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ORIGINAL ARTICLE

Unlocking value: exploring the impact of ESG performance and board gender diversity on mitigating stock price crash risk

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Abstract

We examine the role of environmental, social and governance performance (ESGP), board gender diversity (BGD), and their interactive effect on stock price crash risk (SPCR). Using a dataset of Chinese companies listed in the A-share market between 2015 and 2022 and employing three-stage least squares statistics to address the endogeneity issue, we found that ESGP is negatively associated with SPCR. Notably, BGD exhibits a positive association with SPCR. However, the interaction between ESGP and BGD reveals a negative relationship with SPCR, suggesting that ESGP moderates the positive effect of BGD on crash-related risk. Our results still hold even after conducting a series of robustness checks, such as using a fixed effect model, a two-step GMM estimator, and alternative measures of ESGP and BGD. This study contributes to the governance and sustainability literature by highlighting the influence of ESGP and BGD on SPCR and their interactive role in mitigating crash risk through enhanced transparency, stronger stakeholder relations, and improved risk management. It offers valuable organisational and policy implications, suggesting that Chinese listed companies can leverage ESGP to effectively reduce SPCR and strengthen corporate governance practices.

Keywords ESG performance · Stock price crash risk · CSR · Board gender diversity · China

Introduction

There is a growing recognition among scholars of the significance of evaluating environmental, social and governance (ESG) factors and their relationship with financial performance (Blank et al. 2016; Kamal and Deegan 2013; Feng et al. 2022). This evaluative approach examines the

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societal worth connected to a company's ESG activities. In light of current challenges, such as the continuing impact of the COVID-19 epidemic, the increasing concerns about climate change, and geopolitical tensions, it is crucial to give utmost importance to environmental sustainability and social responsibility. This has led to major changes in societal values (Garel & Petit-Romec 2021; Chen and Xie 2022). This transition is especially relevant in the realm of corporate practises, as organisations endeavour to synchronise their operations with ethical and sustainable ideals, as seen by the increasing focus on ESG factors in capital markets. Nevertheless, in developing markets such as the Chinese market, environmental, social and governance performance (ESGP) assessment is still in its early stages. Investors in such markets tend to prioritise speculating rather than focusing on crucial aspects (Feng et al. 2022).

The introduction and execution of the Chinese national sustainable development strategy has prompted regulatory authorities to increase their focus on evaluating listed enterprises' ESGP. Since the issuance of the *Guidelines for Building a Green Financial System* in 2016 by the Bank of China, along with other government agencies and commissions, ESG considerations have gained widespread

recognition across various sectors of Chinese society (Cheng et al. 2022; Feng et al., 2022). However, despite the growing attention to ESGP, there remains limited empirical evidence on its direct and interactive effect on critical financial risks, such as SPCR, particularly in emerging markets like China. Although several studies have analysed ESGP's individual effect on firm performance (Alatawi et al. 2023; Bae et al. 2021; Gerged et al. 2023; Murata and Hamori 2021; Orazalin et al. 2024), and market outcomes (Gerged et al 2024; Khan et al. 2024; Komal et al. 2022; Tan et al. 2022), few have explored its potential to mitigate or exacerbate financial risks like SPCR (Li et al. 2022; Huang et al. 2024; Wang et al. 2023a, b). This gap in literature underscores the need for a more nuanced understanding of how ESGP intersects with corporate governance factors, such as BGD, to influence SPCR. Investigating this relationship, particularly in emerging markets where corporate governance structures are still evolving (Huang et al. 2024; Saha and Khan 2024a, b), provides a unique study setting. The interaction between ESGP and BGD may reveal complex relationships that are not immediately apparent in more developed markets, where governance mechanisms are more established. Additionally, the rapid growth of China's stock market, coupled with its regulatory developments in ESG (Li et al. 2022), presents an opportunity to explore how corporate governance and sustainability practices can act as mitigating forces against stock price crashes. Understanding this interplay is crucial, as it may offer valuable insights for investors and policymakers seeking to enhance market stability in emerging economies.

Recently, the literature has presented two different yet complimentary viewpoints that provide insight into the relationship between sustainability concerns, business dynamics, and stock market returns. The initial viewpoint, demonstrated by research conducted by Garel and Petit-Romec (2021) and Ong and Han (2019), emphasises the favourable association between ESG disclosure and corporate financial performance. Transparent disclosure of ESG information is believed to improve corporate reputation, facilitate access to financing, and provide a competitive edge for companies as they confront environmental concerns (Ben-Porath et al. 2018; Bofinger et al. 2022; Gillan et al. 2021).

Theoretical frameworks such as stakeholder and signalling theories highlight the importance of satisfying stakeholders' expectations in defining the market value (Shakil 2021). Moreover, the unprecedented occurrence of the COVID-19 pandemic has compelled investors to reassess the influence of environmental and ethical factors on business growth, with ESG disclosures playing a vital role in evaluating risks and making investment decisions (Garel & Petit-Romec 2021).

Conversely, the second viewpoint, illustrated by studies like the one carried out by Ren et al. (2021), focuses on the association between ESG involvement and the reduction of unethical behaviour by managers, especially in markets with inadequate legal and institutional structures, such as China. The article posits that robust ESG engagement serves as a deterrent to management misbehaviour by cultivating ethical norms and establishing a favourable external monitoring milieu through heightened scrutiny from analysts and brokerage firms. This viewpoint adds to the current debate on corporate governance by examining how the internal processes of ESGP affect the behaviour of firms. It also fits with the United Nations Global Compact's inclusion of ESG components in 2004 (Albuquerque et al. 2019).

Building on these perspectives, our research addresses a critical gap in understanding how the interaction between ESGP and BGD influences SPCR, particularly within the unique context of emerging markets like China. As companies face the complex interplay between ethical responsibility, environmental factors, and financial performance, investigating the combined influence of ESGP and BGD is critical for identifying the factors that impact the risk of stock price crashes. Unlike previous studies by Atif and Ali (2021) and Egginton and McBrayer (2019), which emphasise the financial aspects, and Ren et al. (2021), which explore the connection between ESGP and manager misconduct, our research takes a unique approach to provide a comprehensive understanding of the various factors influencing business behaviour and market outcomes.

Furthermore, our research thoroughly examines how BGD interacts with ESGP. Previous studies investigated the influence of gender diversity on corporate misconduct (Gupta et al. 2020). However, our study goes further by examining how BGD affects the relationship between ESGP and SPCR. This sophisticated approach enables us to analyse potential harmonies or conflicts between these two crucial aspects of corporate governance, thus providing a more comprehensive understanding of the complex mechanisms involved. In addition, our research presents new datasets obtained from Chinese institutional investors, providing a distinct viewpoint on the moderating influence of ESGP in gender diversity and SPCR nexus.

Our study explores the complex interactions between these dimensions as stakeholders become more aware of their importance in influencing business behaviour and market outcomes. By investigating this interaction, our research offers valuable insights into mitigating SPCR while promoting sustainable and inclusive corporate practices, addressing both theoretical and practical gaps in the current literature. Our study contributes to the existing literature as follows: *Firstly*, it provides a comprehensive examination of the joint effect of ESGP and BGD on SPCR, offering a novel perspective by integrating both variables to enhance the understanding of their collective impact. This approach differs from previous studies, which have often analysed them in isolation. *Secondly*, this study focuses on Chinese

A-share listed companies during the period (2015- 2022) and employs three-stage Least-Square (3SLS) estimations to address endogeneity issues while testing the hypothesis. The empirical findings reveal a negative association between ESGP and SPCR, indicating that higher ESGP can reduce the likelihood of stock price crashes. *Finally*, the paper uncovers a positive association between BGD and the likelihood of SPCR. However, the interaction between ESGP and BGD demonstrates a negative association with SPCR, suggesting that ESGP moderates the increased risk of SPCR associated with higher BGD.

The rest of the paper is organised as follows: Sect. "Background" provides the literature review and hypothesis development, while Sect. "Theoretical framework" outlines the data and research design. Sect. "Literature review and hypothesis development" presents the results, followed by further analysis in Sect. "Research design and methodology". Sect. "Results and discussions" examines the interaction effect, and Sect. "Summary and conclusion" concludes with key findings and implications.

