−0.001
	(2.67)	(1.51)	(−0.80)
PPE	−0.434 ***	0.070	−0.008 ***
	(−3.24)	(1.11)	(−5.34)
Lev	−0.502 ***	−0.368 ***	0.000
	(−4.64)	(−7.65)	(0.07)
-cons	−12.504 ***	−2.204 ***	−0.008 **
	(−26.11)	(−13.62)	(−2.49)
Year	YES	YES	YES
Ind	YES	YES	YES
N	7221	18,749	26,427
Adj.R^2	0.486	0.652	0.0448

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

4.4.2. Endogeneity Test

To address the issue arising from omitted variables, we adopt a two-way fixed effects model controlling for both individuals and time, replacing the previous fixed effects model that only considered time and industry for the baseline regression. Moreover, to effectively manage heteroskedasticity and autocorrelation issues, we utilize cluster-robust standard errors calculated at the enterprise level. The results are displayed in Column (1) of Table 6.

Table 6. Endogeneity test results.

Variable	LnPat	ESG	LnPat	Mean			*t*-Test			
	(1)	(2)	(3)	(4) U/M	(5) T	(6) C	(7) %bias	(8) *t*	(9) $p >$ | *t* |	(10) LnPat
CO_2		−0.079 ***								
		(−5.34)								
ESG	0.042 ***		1.125 ***							0.269 ***
	(4.10)		(3.78)							(13.36)
Size	0.603 ***	0.337 ***	0.381 ***	U	22.886	22.370	36.000	25.120	0.000	0.744 ***
	(12.97)	(36.43)	(3.72)	M	22.884	22.842	2.900	1.620	0.106	(70.21)
Age	−0.540	−0.090 **	−0.138 **	U	3.010	3.017	−2.800	−1.880	0.060	−0.211 ***
	(−1.52)	(−2.54)	(−2.17)	M	3.009	3.006	1.200	0.710	0.477	(−5.40)
TQ	0.012	0.004	0.031 **	U	2.018	2.098	−6.000	−4.040	0.000	0.028 ***
	(1.07)	(0.48)	(2.47)	M	2.018	1.997	1.500	0.900	0.371	(3.21)
Ato	0.097	0.257 ***	0.105	U	0.636	0.598	9.500	6.400	0.000	0.344 ***
	(1.41)	(8.94)	(1.16)	M	0.635	0.637	−0.300	−0.170	0.866	(10.00)
Board	0.065	0.003	0.226 ***	U	2.127	2.112	7.400	5.010	0.000	0.206 ***
	(0.66)	(0.06)	(2.93)	M	2.127	2.124	1.100	0.630	0.531	(3.81)

Table 6. *Cont.*

Variable	LnPat	ESG	LnPat	Mean			*t*-Test			
	(1)	(2)	(3)	(4) U/M	(5) T	(6) C	(7) %bias	(8) *t*	(9) $p >\|t\|$	(10) LnPat
PPE	0.235	0.250 ***	−0.632 ***	U	0.202	0.201	0.900	0.600	0.547	−0.398 ***
	(1.14)	(3.13)	(−4.46)	M	0.202	0.202	0.300	0.190	0.849	(−4.42)
Lev	−0.221 *	−1.539 ***	1.291 ***	U	0.425	0.443	−9.00	−6.050	0.000	−0.333 ***
	(−1.75)	(−25.25)	(2.72)	M	0.425	0.419	2.800	1.650	0.099	(−4.83)
-cons	−8.197 ***	−3.573 ***	−9.972 ***							−12.482 ***
	(−6.25)	(−13.59)	(−8.54)							(−48.82)
Year	YES	YES	YES							YES
Ind	NO	YES	YES							YES
Stkcd	YES	NO	NO							
N	19,084	14,371	14,371							16,648
R^2	0.121		0.048							0.435

Note: *t*-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Column (1) is to control for omitted variables via two-way fixed effects; Column (2)–Column (3) are to address reverse causation via the instrumental variables method; Column (4)–Column (10) are to address sample selection bias via PSM.

