Does Corporate ESG Performance Improve Innovation Efficiency? Evidence from China's Listed Companies

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***Abstract*—We scrutinize the impact of Environmental, Social, and Governance (ESG) performance on corporate innovation efficiency. Utilizing panel data from China's A-share listed companies spanning 2009 to 2020, our analysis reveals that firms exhibiting superior ESG performance are also marked by heightened innovation efficiency. More precisely, our findings indicate that exemplary ESG performance beneficially influences corporate innovation efficiency. This positive impact is facilitated through the attraction of government subsidies, the alleviation of financing constraints, and the fortification of corporate governance. Furthermore, our results underscore that ceteris paribus, the advantageous impact is particularly pronounced in firms that are non-state-owned, large in scale, highly profitable, and situated in regions with advanced levels of marketization. Through this investigation, we provide novel insights into the ESG-innovation nexus and conduct a comprehensive evaluation of the mechanisms underpinning this relationship.**

***Keywords*—agency theory, corporate innovation efficiency, ESG performance, information asymmetry, sustainable finance**

I. Introduction

ESG performance represents a company's commitment to ethical and responsible practices, measuring its ability to balance short-term financial performance with long-term value creation. Strong ESG performance should underpin high-quality corporate investment behaviours and better interactions with diverse stakeholder groups. According to the Global Sustainable Investment Alliance (2021), ESG-integrated investment in the world's five major markets (Europe, America, Canada, Australia, and Japan) reached an astounding US$ 35.3 trillion by the end of 2020. Gil (2022) asserts that enterprises engaging in ESG activities indirectly create value through interactions with various stakeholders. However, unlike in developed markets where ESG disclosure is mandatory, the ESG framework in China is still in its nascent stages. This unique context provides a valuable opportunity to investigate the effectiveness of ESG development in Chinese corporations.

Regarding the impact of ESG practices, previous discussions have predominantly focused on the financial dimension. Many studies have shown a positive influence of ESG practices on financial performance and firm value (Gold & Heikkurinen, 2018; Brogi & Lagasio, 2019; Giese *et al.*, 2019). Due to the intrinsic value effect, companies are often compelled to allocate a portion of their gains to research and development (R&D) to secure or improve their competitive position and long-term development in line with ESG initiatives. Corporate leaders and experts have long recognized that responsible and sustainable practices create a conducive environment for innovation, providing valuable investment guidance to investors and stakeholders (Battisti *et al.*, 2020). Consequently, companies prioritizing ESG considerations tend to integrate the concept of 'doing well by doing good' into their operations (Chouaibi *et al.*, 2022), stimulating investments and nurturing diverse long-term stakeholder relationships.

However, the relationship between ESG performance and financial performance is complex. While some argue that ESG conduct drives corporate success, others contend that excessive focus on ESG may impose burdens, potentially diminishing corporate investment capacity and profit maximization (Garvey *et al.*, 2016; Xie *et al.*, 2019). The ongoing debates have also raised questions about whether ESG development positively influences corporate innovation. Modern corporations view innovation as a value-investing strategy to distinguish themselves from competitors, leading to financial success and fostering a culture of long-term thinking (Pang & Wang, 2020; Liu & Lyu, 2022). At the macro level, innovation has far-reaching positive effects, creating a virtuous cycle of cost reduction, eco-friendly technology promotion, and high-quality economic development. At the micro level, innovation reshapes companies' development models and maintains their enduring competitive advantage (Muthuri *et al.*, 2012; Montiel *et al.*, 2021). Recognizing the importance of innovative activities, existing literature has explored innovation's impact on firm value, with most studies agreeing that innovation investment yields positive economic outcomes (Block *et al.*, 2017; Cui *et al.*, 2021; Huang *et al.*, 2023). However, research on the influence of ESG performance on corporate innovation behaviours, particularly on corporate innovation efficiency, has been limited.