Background

The context of Chinese companies listed in the A-share market between 2015 and 2022 is particularly appropriate for conducting a study that exploits regulatory and policy issues and developments for several reasons: The A-share market experienced a significant crash in 2015, leading to heightened regulatory scrutiny and reforms. This period saw the Chinese government and regulatory bodies, such as the China Securities Regulatory Commission (CSRC), implement measures to stabilise the market, including circuit breakers, stricter margin trading rules, and enhanced oversight of listed companies (Lennox and Wu 2022). These reforms provide a rich framework to study the impact of regulatory changes on corporate behaviour and market performance. During this period, China continued to open its capital markets to foreign investors through programs like the Shanghai-Hong Kong Stock (Zhang et al. 2022a, b; Hossain et al., 2025). These developments offer insights into how regulatory changes aimed at increasing market accessibility influence the behaviour of domestic companies and investor sentiment. The Chinese government began emphasising ESG reporting and sustainable investing during this period when SynTao Green Finance began disclosing ESG performance scores in 2015 via the WIND database, marking the initiation of more comprehensive ESG data availability (UNEP Finance Initiative, 2019).

This timeline allows for acquiring comprehensive and dependable data on ESG disclosures while reflecting the changing regulatory environment in China. The selection of A-shares is notably significant due to their prominence in the Chinese equity market and their unique regulatory stipulations, guaranteeing enhanced uniformity in reporting standards among companies (Hossain et al., 2025). The period from 2015 to 2022 was chosen for two principal reasons. In 2015, Chinese enterprises began consistent and reliable reporting on ESG issues as legal frameworks and voluntary sustainability disclosures gained substantial momentum. Secondly, the study period ends in 2022 to alleviate potential distortions resulting from the COVID-19 pandemic, which had significant and unusual impacts on business operations and SPCR across multiple industries. Table 2 illustrates the sample selection process and the classification of firms across various industries.

Theoretical framework

Stakeholder theory posits that a company's prosperity and long-term viability hinge upon its ability to accommodate the needs and concerns of various stakeholders, including employees, suppliers, customers, communities, and society at large (Freeman 1984). Companies face significant pressure from stakeholders to address sustainability issues by disclosing their environmental impacts and implementing initiatives to reduce their actual greenhouse gas (GHG) emissions (Orazalin et al. 2024). When companies provide high-quality ESG disclosure, they signal their dedication to long-term value creation and trust-building among stakeholders (Dhaliwal et al. 2011; Deng et al. 2013). This enhanced perception leads stakeholders to recognise the firm more positively, fostering a greater inclination to hold long-term investments, which, in turn, contributes to more stable stock prices (Jones 1995). High ESG scores indicate a firm's active commitment to the environment and social responsibility, enhancing both long-term value and corporate reputation (Wong et al. 2021). As a result, stakeholders recognise the firm more favourably, fostering their willingness to hold long-term investments and contributing to more stable stock prices (Jones 1995).

Signalling theory suggests that strong ESG engagement reflects the high ethical standards of a company's managers, making them more likely to provide high-quality ESG disclosures (Hummel & Schlick 2016; Da Silva 2022). According to this theory, a firm's commitment to social and environmental responsibility sends a positive signal to the market (Spence 1973; Liu et al. 2022), potentially enhancing financial performance and reducing stock price crashes. Investors rely on the quality and quantity of these signals to make well-informed decisions. By leveraging such signals through ESG information, firms can enhance transparency and bridge the information gap, leading to more informed investing decisions (Wu & Hu 2019).

Stakeholder theory and signalling theory can be integrated to explain the relationship between ESGP and SPCR. Stakeholder theory highlights the importance of accommodating stakeholders' interests to ensure long-term value creation (Freeman 1984), while signalling theory adds depth by emphasising how ESG disclosures communicate a firm's quality and commitment to stakeholders (Spence 1973). For example, high-quality ESG disclosures serve as credible signals that reduce information asymmetry and align stakeholders' interests with managerial goals (Jafar et al. 2024). These signals foster trust and long-term engagement, enhancing financial stability and reducing SPCR. The interplay between these theories underscores how ESGP addresses stakeholders' demands and acts as a strategic tool to build reputational capital and attract socially responsible investors.

In addition, we argue that integrating stakeholder theory and signalling theory can explain the role of BGD in mitigating SPCR. Stakeholder theory emphasises the inclusion of diverse voices on corporate boards as a means to ensure that various stakeholder interests are considered (Kang et al. 2007). Diverse boards, particularly those with greater female representation, are often more attuned to social and environmental concerns, which align with stakeholders' broader interests. Signalling theory complements this by asserting that board gender diversity signals a firm's commitment to ethical governance and progressive management practices, which enhances its reputation and reduces information asymmetry (Karasek & Bryant 2012). Thus, board gender diversity not only fulfils stakeholders' expectations but also sends credible signals about a firm's governance quality, strengthening the link between board composition and reduced crash risk.

Literature review and hypothesis development

ESGP and SPCR

Previous studies indicate a positive relationship between climate change initiatives and the market value of firms in 35 countries (Orazalin et al. 2024). Using empirical data from 899 Nordic, Saha and Khan (2024a) found a strong link between ESG initiatives, corporate governance dimensions and financial performance metrics among the surveyed Nordic companies. Additionally, Alatawi et al. (2023) conducted a systematic review of the CSR literature and found that CSR practices positively influence firm financial performance and can enhance firm value by strengthening stakeholder support and, ultimately, increasing valuation.

Using the lens of stakeholder theory, prior research investigated how ESGP affected the likelihood of price crash and found mixed results. Zhou et al. (2021) examined the impact of three CSR dimensions on SPCR by analysing a sample of all listed companies in China during the period (2010–2017). The findings reveal that CSR significantly reduces SPCR, particularly a firm's commitment to the environment and stakeholders. Additionally, reducing earnings management acts as a mechanism through which CSR and stakeholder engagement help mitigate SPCR. Analysing a large sample from the Chinese stock market, Wang et al. (2023a, b) examined the spillover of crash risk indexes across ESG networks from 2015 to 2020. Their findings indicate that stock groups with commendable ESGP tend to experience reduced crash risk.

Further, Dumitrescu and Zakriya (2021) examined the role of CSR initiatives in mitigating SPCR. Their findings indicate that the social CSR dimension largely determines managerial bad news hoarding and subsequent stock crashes, especially in undervalued firms. Feng et al. (2022) examined the association between ESG ratings and SPCR for all Chinese-listed firms from 2009 to 2020. They found a significant negative association between them, which aligns with the stakeholder theory. Additionally, Gao et al. (2022) examined the effect of corporate ESGP on SPCR in Chinese A-share listed companies from 2010 to 2020. Their results suggest that ESGP reduces the likelihood of stock price crashes by attracting greater attention from environmentally conscious investors. Similarly, Yu et al. (2023) analysed the ESG news-based sentiment and the related crash risk indicators of all Chinese A-share listed companies from 2010 to 2021. They found a strong negative association between ESG news sentiment and SPCR, particularly among firms with limited information transparency, lower analyst coverage, and those that are non-state-owned.

Previous studies adopted the signalling theory to explain how a signalling firm's actions impact investors' reactions within the capital market. For instance, Wu and Hu (2019) investigated the effect of CSR components, such as corporate governance and environmental protection, on mitigating SPCR in China's energy industry. The findings indicate a negative association between CSR and SPCR. Liu et al. (2022) explored the association between green commitment and the SPCR of the Chinese listed firms from 2010 to 2018. The findings reveal that a strong commitment to green practices significantly lowers the SPCR, especially in non-state-owned firms and during periods of stock market downturns. Similarly, Jung and Song (2023) investigated the effect of managers' perspectives on climate change on SPCR and provided evidence of a negative association between them. Their results suggest that investor attention and analyst coverage are key mechanisms through which a firm's stance on climate change enhances financial stability, thereby lowering crash risk.

This dual-theoretical framework connects ESGP to SPCR by explaining how stakeholder engagement and market signalling contribute to financial resilience.

H_1. ESG performance negatively affects stock price crash risk.

Board gender diversity and stock price crash risk

Board diversity has recently experienced increasing interest from researchers, businesses, and policymakers, particularly following the global financial crisis and the challenges brought about by COVID-19 on companies and the global economy (Hosny & Elgharbawy 2022). Firms may choose to include female directors not just to meet regulatory requirements but to build stronger connections with diverse industry groups, attract valuable resources, and enhance their corporate reputation and legitimacy (Saha and Khan 2024b). Stakeholder theory advocates argue that stakeholders' representatives should be included on the board to ensure the protection of all stakeholders' interests (Kang et al. 2010; AlQahtani & Elgharbawy, 2020). From the signalling theory perspective, BGD provides a credible signal to the market, reflecting a firm's dedication to ethical practices and sustainability. This helps reduce information asymmetry and decreases managerial bad news hoarding, ultimately lowering price crash risk.