A potential reverse causality issue may exist between ESG performance and sustained innovation. Specifically, sustained innovation could not only directly enhance ESG performance but also indirectly elevate it by increasing corporate value and financial performance, thereby providing resources for ESG-related activities. To mitigate this endogeneity concern, we employ an instrumental variable (IV) approach. Following the methodology of Li and Chen [52], we utilize provincial-level carbon dioxide emission intensity (CO_2) as our instrumental variable, estimating the relationship through a two-stage least squares (2SLS) model. Regions with lower CO_2 emissions tend to prioritize environmental protection, which incentivizes local firms to improve their ESG performance. However, we find no evidence that regional CO_2 levels directly affect firms' innovation capabilities. We have also conducted instrumental variable tests, which indicate that this is a reasonable and valid instrumental variable. As shown in Columns (2) and (3) of Table 6, after accounting for the possibility of reverse causality, the conclusions remain statistically significant.

In reality, enterprises with strong ESG performance may inherently possess higher levels of sustained innovation capability, implying that the selection of these firms is non-random. To address potential sample selection bias, we employ the Propensity Score Matching (PSM) method. Specifically, we classify firms into treatment and control groups based on the annual industry median of ESG performance. We define firms with ESG scores above the annual industry median as having better ESG performance and assign them to the treatment group (Group 1), while firms with scores below the median are assigned to the control group (Group 0). We estimated propensity scores using a logit model incorporating the control variables and industry-year fixed effects, and then performed 1:1 nearest-neighbor matching based on these scores.

The analysis reveals that when using sustained innovation (*LnPat*) as outcome variables for matching, all covariates exhibit standardized biases below 10%, with absolute t-values ($|t|$) after matching being less than 1.96, satisfying the PSM balance test. The average treatment effects (ATT) were all significant at the 1% level, further demonstrating the appropriateness of the PSM matching approach. Importantly, these PSM findings align with the baseline regression results, thereby reinforcing the robustness of our conclusions.

4.5. Mediating Effect Analysis

Sustained innovation requires long-term consistency and stability in an enterprise's innovation activities, ensuring uninterrupted progress despite external environmental fluctuations or internal managerial missteps. Continuous investment in R&D serves as a fundamental driver of this enduring innovative capacity. Our analysis demonstrates

that ESG performance strengthens enterprises' resource allocation to innovation activities, particularly through increased R&D expenditure and the employment of highly qualified R&D personnel, which collectively foster sustained innovation. To empirically validate the resource effect, we measure R&D investment as the ratio of R&D expenditure to operating revenue (*RD*) and R&D personnel as the proportion of R&D personnel to the total workforce (*RH*). Higher values of the two indicators reflect greater resource allocation to innovation, providing direct evidence of how ESG performance strengthens the resource foundations for sustained innovation.

As shown in column (1) of Table 7, ESG performance is significantly positively correlated with R&D investment (*RD*). When both ESG performance and R&D investment are included in column (2), the regression coefficient for *RD* is 0.052 and remains significantly positive at the 1% level, while ESG performance also maintains a significant positive correlation with sustained innovation. These results indicate that R&D investment serves as a partial mediator between ESG performance and sustained innovation. Similarly, the findings in columns (3) and (4) demonstrate that R&D personnel (*RH*) also partially mediate the relationship between ESG performance and sustained innovation. These results collectively show that ESG performance promotes sustained innovation through the resource effect by increasing R&D investment and personnel allocation. Fang and Hu [53] and Li and Li [54] demonstrated that ESG performance enhances corporate innovation through increased investment. Building on this foundation, our study reveals that this mechanism also effectively promotes sustained innovation.

Table 7. Mediating effect analysis results.