The setting of ESG performance in China's enterprises possesses distinctive characteristics that differentiate it from developed markets. Firstly, ESG practices in China are influenced by unique institutional factors. The Chinese government has progressively tightened its Corporate Social Responsibility (CSR) requirements to accelerate ESG development. For example, Wang *et al.*, (2022) explored the impact of low-carbon pilot programs initiated by the National Development and Reform Commission on corporate ESG development and found a positive effect. Additionally, the distinctive ownership structure of Chinese enterprises, marked by a substantial presence of state-owned firms, adds complexity to the governance dimension of ESG research. Unlike private enterprises, State-Owned Enterprises (SOEs) generally face severe agency problems. The significant upfront costs associated with ESG investment have led to management's reluctance to engage in ESG activities (Fang & Hu, 2023). Lastly, as one of the world's largest economies

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and carbon emitters, China faces unique sustainability challenges in its ESG setting (Weber, 2014). Therefore, Chinese entrepreneurs are under immense pressure to adopt ESG practices, not only to comply with domestic regulations but also to align with international sustainability goals (Dutta *et al.*, 2012; Ilhan *et al.*, 2021).

In light of the limited research and the particularity of China's ESG environment, we embarked on an empirical investigation into the impact of ESG performance on corporate innovation efficiency using a sample of firms listed on China's A-share market from 2009 to 2020. The results indicate that enterprises with superior ESG performance exhibit higher levels of innovation efficiency. This relationship remains robust across various robustness and endogeneity tests. In examining the mechanisms, we find that ESG performance enhances innovation efficiency by attracting government subsidies, alleviating financing constraints, and improving corporate governance. Further analysis reveals that the impact of ESG practices on innovation efficiency is heterogeneous, varying depending on the ownership structure, company size, profitability, and the level of marketization in the company's location.

Our study contributes to the literature in three ways. Firstly, unlike previous research that often investigates the separate dimensions of E, S, or G (Albuquerque *et al.*, 2019; Koji & Tram, 2020; Safitri *et al.*, 2020), we examine the integrated influence of ESG on innovation. Our research provides recent evidence from Chinese enterprises, demonstrating how overall ESG performance fosters innovation efficiency, enriching the findings related to ESG performance in developing markets. These findings are robust.

Secondly, we assess the concept of innovation activities from a novel perspective—innovation efficiency. As innovation is a resource-intensive activity, it compels enterprises to focus not only on the quantity of innovative products but also on uniqueness and novelty in a cost-effective manner (Evans *et al.*, 2017; Broadstock *et al.*, 2020). Thus, our study investigates innovation efficiency in terms of both quantity and quality, reflecting the dynamic relationship between ESG performance and innovation activities by assessing how effectively an enterprise converts its innovation efforts into tangible results and value.

Thirdly, our study uncovers the underlying mechanisms by which investment in ESG contributes to innovation efficiency, thereby complementing the logical chain of the impact of ESG on innovative activities. While prevailing literature has focused on the consequences of ESG on internal mechanisms, our analysis extends to include both internal and external pathways: corporate governance, government subsidies, and financing constraints. This comprehensive evaluation of multiple mechanisms enables companies to efficiently manage risks (Sassen *et al.*, 2016), identify opportunities (Khan, 2019), meet stakeholder expectations (Huang, 2021), and create value sustainably and responsibly (Alareeni & Hamdan, 2020).

The remainder of this paper is organized as follows: Section II proposes relevant theories and hypotheses; Section III describes the data and methodology, including sample selection, data source, variable definition, and model specification; Section IV presents empirical findings and robustness checks; Section V explores the economic mechanisms; Section VI performs the heterogeneity analysis; and Section VII concludes the paper.

II. Literature Review and Research Hypothesis

A. Literature Review

1) ESG's concept of sustainability

Over the past few years, the concept of ESG has experienced a marked increase in attention, establishing itself as a crucial theme in academic research. This section begins by exploring the evolving landscape of the ESG framework, particularly within the context of China. Our exploration includes a comprehensive review of ESG practices and their effects on various aspects, such as firm value, investment guidance, firm risk, and corporate investment decisions. Among these aspects, the most relevant to our study is the relationship between ESG and corporate investment behaviours. This focus allows us to deepen our understanding of ESG performance and corporate innovation in the Chinese milieu.

ESG system: The inception of the ESG concept traces back to a 2004 report crafted by 20 financial institutions, spurred by a recommendation from Kofi Annan, the Secretary-General of the United Nations[1]. As evident from its name, ESG entails the amalgamation of environmental, social, and governance considerations into the operational strategies of corporations and investors (PRI, 2018). On the one hand, China stands as an important contributor to the global ESG market and is actively working towards its sustainable development goals. For example, the *National Development and Reform Commission* has set the goal of achieving peak carbon dioxide emissions by 2030 and attaining carbon neutrality by 2060. On the other hand, current research indicates that China's regulations for ESG disclosure lack mandatory provisions and transparency, impeding its developmental strides (He *et al.*, 2022; Liu *et al.*, 2023). For this purpose, it becomes imperative to identify pathways for solidifying ESG disclosure standards and progressing from voluntary to mandatory disclosure.