The literature suggests that BGD enhances disclosure of GHG information (AlQahtani & Elgharbawy, 2020), improves financial performance (Hosny & Elgharbawy 2022; Khan et al., 2024), reduces tax avoidance (Elgharbawy & Aladwey 2025), and improves ESGP of companies (Shakil et al. 2021) boosting investor cash flow (Jizi 2017). Some studies found that a higher percentage of women on the board of a firm is associated with reduced volatility and risk (Qayyum et al., 2021). Sila et al. (2016) found that a board with a balance of female and male members is exposed to less risk than one dominated by males, probably because female board members are risk-averse. In contrast, Bruna et al. (2019) conclude that BGD has no discernible impact on the risk-taking of firms. Overall, Prior research that investigated the relationship between BGD and ESGP provides mixed results (negative, positive, and no significant effect) (Rao and Tilt 2016; Nadeem et al. 2017; Cucari et al. 2018; Shahbaz et al. 2020; Shakil., 2021).

However, a limited number of studies have investigated the link between board diversity and SPCR (Andreous et al., 2016; Yeung & Lento 2018). For instance, Lee et al. (2019) explored whether corporate diversification can serve as a potential predictor of future SPCR. Using a sample of Malaysian firms and data from 2010 to 2015, they present evidence that diversification has a mitigating effect on crash risk, particularly in firms with gender-diverse boards. Kao et al. (2020) investigated the effect of the board of directors'

composition on crash risk in Chinese firms. The findings reveal that non-co-opted independent directors play a mitigating role in reducing crash risk, especially for female directors.

Similarly, Le et al. (2022) examined the effect of insider trading and board characteristics on future SPCR using a sample of 354 major companies listed in 8 markets over the period from 2008 to 2016. They found that having female directors on boards can help mitigate SPCR. Further, Qayyum et al. (2021) investigated the impact of BGD on SPCR at the firm level across twelve Asia–Pacific markets, utilising a dataset of 1,021 listed firms covering the period from 2006 to 2016. Their findings demonstrate that BGD helps reduce SPCR, particularly when firms have three or more female directors on their boards.

H_2. Board gender diversity negatively affects stock price crash risk.

Interaction effect of ESG performance and board gender diversity on stock price crash risk

While both ESGP and BGD are individually expected to mitigate SPCR, their interaction could either reinforce or hinder the positive outcomes they produce individually. Despite the significance of understanding the interplay between ESGP and BGD and whether they complement or substitute each other in terms of their effect on SPCR, prior research has not explored the interactive impact between these variables. Female executives typically exhibit distinct leadership styles and organisational techniques compared to their male counterparts (Shakil 2021). Female board members commonly prioritise environmental and social welfare, while male board members tend to prioritise maximising earnings (Arayssi 2020; Shakil 2021). Women prioritise stakeholders and refrain from engaging in strategic measures that could be detrimental to society (Adams et al. 2011). In addition, female board members provide a range of ecologically and socially conscious solutions, hence enhancing organisations' ability to make informed strategic decisions about environmental and social matters (Cumming et al. 2015). Increased female involvement on corporate boards also reduces the number of environmental lawsuits filed against firms (Dadanlar and Abebe 2020).

A very limited number of studies have addressed the interaction effect of ESGP and BGD on SPCR, including Chebbi (2024), who explored the relationship between ESG disclosures, as well as board characteristics on SPCR in a sample of 38 Saudi-listed firms from 2013 to 2021. The findings reveal a significant and negative association between ESGP and SPCR, suggesting that strong ESGP enhances stock price stability. Additionally, board characteristics, including BGD, are found to moderate the relationship between ESGP and SPCR. However, the small sample size

of Saudi companies limits the generalisability of the findings to other emerging markets with differing regulatory frameworks and corporate structures. Moreover, while the study discussed various theories to address the research problem, it did not explicitly adopt a specific theoretical framework.

To address this gap in the literature (see Table 1), we argue that the interaction between ESGP and BGD can be analysed through the combined lenses of stakeholder theory and signalling theory. Stakeholder theory posits that firms with gender-diverse boards and strong ESGP are better equipped to address stakeholders' needs comprehensively, while signalling theory posits that the simultaneous presence of these two factors amplifies the credibility of signals sent to investors. Gender-diverse boards, with their emphasis on risk-averse and socially conscious decision-making, enhance the effectiveness of ESG signals by ensuring transparency and reducing the likelihood of information asymmetry (Sila et al. 2016). The perceived credible signals attract investors

seeking socially responsible firms, leading to greater financial stability. Thus, by linking ESG performance and board gender diversity, the combined theoretical framework explains how firms create an environment of trust, transparency, and resilience, directly contributing to mitigating SPCR.

H_3. The interaction between ESG performance and board gender diversity is negatively associated with stock price crash risk.

Research design and methodology

Sample and data

This study obtained data from three databases: WIND database, China Stock Market and Accounting Research (CSMAR), and Bloomberg database. These sources include comprehensive economic and financial information and

Table 1 Sample selection & distributions of A-shares Chinese firms based on industry (2015- 2022)

Sample selection	Number of firm-years
Initial sample (A-share listed firms in CSMAR database) during the period (2015–2022)	9,648
Less	
Stocks with implemented risk warnings (ST, *ST)	324
Financial services companies	632
Listed companies issuing B and H shares	363
Observations with missing data on other variables	721
Final sample	7608

Distributions of A-shares Chinese firms based on industry (2015- 2022)

Industry name	Count	Percentage (%)
Agriculture, forestry, animal husbandry, fishery	483	6.35
Mining	323	4.25
Manufacturing	2502	32.89
Utilities (Water, electricity, gas)	539	7.09
Construction	192	2.52
Wholesale and retail	370	4.86
Transportation and warehousing	235	3.09
Accommodation and food services	178	2.34
Information technology	951	12.5
Real estate	444	5.83
Business services	96	1.26
Scientific research services	86	1.13
Public environmental protection	95	1.25
Other services	83	1.09
Education	161	2.11
Health	625	8.22
Cultural communication	97	1.28
Comprehensive	148	1.94
Total	7608	100%

data on ESG attributes related to sustainability indices. The final sample was 7,608 firm-year observations for 951 Chinese A-share listed firms, covering reporting periods (2015–2022). Notably, SynTao Green Finance began disclosing ESG performance scores (ESGP) in 2015 via the WIND database, marking the initiation of more comprehensive ESG data availability (UNEP Finance Initiative, 2019) (Table 2).

Empirical model

Trinh et al. (2023) have pointed out that there may be a causal connection between ESGP and SPCR, which could result in biases related to endogeneity. Therefore, we conduct a baseline regression analysis using 3SLS estimations to examine the impact of BGD and ESGP in Chinese-listed firms on their SPCR from 2015 to 2022.

To tackle the potential endogeneity issue, we follow the approach of He et al. (2022) and Luo et al. (2023) by using the intensity of Confucian culture at the city level as an instrumental variable. This choice is justified by the significant influence of China's institutional and cultural environments on business practices. Traditional Confucian ethical principles, in alignment with contemporary corporate ESG principles, are essential aspects of Chinese cultural traditions, thus impacting firms' adoption of ESG practices (Luo et al. 2023). To quantify the concentration of Confucian culture, we use the number of academies spreading Confucian culture in each city. We find that the strength of regional Confucian culture does not have a direct impact on SPCR, validating its appropriateness as an instrumental variable for encouraging environmental and ethical practices among Chinese businesses. Regression model (1) portrays the effect of ESGP and BGD on SPCR.

$$\text{SPCR}_{it} = \beta_0 + \beta_1 \text{ESGP}_{it} + \beta_2 \text{BGD}_{it} + \delta \text{Control}_{it} + \text{Industry}_{it} + \text{Year}_{it} + \varepsilon_{it} \tag{1}$$

In addition, we test the interaction effect between both ESGP and BGD on SPCR in the regression model (2) as follows:

$$\text{SPCR}_{it} = \gamma_0 + \gamma_1 \text{ESGP}_{it} + \gamma_2 \text{BDG}_{it} + \gamma_3 (\text{BDG}_{it} * \text{ESGP}_{it}) + \delta \text{Control}_{it} + \text{Industry}_{it} + \text{Year}_{it} + \varepsilon_{it} \tag{2}$$

Variables measurement

Dependent variable: stock price crash risk

We constructed three measures of SPCR, following Kim et al. (2011), Zaman et al. (2021), and Feng et al. (2022). We begin by estimating firm-specific weekly returns for each firm and each year using the following time-series regression:

$$r_{j,t} = \alpha_j + \beta_{1,j} r_{m,t-2} + \beta_{2,j} r_{m,t-1} + \beta_{3,j} r_{m,t} + \beta_{4,j} r_{m,t+1} + \beta_{5,j} r_{m,t+2} + \varepsilon_{j,t} \tag{3}$$

where $r_{j,t}$ represents the stock return of stock j in week τ, including cash dividends reinvestment and $r_{m,t}$ denotes the value-weighted return of all shares within the same week. The idiosyncratic return of stock j in week τ is $W_{j,t} = \ln (1 + \varepsilon_{j,t} \text{ j}, \tau)$, where $\varepsilon_{j,t}$ is the error term from Regression (1).