Variable	(1) RD	(2) LnPat	(3) RH	(4) LnPat	(5) Myp	(6) LnPat
ESG	0.145 ***	0.128 ***	0.325 ***	0.131 ***	−0.001 ***	0.135 ***
	(5.43)	(14.98)	(4.70)	(15.25)	(−3.58)	(15.63)
RD		0.052 ***				
		(19.91)				
RH				0.014 ***		
				(14.82)		
Myp						−0.540 ***
						(−3.36)
Size	−0.034	0.730 ***	−0.242 ***	0.732 ***	−0.002 ***	0.727 ***
	(−1.17)	(74.30)	(−3.13)	(73.86)	(−4.05)	(72.86)
Age	−1.279 ***	−0.140 ***	−2.534 ***	−0.171 ***	0.015 ***	−0.199 ***
	(−11.47)	(−3.97)	(−8.56)	(−4.82)	(9.44)	(−5.58)
TQ	0.483 ***	−0.002	0.961 ***	0.009	−0.001 ***	0.022 ***
	(15.00)	(−0.31)	(12.02)	(1.17)	(−3.29)	(2.84)
Ato	−3.122 ***	0.471 ***	−2.862 ***	0.348 ***	−0.001	0.307 ***
	(−37.64)	(14.29)	(−12.98)	(10.92)	(−0.38)	(9.58)
Board	−0.068	0.192 ***	−1.090 ***	0.204 ***	0.005 **	0.191 ***
	(−0.45)	(3.94)	(−2.59)	(4.17)	(2.33)	(3.88)
PPE	−1.882 ***	−0.227 ***	−16.638 ***	−0.087	0.028 ***	−0.310 ***
	(−8.28)	(−2.81)	(−28.04)	(−1.05)	(7.48)	(−3.79)
Lev	−2.813 ***	−0.034	−4.698 ***	−0.114 *	0.009 ***	−0.177 ***
	(−14.32)	(−0.56)	(−9.53)	(−1.90)	(3.06)	(−2.92)
_cons	11.768 ***	−13.080 ***	35.450 ***	−12.971 ***	0.051 ***	−12.436 ***
	(16.10)	(−56.97)	(18.49)	(−56.18)	(4.99)	(−53.88)
Year	YES	YES	YES	YES	YES	YES
Ind	YES	YES	YES	YES	YES	YES
N	19,084	19,084	19,084	19,084	19,084	19,084
Adj.R^2	0.445	0.455	0.450	0.448	0.112	0.440

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

Our analysis further reveals that ESG performance contributes to sustained innovation through its governance effect by mitigating managerial myopia. To empirically examine this mechanism, we develop a textual measure of managerial short-term orientation using text analysis techniques. Specifically, we first identify myopia-related vocabulary through text mining and natural language processing of the "Management's Discussion and Analysis" (MD&A) sections in corporate annual reports, capturing both explicit short-term expressions and implicit myopic tendencies. We then employ the Continuous Bag of Words (CBOW) model from Word2Vec to semantically expand our word list, ultimately identifying 43 definitive terms that characterize managerial myopia after training on our annual report corpus. Using the WinGo text analytics platform, we calculate word frequencies to construct our managerial myopia index (*Myp*), computed as the ratio of the total short-term word frequency to total MD&A word count multiplied by 100.

The regression results in Table 7 column (5) show that ESG performance is significantly negatively correlated with managerial myopia (*Myp*) at the 1% level. Column (6) includes both variables, with managerial myopia showing a significantly negative coefficient of −0.54 on sustained innovation, while ESG performance maintains its positive significance. This indicates that managerial myopia partially mediates ESG's effect on sustained innovation. The findings demonstrate ESG's governance effect, as it curbs managerial myopia and thereby encourages managers to be more inclined to invest in innovation activities.

5. Further Research: Analysis Based on the Perspective of Multiple Pressures in the VUCA Context

The relationship between ESG performance and sustained innovation is critically influenced by external VUCA conditions, which directly impact innovation resource allocation and managerial decision-making, ultimately shaping corporate innovation strategies. Prior research has shown that corporate CSR performance has a positive effect on the stock market in an unfavorable environment, mitigating the effects of unfavorable conflicts [55]. Macroeconomic uncertainty typically leads firms to prioritize liquidity reserves while cutting or postponing investments, which exacerbates the crowding-out effect of ESG initiatives on technological innovation. Conversely, heightened market competition fosters a peer effect that drives companies to improve ESG performance as they vie for a competitive advantage, thereby accelerating technological innovation and strengthening ESG's positive impact on sustained innovation. Accordingly, this study systematically investigates how VUCA environment pressures manifest through three key dimensions: macroeconomic uncertainty, industry competition intensity, and market attention to differentially influence the connection between ESG performance and corporate innovation outcomes.