ESG and firm value: Prior literature has examined the effects of Environmental (E), Social (S), and Corporate Governance (G) factors on firm value individually. Among these, the prevalent perspective affirms that effective corporate governance exerts a positive influence on firm value (Chou *et al.*, 2013; Koji & Tram, 2020). Yet, the relationship between environmental and social responsibility and firm value remains a topic of debate. While some studies advocate for a positive impact (Prado-Lorenzo *et al.*, 2008; Aggarwal, 2013; Eccles *et al.*, 2014; Lu *et al.*, 2014; Albuquerque *et al.*, 2019), others raise scepticism (Roy & Ghosh, 2011; Safitri *et al.*, 2020).

With the increasing acceptance of the ESG concept across various societal sectors, scholars have shifted their focus to appraising the impact of overall ESG performance on firm

[1] The term ESG first appeared in a 2004 paper entitled *Who Cares Wins*, which was jointly prepared by a number of financial institutions at the invitation of the United Nations, encouraged businesses to adopt sustainable and socially responsible policies and practices, with ESG factors as a central part of these efforts, https://www.unepfi.org/fileadmin/events/2004/stocks/who_ cares_ wins_global_compact_2004.pdf.

value, which has led to the emergence of new controversies. For instance, Dowell *et al.,* (2000) and Flammer (2013) have empirically shown that firms committed to ESG activities tend to exhibit higher market values. Dimson *et al.,* (2015) and Brogi and Lagasio (2019) contend that positive market responses are linked to successful ESG engagement. Despite literature backing the notion that ESG enhances firm value, certain studies assume a negative association between ESG investments and corporate financial performance (Giuli & Kostovetsky, 2014; Masulis & Reza, 2015; Buallay, 2019), while others detect only a slight or no positive correlation (Margolis *et al.,* 2009; Humphrey *et al.,* 2012; Lahouel *et al.,* 2019). Such an absence of consistent evidence may stem from various factors, including differing motives for conducting ESG initiatives, discrepancies in the proxies used for measuring ESG performance and firm performance, the trade-offs firms navigate among ESG components, and the evolving market perception (Rau & Yu, 2023). With conflicting perspectives in play, a thorough investigation into the multiple mechanisms by which ESG performance shapes firm value is essential. Addressing these gaps in the logical chain can help to gain a deeper comprehension of the intricate links between ESG initiatives and corporate financial performance.

ESG and investment guidance. A growing interest among investors revolves around incorporating ESG factors into decision-making, a trend motivated not just by financial considerations but also by the pursuit of responsible and sustainable investment opportunities. Fang and Hu (2023) note that this trend has gained momentum in China, where the adoption of the Principles for Responsible Investment (PRI) officially acknowledges the impact of ESG issues on investment portfolio performance. By 2022, a remarkable 24 public funds in China had pledged support for PRI, resulting in substantial investments of RMB 498.4 billion in ESG public funds and RMB 1,670 billion in ESG bond issuance.[2]

Regarding global investment, Krueger *et al.,* (2020) revealed in their worldwide survey of sustainable funds that the launch of new ESG-related funds had attracted significant inflows. In guiding investment decisions within both equity and bond markets, researchers have highlighted the importance of ESG performance. Institutional investors, for example, who actively include ESG-conscious firms in their capital allocation, aim to mitigate ESG-related risks and better align with the broader objectives of society (Chen *et al.,* 2020; Hoepner *et al.,* 2020; Brandon *et al.,* 2021). Studies indicate that enterprises with strong ESG performance can hedge against idiosyncratic risks, offering enhanced protection for investors. Thus, ESG has transitioned from a theoretical concept to a mainstream consideration in investment guidance. Investors recognize that integrating ESG factors into investment strategies can affect risk and return, align with ethical values, and comply with regulatory mandates.