We calculate the three measures of SPCR using the idiosyncratic return (Feng et al. 2022). The first measure is the negative coefficient of skewness (NCSKEW).

$$\text{NCSKEW}_{J,T} = \left[n(n-1)^{3/2} \sum_{j,t} W^3 \right] / \left[(n-1)(n-2)(\sum_{j,t} W^2)^{3/2} \right] \tag{4}$$

n represents the number of trading weeks of stock j during the year. A higher *NCSKEW* value means higher SPCR.

The second measure is the down-to-up volatility (DUVOL).

$$\text{DUVOL}_{j,T} = \log \{ (n_U - 1) \sum_{\text{down}} W_{i,t}^2 / (n_D - 1) \sum_{\text{up}} W_{i,t}^2 \tag{5}$$

where n_u/n_d denotes the number of weeks where the idiosyncratic return of stock j, $W_{j,t}$ is higher or lower than its average for the year. A higher DUVOL value signals greater crash risk (Wen et al. 2019; Zaman et al. 2021; Zhang et al. 2022a, b; Feng et al. 2022).

The third measure is Crash following Zhang et al. (2022a, b) is defined as follows:

$$\text{Crash}_{i,t} = 1 \left[W_{i,s} \leq \text{Average} (W_{i,s}) - 3.09 \sigma_{i,s} \right]$$

1[0] represents the indicator function. When a firm-specific weekly returns $W_{i,s}$ fall more than the area of 3.09 standard deviations below the average weekly return for firm i in a given fiscal year t, the Crash variable is set to 1, indicating a stock crash. Otherwise, it is set to 0.

Independent variable: ESG performance

We obtained information on ESG performance indices from reputable Chinese rating organisations that issue ESG rating reports; consequently, all ESGP indices are accessible in the WIND database. To measure ESGP, we used the SynTao Green Finance (STGF) ESG rating index (ST-ESG) as a unique database assessment of companies' ESGP ranging

Table 2 Variable definitions

Variables		Abbreviations	Definitions	Source
Dependent variable	SPCR	NCSKEW	The negative coefficient of skewness is calculated by taking the negative of the third moment of firm-specific weekly returns for each sample year and dividing it by the standard deviation of firm-specific weekly returns raised to the third power	CSMR Database
		DUVOL	Down-to-up volatility is calculated by first dividing all weeks of firm i in year $t+1$ into two groups: (1) weeks with firm-specific weekly returns below the annual mean (down weeks) and (2) weeks with firm-specific weekly returns above the annual mean (up weeks). The standard deviation is then computed separately for each group. Finally, the natural logarithm of the ratio of the standard deviation of down weeks to the standard deviation of up weeks is taken	
		Crash	A dummy variable is set to 1 if a firm experiences at least one crash week during year $t+1$, and 0 otherwise. A crash week is defined as a calendar week where the firm-specific weekly return falls by 3.09 or more standard deviations below the mean of the firm-specific weekly returns for year $t+1$	
Independent variables	ESG performance	ESGP	The ESG rating index (ST-ESG) measures environmental performance, with ratings ranked on an ordinal scale from 1 to 10, where 1 represents the lowest and 10 represents the highest level of environmental performance for companies during the year	WIND Database & Bloomberg database
	Board gender diversity	BGD	It is represented as a dummy variable that equals 1 if the firm has at least one female director and 0 otherwise	CSMR Database
Control variables	Board size	BSIZE	The total number of directors serving on the board	CSMR Database
	Board meeting	BMEET	Number of meetings held by the board of directors	
	CEO Duality	Dual	A dummy variable is set to 1 if the CEO also holds the position of chairman and 0 otherwise	
	Board tenure	BTENUR	The mean duration of directors' service on the board	
	Institutional investors	Instinvest	The percentage of shares held by institutional investors	
	State shares	Stateshare	The percentage of shares held by government entities	
	Foreign investors	Finvestor	The proportion of shares owned by foreign investors	
	Firm size	Fsize	Measured as the natural logarithm of total assets at the end of the fiscal year	
	Leverage	Lev	Calculated as total debt divided by total assets	
	Return on assets	ROA	Net income divided by total assets	
	RET	RET	The mean of firm-specific weekly returns over the fiscal year	
	SIGMA	Sigma	The standard deviation of firm-specific weekly returns over the fiscal year	
	Market to Book ratio	MTB	Total market value /total assets	
	R&D investment	R&D	The ratio of research and development (R&D) expenditures to operating income	
	Growth	Growth	The annual percentage increase in business revenue	
	Herfindahl–Hirschman index	HHI	The HHI index is calculated as follows: $Hhi = \sum_{i=1}^{n} P_i^2$ Where **n** represents the number of industries in which the company operates, while P_i denotes the proportion of industry income for the company **i** relative to its total revenue	

from 1 to 10 on an ordinal scale (Landi & Sciarelli 2018; Zhang et al. 2023; Maire et al., 2024a).

Moderating effect: board gender diversity

We also used two measures of board gender diversity. First, a dummy variable is used, which equals 1 if there is at least one female director and 0 otherwise. Second, an alternative dummy variable is employed, which equals 1 if there are three or more female directors on the board and 0 otherwise (Brahma et al. 2021; Kyaw et al. 2022; Sattar et al. 2023; Marie et al. 2024b).

Control variables

We control for a range of firm-level characteristics typically related to financial performance. The control variables comprise: board size (Faleye & Krishnan 2017; Marie et al. 2021; Elnahass et al. 2022); board meetings (Liang et al. 2013; Elnahass et al. 2022); CEO Duality (Marie et al. 2021; Elnahass et al. 2022), board tenure, age diversity (Tihanyi et al. 2000), institutional investors, state ownership, foreign Investors. In addition, we control for firm size (Benlemlih & Girerd-Potin 2017), financial leverage, R&D investment, growth opportunity,

and firm age (Trinh et al. 2023). Additionally, we incorporate the Herfindahl–Hirschman Index (HHI) to control for static competition levels, as well as industry fixed effects (INDUSTRY), and year dummies (YEAR) (Hoberg et al. 2014). Table 3 provides the definitions and notations of the variables used in our models.

Results and discussion

Descriptive statistics

Table 4 presents the descriptive statistical analysis for the key variables. The mean and median values of NCSKEW are −29% and −26%, respectively, with a standard deviation of 70%. For DUVOL, the mean and median values are −20% (−20%), with a standard deviation of 48%. However, for the Crash variable, approximately 11% of the firm-year observations are associated with at least one crash event. This result demonstrates a notable inconsistency in the likelihood of SPCR across the sample, aligning with the results of Feng et al. (2022). Furthermore, the mean value of ESGP is 5.123, with a standard deviation of 66%, suggesting a significant degree of ESGP, and the values exhibit considerable variation across all Chinese enterprises. The outcome is aligned with the findings of Broadstock et al. (2021). The mean value of BGD is 34.2%, reflecting the widespread presence

Table 3 Descriptive statistics

Variable	N	Mean	SD	Min	p25	p50	P75	Max
NCSKEW	**7608**	−0.291	0.707	−2.425	−0.690	−0.261	0.0126	1.799
DUVOL		−0.209	0.482	−1.373	−0.534	−0.209	0.103	1.096
Crash		0.113	0.318	0	0	0.109	0	1
ESGP		5.123	0.665	3.39	5.090	4.71	5.550	6.88
BGD		0.342	0.474	0	0	0.340	1	1
BSize		0.948	0.099	0 .698	0.903	0.954	1	1.204
BMEET		1.007	0.174	0 .602	0.903	1	11.114	1.447
Dual		0.223	0.416	0	0.219	0	0	1
BTENUR		1.653	0.169	1.162	1.547	1.662	1.769	2.015
Instinvest		3.833	0.712	−8.112	3.656	4.055	4.278	4.554
Stateshare		2.901	1.371	−1.171	2.012	3.474	3.942	4.289
Finvestor		2.177	1.152	−0.494	1.353	2.471	3.279	3.399
LOGSize		23.815	1.551	20.983	22.749	23.547	24.572	29.413
Lev		0.49271	0.209	0.077	0.331	0.492	0.646	0.932
ROA		0.058	0.066	−0.176	0.015	0.039	0.088	0.253
RET		0.003	0.009	−0.015	−0.003	0.002	0.008	0.033
Sigma		0.060	0.024	0.020	0.043	0.056	0.072	0.139
Growth		0.190	0.533	−0.586	−0.016	0.104	0.259	3.863
MTB		2.030	3.413	0.076	0.414	0.898	2.067	21.972
R&D		5.60	1.54	0	2.060	5.540	4.520	9.98
HHI		0.167	0.188	0.026	0.097	0.066	0.175	1