5.1. Moderating Effects of Macroeconomic Uncertainty

Previous research suggests that macroeconomic uncertainty exacerbates the volatility of corporations' future cash flows and elevates the risk of financial distress. Consequently, managers have to adopt more conservative strategies due to heightened concerns about future earnings and potential risks. The defensive mindset drives companies to increase cash reserves and reduce non-essential expenditures. At the same time, uncertainty intensifies information asymmetry between investors and firms, making it increasingly challenging to assess the potential outcomes of investment and innovation initiatives, thereby weakening corporate enthusiasm for sustained innovation. Both ESG and sustained innovation share the characteristic of consuming funds while failing to generate direct returns in the short term. Thus, when external macroeconomic pressures intensify and firms face constraints in acquiring additional resources, ESG and innovation compete for limited capital. ESG activities may crowd out innovation investment or lead to superficial innovation strategies that

emphasize quantity over quality, ultimately undermining the accumulation of innovation experience and long-term innovation efforts.

The established literature has demonstrated that the China Monthly Economic Policy Uncertainty Index, calculated based on data from the South China Morning Post in Hong Kong, aligns with the fluctuation trends of the Chinese economy (Baker et al., 2016 [55]). Therefore, we calculate the annual data by taking the geometric mean of this index and dividing it by 100 to measure macroeconomic uncertainty (EPU). A higher value of this index indicates greater macroeconomic uncertainty. The regression results for the moderating effect are shown in Column (1) of Table 7, where the coefficient of the interaction term between ESG and EPU is −0.008, which is significantly negative, indicating that macroeconomic uncertainty negatively moderates the positive relationship between ESG performance and innovation sustainability.

5.2. Moderating Effects of Industry Competitiveness

The impact of industry competition on enterprises is relatively complex. Intense industry competition implies greater uncertainty in business operations, yet evading or stagnating can only put enterprises at a disadvantage in competition. Emerging prominently among peers is an effective strategy for enterprises to cope with competition. Research has found that enhancing ESG performance to create a more prominent corporate image is one of the means to distinguish oneself in industry competition. When industry competition intensifies, customers' attention and sensitivity toward corporate ESG performance increase. Consequently, enterprises will pay more attention to ESG practices to enhance their reputation and attract the attention of stakeholders such as customers. Heightened industry competition leads to greater transparency of information [56], enabling shareholders to have a clearer understanding of enterprises' continuous investment in innovation. Moreover, ESG can help guide managers to carry out high-quality innovation, promoting enterprises to create differentiated and more valuable products [57]. Therefore, this paper argues that in the face of intense industry competition, the role of corporate ESG performance in enhancing the sustainability of technological innovation is more pronounced.

In empirical research, we refer to the study by Yi et al. [58] and use the Herfindahl–Hirschman Index (HHI) to represent market competitive pressure. A lower value of HHI indicates greater competition within the market industry. The regression results in Column (2) of Table 7 show that the coefficient of the interaction term between ESG and HHI is −0.164, which is significantly negatively correlated at the 5% level. This proves that industry competitive pressure positively moderates the relationship between ESG performance and corporate sustained innovation. This means that the greater the industry competitive pressure, the stronger the effect of ESG performance on sustained innovation.

5.3. Moderating Effects of Market Attention

Listed companies operate within the dual realms of product markets and capital markets, where investor attention serves as a barometer of the pressures they face in the capital market. The growth and development of these companies are inextricably linked to the support provided by investors. In pursuit of enhanced returns, investors closely monitor ESG behaviors and innovation activities, which are pivotal to the long-term sustainability of enterprises. The heightened market attention increases the transparency of managerial transactional activities, thereby reducing the degree of information asymmetry associated with corporate ESG practices and innovation endeavors [59]. This, in turn, forms constraints and supervision on managers. Therefore, from the perspective of external pressure, it is believed that in order to respond to investors' concerns and obtain more resource support from them, companies will engage more in behaviors that meet investors'

expectations, such as conducting ESG activities to promote sustained innovation. Based on this, this paper argues that capital market attention positively moderates the enhancing effect of ESG performance on sustained innovation.