ESG and Firm Risk. Negative ESG events can profoundly influence a company's risk-taking and investors' ability to obtain trustworthy information, potentially triggering stock price crashes (Roychowdhury, 2019). Research, exemplified by works from Starks (2009) and Fafaliou *et al.,* (2022), outlines that companies revealing unethical activities may encounter risks spanning reputation, regulation, supply chain, and litigation, often resulting in financial dilemmas. Nonetheless, companies with robust ESG profiles can benefit from an expanded investor base, especially during financial crises (Hong & Kacperczyk, 2009; El Ghoul *et al.,* 2011). Therefore, ESG disclosure goes beyond merely informing investors and other stakeholders; it also shapes their responses to the disclosure, influencing how enterprises allocate resources to different risky projects and the levels of risk they are willing to undertake (Kanodia & Sapra, 2016; Gold & Heikkurinen, 2018). Understanding the mechanisms through which ESG disclosure influences corporate risk exposure is crucial. Moreover, further investigation is warranted to assess how this impact varies under different external governance environments.

ESG and Investment Decisions. In the corporate investment arena, researchers posit that ESG practices significantly influence enterprises' investment decisions. The empirical study by Gao *et al.* (2021) has unveiled a positive correlation between enterprises' ESG performance and corporate investment efficiency. ESG practices help resolve over- and under-investment problems by mitigating agency conflicts and costs. Especially in situations with information opacity or asymmetry, enterprises with favourable reputations can preserve stakeholder trust, leading to cost savings on investments (Houston & Shan, 2022). With growing concerns related to environmental and social issues, firms holding ESG advantages are more resilient in handling intangible barriers, such as security audits or environmental regulations, when deliberating investment decisions (Xie & Lv, 2022).

In the vision of forward-thinking enterprises, innovation is strategically invested in for its potential to secure prolonged competitive advantages, expand market share, and generate future profits (Liu & Lyu, 2022). Existing scholarship on the connection between ESG performance and corporate innovation, as illustrated by Lin *et al.* (2021), contends that building relationships with stakeholders possessing external knowledge and financial resources can stimulate corporate innovation. This proposition gains empirical support from recent studies, indicating that positive ESG activities contribute to enhancing corporate innovation (Zhai *et al.,* 2022; Li *et al.,* 2023; Zheng *et al.,* 2023). Alternative research perspectives underscore the inquiry into whether ESG performance functions as a more effective catalyst for collaborative rather than independent innovation. The rationale behind this argument lies in the recognition that positive social impact signifies reliability as a collaborative partner. Engaging in positive ESG practices opens up opportunities for establishing networks, enabling resource exchange, and cross-brand cooperation, such as technology sharing—a crucial aspect of innovation development (Bereskin *et al.,* 2016).

Despite productive discussions, academia still grapples with whether there is a variation in the impact of ESG on corporate innovation amid uncertain ESG performance. Providing clarity on this question is essential for enhancing firms' long-term value and fostering alignment between their

[2] China Sustainable Investment Review 2022, CSIR2022, https://en.chinasif.org/products/csir2022, assessed in December 2022.

economic and social values. With the increasing acknowledgement that ESG practices offer avenues for growth, resilience, and market leadership, companies are prompted by the association between ESG performance and innovation to surpass mere adherence to ESG expectations and instead wield it as an instrument for inspiration and differentiation.

2) Corporate innovation behaviour

Several internal and external factors converge to shape the innovation trajectory within the realm of corporate innovation. Corporate governance, an internal factor, involves mechanisms and strategies used within an organization. In contrast, external factors, such as government actions, are external forces capable of facilitating forward-looking programs (Chang *et al.,* 2015).

Examining the relationship between corporate governance and innovation through agency theory is crucial in contemporary business dynamics (Khoreva & Wechtler, 2020). This theory posits a fundamental conflict of interest between shareholders (principals) and managers (agents) within a firm's organizational structure. Businesses can mitigate agency conflicts by focusing on governance strategies that emphasize innovation, motivating managers to prioritize long-term value over short-term profit maximization (Munari *et al.,* 2010; Jia *et al.,* 2019). For example, boards committed to oversight and information transparency can ensure managerial decisions align with firms' strategic prospects (Shapiro et al., 2015; Scherer & Voegtlin, 2020). Furthermore, incorporating incentive structures that link executive compensation to innovation performance acts as a driver for managers to pursue innovative strategies (Tsao *et al.,* 2015). Achieving alignment fosters trust and shared objectives, encouraging collaborative efforts in R&D and creating a mutually beneficial environment for all stakeholders.