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

Table 4 Pairwise correlations

Variables	VIF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) NCSKEW		1.000											
(2) DUVOL		0.582*	1.000										
(3) Crash		0.501*	0.417*	1.000									
(4) ESGP	1.04	0.046*	0.048*	0.030*	1.000								
(5) BGD	1.01	−0.003	−0.016	0.021	−0.002	1.000							
(6) BSize	1.19	0.015	0.025*	0.011	0.109*	−0.012	1.000						
(7) Dual	1.08	−0.009	−0.008	0.002	−0.026*	−0.008	−0.051*	1.000					
(8) BMEET	1.08	−0.015	−0.013	−0.002	−0.109*	−0.013	−0.179*	0.011	1.000				
(9) BTenur	1.04	−0.021	−0.013	−0.007	0.001	0.001	−0.049*	−0.065*	0.038*	1.000			
(10) Instinvest	1.19	−0.022	−0.019	−0.043*	0.030*	0.016	0.049*	−0.020	−0.030*	−0.060*	1.000		
(11) Stateshare	1.12	−0.025*	−0.025*	−0.014	−0.011	0.025*	0.078*	−0.009	−0.018	−0.035*	0.308*	1.000	
(12) Finvestor	1.03	0.028*	0.025*	−0.014	0.010	0.005	−0.008	0.023	−0.028*	−0.041*	0.135*	−0.009	1.000
(13) Firm size	2.84	0.018	0.030*	−0.005	0.155*	−0.010	0.349*	0.128*	−0.165*	−0.037*	0.072*	0.058*	0.030*
(14) ROA	1.42	0.012	0.016	−0.001	0.068*	−0.007	0.222*	0.209*	−0.118*	−0.116*	0.062*	0.051*	0.015
(15) Lev	2.36	−0.023	−0.009	0.014	−0.026*	0.000	−0.098*	−0.111*	0.150*	0.092*	−0.027*	−0.033*	−0.003
(16) Ret	1.42	−0.177*	−0.190*	−0.176*	0.007	0.002	−0.024*	−0.023	0.007	0.019	0.013	−0.053*	0.039*
(17) Sigma	1.44	−0.129*	−0.137*	−0.037*	−0.023	−0.008	−0.052*	0.003	0.022	0.040*	−0.118*	−0.022	−0.007
(18) Growth	1.10	−0.034*	−0.027*	−0.029*	−0.045*	0.018	−0.048*	0.101*	0.040*	−0.071*	−0.016	−0.002	0.001
(19) MTB	2.27	0.024	0.027*	0.000	0.107*	−0.038*	0.299*	0.079*	−0.110*	−0.071*	0.050*	0.038*	0.032*
(20) R&D	1.06	−0.029*	−0.040*	−0.024	0.047*	0.042*	0.015	−0.021	0.049*	−0.021	0.186*	0.078*	0.006
(21) HHI	1.02	−0.019	−0.008	−0.005	0.001	0.014	0.032*	−0.009	−0.015	−0.068*	0.027*	0.044*	−0.003

Variables	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
(13) Firm size	1.000								
(14) ROA	0.662*	1.000							
(15) Lev	−0.231*	−0.468*	1.000						
(16) Ret	−0.038*	−0.021	−0.001	1.000					
(17) Sigma	−0.101*	−0.069*	0.040*	0.525*	1.000				
(18) Growth	−0.015	0.016	0.212*	0.024	0.013	1.000			
(19) MTB	0.527*	0.586*	−0.272*	0.018	0.040*	−0.054*	1.000		
(20) R&D	−0.004	0.012	0.018	0.011	0.009	−0.081*	−0.027*	1.000	
(21) HHI	0.076*	0.042*	0.009	−0.084*	−0.029*	0.008	0.083*	−0.042*	1.000

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

Table 5 The effect of ESG performance on stock price crash risk

	Panel A	Panel B	Panel C
	NCSKEW	DUVOL	Crash
ESGP	− 0.435*** (− 1.43)	− 0.331*** (− 3.66)	− 0.218*** (− 3.70)
BGD	0.017*** (0.83)	0.004** (0.27)	0.016**(2.28)
BSize	0.076** (0.32)	0.034** (1.73)	0.193*** (2.97)
Dual	0.021 (0.12)	0.034** (0.77)	− 0.022** (− 1.98)
BMEET	− 0.107** (− 1.87)	− 0.074** (− 1.92)	0.003 (0.16)
BTENURE	− 0.117** (− 1.99)	− 0.045** (− 1.59)	− 0.028 (− 1.38)
Instinvest	− 0.043** (− 2.00)	− 0.042** (− 1.57)	− 0.381 (− 1.01)
Stateshare	− 0.001** (− 1.68)	− 0.021** (− 1.92)	− 0.001** (− 2.50)
Finvestor	0.014** (2.31)	0.003** (2.04)	0.004 (0.02)
LOGSize	− 0.002 (− 0.14)	0.007 (0.77)	− 0.002 (− 0.43)
ROA	− 0.132 (− 0.96)	− 0.021 (− 0.17)	0.226*** (3.31)
Lev	0.061 (0.83)	0.042 (0.86)	0.056**(2.17)
Ret	− 14.277*** (− 10.86)	− 10.754*** (− 12.09)	− 8.544*** (− 15.48)
Sigma	− 1.867*** (− 3.66)	− 1.245*** (− 3.31)	1.371*** (7.26)
Growth	− 0.031** (− 1.65)	− 0.013 (− 1.04)	− 0.023*** (− 3.31)
MTB	0.009 (1.55)	0.002 (0.65)	0.001 (0.27)
R&D	− 0.001*** (− − 3.36)	− 0.002*** (− 3.94)	− 0.001 (− 0.69)
HHI	− 0.064** (− 1.12)	− 0.082** (− .162)	− 0.034** (− 1.84)
Constant	− 2.643*** (− 4.21)	− 2.323*** (− 5.32)	1.265*** (4.10)
Fixed Effects	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes
Observations	7608		
R2	0.34	0.46	0.29
LM Statistics (*p*-value)	0.000	0.000	0.000
Sargan test (*p*-value)	0.638	0.639	0.583

Note: Table 4 presents three-stage least-square (3SLS) estimations for the full sample of Chinese firms identifying the impact of ESGP on a firm's SPCR, which is measured by (NCSKEW (Panel A), DUVOL (Panel B), and Crash (Panel C)

of female board members in Chinese-listed firms. Descriptive statistics for the other variables generally align with the previous literature (Chen & Xie 2022). Table 5 shows the Pearson correlation coefficients for all study variables, confirming that multicollinearity is not a major concern, as no explanatory variables exhibit high correlations (below 0.7), and the variance inflation factors (VIFs) are all under 10.

Multivariate analysis

The effect of ESGP and BGD on SPCR

In Table 6, we report the 3SLS estimations for the baseline results for ESGP and SPCR based on Eq. (1). We found that the ESGP is negatively and significantly associated with all measures of SPCR (NCSKEW, DUVOL and Crash), at the 1% level, which supports our first hypothesis (H_1). These findings suggest that Chinese companies exhibiting strong ESGP are relatively more resilient to SPCR. This underscores investors' concerns not only about a company's

profitability and market performance but also about its ESGP. The findings align with the predictions of both stakeholder theory and signalling theory. Stakeholder theory posits that firms prioritising broader stakeholder interests, such as environmental and social considerations, are more likely to build trust and reduce information asymmetries. This trust minimises adverse market reactions and instils confidence in long-term investors, thereby reducing SPCR. Further, signalling theory posits that strong ESGP sends a positive signal to investors regarding a firm's commitment to sustainability and transparency, mitigating concerns about hidden risks or unethical practices. The findings also corroborate prior empirical evidence (e.g. Krüger 2015; Aouadi and Marsat 2018; Shakil 2021) that robust ESGP contributes to market stability and resilience against abrupt price crashes.