In capital market practices, a higher online search volume indicates greater public attention and greater investor pressure on the firm. Therefore, drawing on the research of Wang and Gao [60], as well as Cao et al. [61], this paper adopts the Baidu Search Index as a measure of Market Attention (MA) and takes the natural logarithm. As shown in Column (3) of Table 8, the coefficient of the interaction term between ESG performance and market attention is 0.045, which is significantly positive at the 1% level. This suggests that under higher market attention, ESG performance has a more pronounced effect on enhancing sustained innovation.

Table 8. Moderating effects of the regression results.

	Lnpat		
	(1)	**(2)**	**(3)**
ESG	0.134 ***	0.132 ***	0.136 ***
	(15.29)	(15.25)	(15.34)
ESG × EPU	−0.008 *		
	(−1.82)		
ESG × HHI		−0.164 **	
		(−2.52)	
ESG × MA			0.045 ***
			(4.14)
EPU	−0.046 ***		
	(−6.36)		
HHI		0.242	
		(1.08)	
MA			0.033 **
			(2.29)
Size	0.733 ***	0.738 ***	0.708 ***
	(72.91)	(74.13)	(59.42)
Age	−0.236 ***	−0.203 ***	−0.214 ***
	(−6.65)	(−5.70)	(−5.72)
TQ	0.051 ***	0.022 ***	0.020 **
	(6.57)	(2.84)	(2.39)
Ato	0.303 ***	0.273 ***	0.299 ***
	(9.36)	(8.49)	(9.13)
Board	0.203 ***	0.161 ***	0.185 ***
	(4.09)	(3.23)	(3.63)
PPE	−0.293 ***	−0.370 ***	−0.317 ***
	(−3.56)	(−4.49)	(−3.79)
Lev	−0.144 **	−0.134 **	−0.180 ***
	(−2.36)	(−2.20)	(−2.90)
GDP	−3.374 ***		
	(−7.63)		
M2	−16.589 ***		
	(−19.14)		
_cons	−11.151 ***	−12.047 ***	−11.436 ***
	(−37.24)	(−50.52)	(−39.23)
Year	NO	YES	YES
Ind	YES	YES	YES
N	19,084	18,521	18,173
Adj.R^2	0.430	0.447	0.443

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

6. Conclusions and Implications

6.1. Research Conclusions

As ESG practices represent an endogenous driver of corporate sustainable development, this study investigates how ESG performance affects sustained innovation. Using a sample of Chinese A-share listed companies from 2015 to 2022, we find that ESG performance significantly promotes corporate sustained innovation, with the results remaining robust after addressing endogeneity concerns through multiple approaches. The empirical results establish that ESG performance fosters sustained innovation through dual pathways of resource and governance effects. Specifically, ESG performance effectively alleviates corporate financing constraints and attracts higher-quality talent, thereby directly strengthening firms' capacity for sustained innovation. Concurrently, by mitigating managerial myopia, ESG practices increase innovation investment intensity.

Furthermore, the study also reveals the moderating influence of the VUCA environment. We find that macroeconomic uncertainty significantly weakens the positive impact of ESG performance on sustained innovation, as firms facing resource constraints during turbulent periods tend to prioritize short-term survival. Conversely, intense industry competition and strong market attention substantially strengthen ESG's positive effects on sustained innovation. The findings indicate that while macroeconomic volatility may temporarily constrain ESG's innovation benefits, competitive pressures and stakeholder monitoring reinforce the importance of ESG practices for sustained innovation. Our study makes distinct contributions to the literature by analyzing ESG's impact on sustained innovation through a multi-level VUCA framework. Specifically, we decompose the VUCA environment into three dimensions, revealing how ESG effects vary significantly across these different environments. Our approach broadens the analytical perspective and enriches understanding of both the economic consequences of ESG practices and the drivers of sustained innovation.