Surprisingly, the study indicates a significant positive association between BGD and SPCR, contradicting our second hypothesis (H_2). While this result may initially appear counterintuitive, there are plausible explanations for this result. China's distinctive business and cultural

Table 6 Fixed effect and system GMM estimation results

	Panel A		Panel B		Panel C	
	NCSKEW		DUVOL		Crash	
	FOLS	GMM	FOLS	GMM	FOLS	GMM
Dependent (t_1)	0.155*** (2.34)	0.196*** (0.32)	0.121*** (2.34)	0.342*** (1.92)	0.152*** (0.82)	0.238*** (3.63)
ESGP	−0.012***(0.46)	−0.021*** (0.73)	−0.571*** (−1.43)	−0.172** (−0.63)	−0.392** (1.61)	−1.82 *** (1.73)
BGD	0.028** (0.10)	0.069*** (1.53)	0.018 (0.96)	0.039* (1.31)	0.023*** (1.79)	0.021** (1.07)
Constant	1.726*** (3.83)	3.731** (3.72)	−1.439*** (−7.10)	−1.052** (−2.04)	−2.327*** (−1.74)	−2.325*** (−2.28)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6657	6657	6657	6657	6657	6657
R2	0.33	–	0.36	–	0.42	–
AR (1) test (*p*-value)	–	0.000	–	0.000	–	0.001
AR (2) test (*p*-value)	–	0.652	–	0.661	–	0.723
Hansen test of over-identifica-tion (*p*-value)	–	0.382	–	0.572	–	0.533
Diff-in- Hansen test of exogeneity (*p*-value)	–	0.743	–	0.682	–	0.682

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

Table 7 Heterogeneous effects of ESG score

	Panel A		Panel B		Panel C	
	NCSKEW		DUVOL		Crash	
Models	High-score ESG	Low-score ESG	High-score ESG	Low-score ESG	High-score ESG	Low-score ESG
ESGP	−0.521*** (2.83)	0.562*** (0.45)	−0.352*** (1.52)	0.535** (−0.66)	−0.472*** (−6.42)	0.452** (0.41)
BGD	0.020** (0.73)	−0.004***(−0.15)	0.007 (0.42)	−0.018** (−0.86)	0.019*** (2.16)	−0.025**(1.62)
Constant	2.230*** (1.87)	2.543** (2.43)	−1.224*** (−1.73)	1.453* (3.53)	−1.880*** (−6.36)	2.322 (0.53)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3651	3957	3651	3957	3651	3957
R2	0.35	0.34	0.41	0.39	0.32	0.40
Coef. Difference Test	632***		592***		483***	
Sargan test (*p*-value)	0.561	0.448	0.682	0.710	0.423	0.479

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

environment may lead to different outcomes compared to Western countries. Boards with gender diversity may include directors lacking extensive experience in their roles, potentially contributing to a higher crash risk. Our findings are in line with Fitzsimmons (2012) and Nielsen and Huse (2010), who reported that the mere presence of gender diversity on boards does not guarantee improved decision-making or risk management.

Furthermore, investors and market participants in China may perceive BGD differently compared to their counterparts in other regions. These findings highlight the complexities of translating diversity into effective governance

Table 8 Heterogeneous effects of life cycle heterogeneity

Models	Panel A		Panel B		Panel C	
	NCSKEW		DUVOL		Crash	
	Old firm	Young firm	Old firm	Young firm	Old firm	Young firm
ESGP	− 0.072*** (0.62)	0.812*** (1.62)	− 0.261** (1.02)	0.558*** (3.21)	− 1.342*** (−3.72)	0.107 (0.50)
BGD	0.028** (1.10)	− 0.002***(− 0.07)	0.008** (0.47)	− 0.005*** (− 0.26)	0.016***(1.42)	− 0.019** (− 1.47)
Constant	1.324** (2.31)	2.645*** (1.43)	− 1.640* (2.53)	2.98*** (2.51	1.922*** (3.41)	− 1.912*** (− 1.91)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4413	3195	4413	3195	4413	3195
R2	0.36	0.42	0.26	0.28	0.41	0.32
Coef. Difference Test	638***		591***		483***	
Sargan test (*p*-value)	0.643	582	482	474	634	518

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

outcomes. Additionally, the positive association between BGD and SPCR provides a nuanced perspective that diverges from the theoretical assumptions of stakeholder theory. While stakeholder theory emphasises the importance of diverse boards in improving governance, the findings suggest that cultural and contextual factors in China may influence the efficacy of gender diversity in reducing crash risk. According to signalling theory, the presence of gender-diverse boards could inadvertently signal inexperience or inefficiency in decision-making if such diversity is perceived as superficial or symbolic, especially in markets less accustomed to diverse governance structures.

Fixed effects and system GMM estimation results

Because the ESGP score is time-varying, we incorporate the first-order lag terms of the dependent variable (Dependent (t−1) and assess the robustness of our results using both a fixed effects model and a two-step system generalized method of moments (GMM) estimator (Arellano & Bond 1991; Arellano & Bover 1995). Additionally, we use the dependent variable, lagged by two periods, as an instrumental variable (Chen & Xie 2022). The coefficient of the first-order lag of the dependent variable, as presented in Table 7, is significant at the 1% level, suggesting that ESGP exhibits a notable lag effect. Our findings in Table 7 remain largely unchanged after accounting for unobserved heterogeneity, simultaneity, and dynamic endogeneity.

Heterogeneity analysis

In this section, we analyse whether ESGP and BGD have a heterogeneous impact on SPCR across different firms. To assess this, we divide the sample into two sub-samples based on the ESG score, firm age, green innovation, and state-owned enterprise (SOE) for heterogeneity analysis in order to examine whether the means of various variables significantly differ between the two groups.

ESG scores

China's stock market differs notably from developed capital markets regarding environmental information and investor behaviour (Chen & Xie 2022). The impact of ESGP and board diversity on SPCR could differ between firms with high/low ESG profiles. We categorise the sample into two subgroups based on ESGP, using ESGdum as a dummy variable: it equals 1 if a company has a high ESGP score (4.5 or above, referred to as H-ESGdum) and 0 otherwise (L-ESGdum). Table 8 presents our analysis of these two sub-samples.

The results confirm our primary finding, showing a negative association between SPCR and high-score ESGP. Conversely, we found a significant positive association between SPCR and ESGP in low-score ESGP Chinese firms. Conversely, BGD only results in decreasing price crash risk when the ESG score is low. However, BGD may have a positive or no effect on price crash risk when the ESG scores are high. When the overall governance and ethical standards are weaker (as reflected in low ESG scores), the presence

Table 9 Heterogeneous effects of green innovation

	Panel A		Panel B		Panel C	
	NCSKEW		DUVOL		crash	
	High-GI	Low-GI	High-GI	Low-GI	High-GI	Low-GI
ESGP	−0.327*** (−3.27)	0.165 (1.63)	−0.342*** (−3.23)	0.197** (1.23)	−0.208*** (−1.41)	0.184*** (2.03)
BGD	−0.009** (−0.21)	0.018* (0.81)	−0.015*** (−0.51)	0.007** (0.46)	−0.009*** (−0.44)	0.019 ** (2.06)
Constant	2.354*** (1.65)	−1.675*** (0.92)	2.076** (0.46)	1.541*** (2.21)	−2.492*** (−10.51)	−1.424*** (−8.92)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1369	6239	1369	6239	1369	6239
R2	0.45	0.43	0.21	0.38	0.31	0.24
Coef. Difference Test	631***		640***		538***	
Sargan test (*p*-value)	0.483	0.742	0.382	0.389	0.408	0.681

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

of diverse perspectives on the board may help identify and address potential risks more effectively. Gender diversity can bring different viewpoints and approaches to risk management. However, companies with high ESG scores are likely to have boards that include members with specific expertise in ESG-related matters. In such cases, gender diversity may not have a pronounced effect on risk reduction because the board already possesses the required skills and knowledge to manage ESG-related risks effectively.

Firm age

The age of a firm influences many aspects of its characteristics and corporate behaviour (Kieschnick & Moussawi 2018). Table 9 extended our examination to two sub-samples (old and new). We found a significant negative association between ESGP and SPCR in older firms. Older firms maintain stable asset portfolios and market values, as well as experience-based economies of scale through learning and usually achieve superior performance when compared to new companies (Aouadi & Marsat 2018). On the other hand, young firms proactively adopt ESGP measures to attract investor confidence, secure government and bank support, and align with the prevailing trend of advancing environmental and social sustainability. However, this proactive stance can significantly increase these firms' vulnerability to stock price crashes.

Conversely, BGD only decreases SPCR in old firms. However, BGD may positively or negatively affect SPCR in young firms. The same justification of the effect of BGD on SPCR in companies with high/low ESG scores can be applied to old/new firms. Young firms may experience a more pronounced reduction in crash risk when embracing gender diversity on their boards due to their agility and alignment with contemporary expectations, whereas older firms may see a less immediate or noticeable effect due to their stability and established practices.

Green innovation

Green innovation is essential in China due to its direct impact on corporate environmental performance and the government's capacity to influence ESG decisions. Green innovation constitutes a type of technological advancement that corresponds with economic development objectives (Harel et al., 2021). While advantageous, green innovation involves substantial expenditures, risks, and extended return periods (Jiao et al. 2020), requiring investments from capital markets and financial institutions (Tan and Zhu 2022). The patenting information of firms is derived from the latest Chinese Patent Data Project (CPDP) database, established by He et al. (2013). The project correlates SIPO (State Intellectual Property Office) patent applications with registered Chinese enterprises. It encompasses explicitly all main A-share companies listed on the Shanghai and Shenzhen stock exchanges (Zhang et al. 2019). Scholars such as Liao et al. (2020), Tang et al. (2021), and Marie et al. (2024b) have employed the number of green invention patents generated by publicly traded corporations in designated areas to assess green innovation activities. The logarithm of one plus

Table 10 Heterogeneous effects of State-owned enterprises (SOE)

	Panel A		Panel B		Panel C	
	NCSKEW		DUVOL		Crash	
	SOE	Non-SOE	SOE	Non- SOE	SOE	Non- SOE
ESGP	−0.146*** (−1.52)	0.609** (2.32)	−0.252** (−2.43)	0.251 (1.29)	−0.148** (−2.26)	0.404** (0.41)
BGD	−0.011*** (−0.37)	0.041** (1.42)	−0.211* (−0.55)	0.017***(0.85)	−0.015** (−1.45)	0.019***(1.53)
Constant	2.653*** (0.54)	3.636** (1.63)	1.945 *** (2.46)	3.673** (1.27)	−3.110*** (−11.82)	−2.170*** (−6.64)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3500	4108	3500	4108	3500	4108
R2	0.34	0.27	0.43	0.32	0.35	0.45
Coef. Difference Test	549***		483***		529***	
Sargan test (*p*-value)	0.653	0.484	0.533	0.559	0.483	0.639

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

Table 11 The moderating role of ESG on the relationship between board gender and stock price crash risk

	Panel A NCSKEW	Panel B DUVOL	Panel C crash
ESG Performance	−0.412*** (−3.23)	−0.330*** (1.16)	−2.191*** (−2.72)
BGD	1.687** (2.40)	1.313*** (2.76)	−0.634** (−1.89)
ESGP×BGD	−0.326*** (−2.39)	−0.255*** (−2.77)	0.612** (1.95)
Constant	2.433 *** (1.62)	−2.428** (3.52)	2.733*** (0.28)
Controls	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes
Observations	7608	7608	7608
R2	0.43	0.32	0.24
Sargan test (*p*-value)	0.719	0.562	0.530

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

the count of green innovations is utilised in these investigations to alleviate any possible variable skewness.

We divide the sample into two equal parts based on green innovation, categorising firms into high and low green innovation groups for heterogeneity analysis. In Table 10, firms with high green innovation, both ESGP and gender diversity, have a negative association with SPCR, as they have a strong focus on green innovation and are often proactive in identifying and managing environmental risks. This proactive approach contributes to a lower overall risk profile, including a reduced risk of stock price crashes. In contrast, we found that both ESGP and board diversity have significantly increased SPCR in firms with low green innovation. Companies with limited green innovation may have higher exposure to environmental and social risks. When these risks materialise, they can lead to significant price crashes. Companies with inadequate green innovation may face regulatory and legal risks related to non-compliance with environmental and social regulations.

State-owned enterprise

State-owned enterprises (SOEs) hold a crucial position in the Chinese economy and are a unique feature of its economic system (Cheng et al. 2025). SOEs are central to China's state-capitalist model, where the state plays a dominant role in the economy while allowing market forces to operate in specific sectors. They are seen as a tool for achieving national strategic goals, such as technological self-reliance

Table 12 The moderating role of board gender diversity on the relationship between ESG performance and stock price crash risk pre- and post-COVID-19 pandemic

	Panel A		Panel B		Panel C	
	Pre-COVID-19	Post -COVID-19	Pre-COVID-19	Post -COVID-19	Pre-COVID-19	Post -COVID-19
	NCSKEW		DUVOL		Crash	
ESGP	1.520 (6.25)	− 1.053*** (0.13)	1.026***(5.45)	− 0.052*** (0.69)	1.123*** (1.23)	− 0.469*** (− 5.24)
BGD	4.723 (4.03)	0.206* (0.19)	3.117** (3.49)	0.485** (1.42)	0.452** (0.42)	1.421*** (2.52)
ESGP×BGD	1.274 (1.02)	− 0.043** (− 0.73)	0.572** (1.48)	− 0.063*** (− 0.42)	0.153*** (− 0.67)	− 0.283*** (− 0.14)
Constant	1.894*** (0.72)	− 1.732 *** (2.83)	0.527 *** (0.89)	− 2.763** (− 0.96)	− 1.523*** (− 1.01)	− 1.523*** (− 1.31)
Controls	YES	YES	YES	YES	YES	YES
Fixed effects	YES	YES	YES	YES	YES	YES
Industry effects	YES	YES	YES	YES	YES	YES
Observations	4337	3271	4337	3271	4337	3271
R2	0.27	0.29	0.25	0.32	0.28	0.23
Coef. Difference test	736***		783***		522***	
Sargan test (*p*-value)	0.371	0.763	0.430	0.463	0.440	0.543

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

and global economic influence. Principal shareholders in SOE generally emphasise the long-term development and viability of the organisations (Deng & Cheng 2019). Wang et al. (2023a, b) argue that SOEs with concentrated equity ownership maintain long-term investment prospects, which is more favourable for implementing ESG policies. Moreover, SOEs are anticipated to reap both economic and social benefits due to their support from fiscal policies, which incentivise them to fulfil social responsibilities and obligations (Marie et al. 2024b). The data source for SOE vs non-SOE was obtained from the CSMR Database. Scholars such as Zahid et al. (2023) and Marie et al. (2024b) have employed SOE measurement as a dummy variable, taking a value of 1 if the government controls the firm and 0 otherwise.

We divide the sample based on ownership type (state-owned vs. non-state-owned). We found that ESGP is negatively associated with the crash risk of state-owned companies, as shown in Table 11. In contrast, ESGP is positively associated with the SPCR of non-state-owned enterprises. One possible explanation could be that state-owned companies often enjoy strong government backing and support. This support can translate into stability and resilience in the face of economic and market challenges, reducing their susceptibility to severe stock price crashes.

Similarly, BGD negatively affects SPCR in state-owned companies and positively affects SPCR in non-state-owned companies. BGD is encouraged and embraced by the government within state-owned companies, which can be viewed as a positive signal of progressive governance in alignment with government goals, including ESG principles. However, non-state-owned companies in China often face intense market competition and may prioritise

short-term profitability to remain competitive. In such competitive environments, diversity on the board may not align with the firm's short-term profit orientation.

Interaction between ESGP and board gender diversity

Given that ESGP and BGD mostly influence SPCR in opposing directions, it was of paramount importance to explore whether either of these variables exerts a moderating effect on SPCR. To explore this, we introduced the interaction term between ESGP and BGD into the baseline regression model. Table 12 confirms the negative association between ESGP and all measures of SPCR and the positive association between BGD and two measures of SPCR (NCSKEW and DUVOL). Furthermore, the interaction term between ESGP and BGD is significantly and negatively associated with the same two measures of SPCR. This result indicates that ESGP acts as a moderating factor for the positive effect of BGD on SPCR, which supports our third hypothesis (H$_3$). ESGP is often associated with reduced SPCR because it reflects a company's proactive approach to risk management, investor confidence, and resilience.