6.2. Policy Suggestions and Managerial Implications

The insights contribute to both stakeholder theory and resource-based view by demonstrating how ESG performance ensures sustained innovation under environmental uncertainty, while offering practical guidance for firms facing external uncertainties. Firstly, companies should actively participate in ESG activities. Research has confirmed the positive impact of corporate ESG performance on sustained innovation and identified it as an effective means for companies to compete in the market and address investors' concerns. Therefore, companies should strategically balance ESG investments with other critical business investments, while staying informed about national green development policies, strengthening social responsibility initiatives, enhancing governance structures with clear innovation incentives, and improving transparency in non-financial disclosures.

Second, stakeholders should broaden their focus beyond financial performance and product competitiveness to incorporate both ESG performance and sustained innovation. Research confirms the mutually reinforcing relationship between ESG practices and sustained innovation. Stakeholders can focus more on non-financial performance and long-term benefits while increasing tolerance for innovation failures, thereby facilitating synergistic effects between ESG and sustained innovation.

Thirdly, the government needs to formulate a series of policies based on the blind spots and deficiencies in corporate practices, aiming to promote corporate ESG performance. Currently, the inconsistent ESG information disclosure requirements across countries pose significant challenges for businesses. It is imperative to promote the establishment of ESG information disclosure standards with national characteristics that are both effective and comparable. For instance, the IFRS Sustainability Disclosure Standard represents a

beneficial attempt in this direction. In addition, both ESG and innovation activities are challenging to generate economic benefits in the short term, leaving companies in a VUCA environment with the difficult choice of prioritizing one over the other. The government can provide certain support to address these corporate difficulties, encouraging enterprises to engage in ESG practices and enhance their innovation performance.

6.3. Limitations and Future Research

While this study provides valuable insights, two limitations should be acknowledged to guide future research directions. The ESG ratings used in our analysis are primarily derived from corporate ESG reports, which reflect what companies "say" rather than what they actually "do", which limits our ability to assess real ESG practices. Future research could employ mixed-methods approaches to obtain more reliable data. Specifically, in-depth case studies, field surveys, and questionnaires could be conducted with select firms to examine how their actual ESG behaviors, rather than just reported information, affect sustained innovation. Such methodological refinements would provide more nuanced insights into the relationship between ESG implementation and innovation continuity.

On the other hand, we recognize that sustained innovation inherently involves long time horizons. The current measurement approach does not fully capture how sustained innovation varies across different corporate life stages. For example, "go-for-broke" strategies in growth-phase firms differ fundamentally from the calibrated innovation approaches of mature enterprises. Future research could productively explore this connection by systematically analyzing innovation persistence patterns across different organizational life stages.

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Appendix A

Table A1. Definition and Measurement of All Variables.

Variables' Type	Variable Name	Variable Symbol	Variable Definition
Explained variable	Sustained Innovation	LnPat	Ln [(2-year CAGR of patents) × ($patents_t$ + $patents_{t-1}$) + 1]
Explanatory variable	ESG performance	ESG	Scoring based on Hua Zheng ESG ratings

Table A1. *Cont.*

Variables' Type	Variable Name	Variable Symbol	Variable Definition
Control variable	Firm size	$Size_{it}$	Ln (the total assets of the firm in year t)
	Firm age	Age_{it}	the number of years the firm has been established in year *t*
	TobinQ	TQ_{it}	the Tobin's Q ratio of the firm in year t
	Total asset turnover	Ato_{it}	the *i* company's total revenue/its average total assets in year *t*
	Board size	$Board_{it}$	Ln (Number of board of directors)
	Fixed assets ratio	PPE_{it}	percentage of fixed assets in a company's total assets
Substitution of variables	ESG performance	ESG	Scoring based on Peng Bo ESG ratings
	Sustained Innovation	LnPat2	Increase in intangible assets divided by total assets for the period
	Sustained Innovation	$Lnrd_{it}$	Ln (R&D investment ∗ year-on-year growth rate + 1)
instrumental variable	Carbon dioxide emission intensity	CO_2	Carbon dioxide emissions of the province of registration divided by GDP
moderator variable	economic uncertainty	EPU	Geometric mean of monthly economic policy uncertainty index divided by 100
	Industry Competitiveness	HHI	Herfindahl index
	Market Focus	MA	Ln (web search index)

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