On the other hand, BGD, while promoting diverse perspectives, can introduce governance challenges and potential market sensitivity, which may increase SPCR in certain circumstances. The impact of both factors on crash risk depends on their effective integration into a company's overall governance and risk management strategies. The interaction term between ESGP and BGD and its negative association with SPCR, highlights the importance of integrating ESG initiatives with board diversity. From a stakeholder theory perspective, this result underscores the

Table 13 The moderating role of board gender diversity on the relationship between the ESG rating index and stock price crash risk

	Panel A NCSKEW	Panel B DUVOL	Panel C Crash
ESG rating Index	−0.341*** (−3.01)	1.185** (1.50)	−0.233*** (−0.87)
BGD	0.044** (0.68)	−0.013*** (−0.16)	0.026** (0.37)
ESG rating Index × BGD	−0.420*** (−0.70)	−1.123*** (−0.12)	−0.237** (−0.69)
Constant	2.365*** (1.44)	−2.717*** (1.82)	2.743** (0.424)
Controls	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes
Industry Effects	Yes	Yes	Yes
Observations	7608	7608	7608
R2	0.32	0.36	0.48
Sargan test (*p*-value)	0.372	0.473	0.537

***, **, and * indicate significance levels at 0.01, 0.05, and 0.10, respectively

synergistic potential of aligning ESGP with diverse board structures to effectively address multiple stakeholders' interests. ESGP appears to act as a stabilising factor that mitigates the potential governance challenges associated with BGD, particularly in contexts where diverse boards may otherwise lack cohesion or experience. This dynamic is consistent with signalling theory, as the combination of ESGP and BGD sends a multifaceted signal to investors that the firm is both committed to sustainable practices and capable of managing the complexities introduced by board diversity.

However, when we use Crash as a proxy for crash risk in panel C, we observe that both ESGP and BGD show a negative association with SPCR, while the interaction term between these two variables exhibits a positive association with crash risk. The observed positive association between the interaction term and crash risk, as captured by the "Crash" proxy in Panel C, suggests a more complex interplay that warrants deeper consideration. This result may indicate that the benefits of ESGP in moderating BGD-related risks are contingent on specific contexts or thresholds. Therefore, further analysis will be conducted by dividing the sample into two sub-samples: pre- and post-COVID-19 pandemic. Additionally, Stakeholder theory suggests that when ESGP and BGD are not effectively integrated into a cohesive governance framework, their combined impact might introduce uncertainty or mixed signals to the market, potentially exacerbating crash risk. This complexity highlights the need for firms to ensure that ESG and governance initiatives are not pursued in isolation but rather embedded within a holistic risk management strategy.

Interaction effect pre- and post-COVID-19 pandemic

The pre-COVID-19 period in Table 13 shows either a positive (panel B&C) or no association (panel A) between ESGP and SPCR because ESGP was not widely recognised as a

key factor influencing price crash risk during this time. However, this association has become notably negative after the COVID-19 pandemic, as the crisis heightened awareness of the importance of ESG factors. Investing in ESGP is now increasingly seen as an effective strategy to mitigate the extreme price fluctuations observed during the pandemic (Yoo et al. 2021).

However, BGD continually exhibits a positive association with SPCR pre- and post-Covid-19. Gender-diverse boards may be less experienced, which could lead to poorer decision-making and increased risk of price crashes. They are also more likely to focus on ESGP rather than on financial performance, which could lead to lower profits and increased risk of price crashes (Yi et al. 2022).

Moreover, the interaction coefficient between ESGP and BGD is positively associated with SPCR pre-COVID-19 due to the positive effect that both variables already had on SPCR pre-COVID-19. However, the interaction coefficient exhibits a negative association with price crash post-COVID-19 due to the negative impact of the ESGP on SPCR after the pandemic. This result verifies that ESGP moderates the positive effect of BGD on the crash ratio post-COVID-19 pandemic.

Interaction effect using alternative measures of ESG and gender diversity

We used different ESGP and BGD measurements to ensure our findings were robust. First, we utilised the ESG rating index according to the Huazheng ESG evaluation system (Wang & Wang 2022; Li et al. 2022). This index measures the level of all A-share listed companies through a combination of regular quarterly evaluations and dynamic tracking (out of 100 points) and correspondingly giving a nine-level rating of "AAA-C", with more than 20,000,000 for ESG evaluation data (Li et al. 2022). Second, we measured BGD using a dummy variable set to 1 if three or more female

directors are on the board and 0 otherwise (Brahma et al. 2021). The results in Table 13 are align with our main findings presented in Table 5, except when using DUVOL as a proxy for crash risk in panel B, probably because of the use of a different database for ESG scores.

Summary and conclusion

We empirically investigate the effect of both ESGP and BGD and their interaction effect on SPCR within the context of Chinese firms. The findings highlight that ESGP is significantly and negatively associated with SPCR, which is consistent with our conjecture that ESGP can effectively decrease information asymmetry, suggesting that companies with strong ESGP exhibit resilience to stock price crashes. This result supports the argument that ESGP enhances firms' reputational capital and aligns with prior studies such as Krüger (2015), Aouadi and Marsat (2018), and Shakil (2021), which emphasise the value of ESGP in mitigating risk and improving investor confidence. When alternative measures of ESGP and BGD are used, a significant association between ESGP and SPCR still exists. Conversely, the findings reveal a significant positive association between BGD and SPCR, challenging conventional expectations. This outcome may be attributed to the unique cultural and business environment in China, where gender-diverse boards might include members with less extensive experience, thereby increasing crash risk. This explanation is supported by prior research, including Fitzsimmons (2012) and Nielsen and Huse (2010), which found that BGD alone does not necessarily enhance decision-making or risk management. The heterogeneity analysis provides further insights into these relationships. ESGP's negative impact on SPCR is more pronounced among firms with high ESG scores, older firms, and those with robust green innovative initiatives. These findings suggest that firms with established ESG frameworks and operational stability are better equipped to manage crash risk, consistent with the arguments of Chen and Xie (2022) and Aouadi and Marsat (2018). Similarly, BGD reduces SPCR in firms with low ESG scores, younger firms, and those with lower green innovation, highlighting the importance of context-specific factors in shaping the impact of board diversity on crash risk.

Interestingly, the interaction analysis demonstrates that ESGP moderates the effect of BGD on SPCR. Specifically, ESGP mitigates the potential governance challenges and market sensitivities associated with gender-diverse boards, underscoring the importance of integrating ESG considerations into broader governance strategies. These findings align with Yoo et al. (2021), who highlighted the increasing

relevance of ESG investments post-COVID-19 and further confirmed that ESGP acts as a stabilising force in volatile markets.

Our findings contribute to the body of research on ESGP and offer empirical evidence underscoring the growing significance of ESGP in reducing the price crash risk in emerging markets. Furthermore, the study provides regulatory implications and encourages policymakers to promote environmentally conscious, socially responsible, and governance-sound practices. The findings also demonstrate that higher ESGP does not necessarily result in higher costs. Instead, it tends to attract more investors, support, and assistance from governments and banks, which can ultimately contribute to reducing SPCR in the long run. Further, the results indicate that BGD does not always enhance the ability of board directors to make decisions that mitigate SPCR. Finally, examining the interaction between ESGP and BGD indicates that best practices may reinforce or counteract each other's effects on SPCR, offering nuanced insights into the complexities of corporate decision-making. Overall, this research provides insights for both corporate leaders and policymakers in China and beyond, contributing to more sustainable, diverse, and resilient business practices that align with the evolving expectations of stakeholders in the modern global economy.

The findings of this study highlight significant policy implications for corporate governance and sustainability. Regulators should advocate for the integration of ESG factors into corporate decision-making, emphasising their role in mitigating SPCR and fostering long-term market stability. This could be achieved by mandating enhanced ESG disclosures, ensuring standardised reporting frameworks, and encouraging firms to adopt ESG best practices to reduce SPCR. Additionally, the study warns that BGD alone may increase SPCR in developing countries like China. However, when combined with strong ESG performance, the risk is mitigated. Policymakers should ensure that gender diversity initiatives are complemented by robust ESG strategies to enhance corporate governance and risk management.

Despite the significant insights provided by our study, several limitations present opportunities for further research. First, the analysis focuses solely on Chinese firms, limiting the generalisability of the findings to other regions with different cultural, regulatory, and economic contexts. Future research could expand this investigation to diverse countries to capture global variations in the ESGP, BGD, and SPCR nexus. Second, while robust methods like 3SLS and GMM were employed, potential biases inherent in observational data remain a concern. The reliance on existing ESGP and BGD metrics, which may vary across firms and evaluators, could impact the results. Future studies should explore alternative datasets or metrics to validate and enhance these

findings. Finally, this study emphasises ESGP and BGD without considering other board characteristics, such as tenure, independence, or educational background, which may also influence SPCR. Examining these factors could provide a more comprehensive understanding of governance dynamics.

Data availability Data will be made available on request.

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