Promoting corporate innovation also involves crucial external elements, such as government initiatives. Externalities and risks associated with enterprise innovation activities can lead to market failure, necessitating targeted government intervention through industrial policies (Guo, 2018). The Chinese government's top-down approach to fostering innovation is well-documented, with studies by Liu and Zhao (2016) and Wen *et al.,* (2022) showing a positive correlation between government subsidies and corporate innovation. Empirical studies also provide evidence that policies allocating funds for technological innovation in small and medium-sized enterprises (SMEs) effectively enhance their independent innovation capabilities and economic performance (Xu & Chen, 2020). Therefore, external policies compensate for market failures in the innovation process, creating an environment conducive to R&D pursuits (Szücs, 2018). For optimizing industrial structures and transitioning economic models, comprehensive and supportive government policies for corporate innovation are necessary.

While current research has delved into the impact of ESG on various aspects of firms, including value creation, risk-taking, and investment decisions (Hong & Kacperczyk, 2009; Masulis & Reza, 2015; Chang *et al.,* 2019), a significant gap remains in understanding how ESG performance specifically influences innovation efficiency. Existing research tends to scrutinize the influence of ESG on firms' innovation by separately analysing R&D inputs and outputs, often overlooking the dynamic interrelationship between these components, namely, innovation efficiency. Innovation efficiency, to some extent, reflects an enterprise's holistic capability to allocate resources and convert R&D input into valuable output (Gao & Chou, 2015; Chang *et al.,* 2019), crucial for staying ahead in a rapidly evolving business environment. Considering this, our objective is to bridge this gap by exploring the nexus between ESG performance and corporate innovation efficiency, using the number of patents generated per unit of R&D expenditure as a metric.

B. Theory & Research Hypothesis

1) The impact of ESG performance on corporate innovation

Theoretical work by Donaldson and Preston (1995) highlights that firms can access a substantial reservoir of knowledge through engagement with a variety of stakeholders, including customers, shareholders, and suppliers. Engaging with stakeholders not only strengthens a firm's connection to its human capital but also serves as a source of creative thinking, enabling firms to develop proprietary expertise and enhance their innovation outcomes (Lin *et al.,* 2021). Regarding social responsibility (S), companies implementing robust employee social responsibility policies reap the benefits of improved employee stability and motivation, factors crucial for attracting top-tier talent (Zhang *et al.,* 2015; Yang & Hu, 2022). In the realm of environmental practices (E), commitment to environmental responsibility compels firms to reduce their environmental impact by adopting sustainable resource management and lowering emissions (Aggarwal, 2013; Bárcena-Ruiz *et al.,* 2023). This increasing ecological awareness fosters the development of eco-friendly technologies and practices that align with the preferences of environmentally conscious stakeholders. Therefore, achieving social and environmental performance not only enhances a company's reputation but also ensures the financial and resource support necessary for continuous innovation (Li *et al.,* 2020).

The integration of interests of various stakeholders reflects the governance (G) capacity of enterprises. Considered a contractual relationship, an enterprise may establish explicit or implicit agreements between shareholders and diverse stakeholders (Deng *et al.,* 2013; Mahajan *et al.,* 2023). The implicit contract arises from mutual trust, requiring enterprises to demonstrate proficient governance capabilities. Unlike firms with low ESG scores, those with high ESG performance exhibit a more harmonious alignment of interests among shareholders and other stakeholders (Nirino *et al.,* 2021). From a broader perspective, ESG initiatives act as a unifying force, aligning shareholders with a wide range of stakeholders and driving innovation efficiency by mitigating detrimental tendencies and providing the necessary resource support in enterprises. Accordingly, our first hypothesis (H1) is formulated as follows:

Hypothesis 1 (H1): ESG performance can effectively improve the efficiency of corporate innovation.

2) The mechanism role of government subsidies

In China, government subsidies serve as a crucial policy

tool to address market failures. Rooted in resource dependence theory, external entities like government sectors enhance corporate innovation activities by providing financial support and ensuring accountability and transparency in the allocation and use of subsidies (Bronzini & Piselli, 2016; Jiang & Chen, 2022). Beyond direct innovation subsidies, government entities also offer tax incentives to enterprises, which help offset innovation-related costs, encouraging companies to embark on more ambitious and riskier innovation projects. Enterprises that prioritize ESG performance are likely to gain recognition from government sectors for their long-term commitment (Zhang *et al.*, 2023). Moreover, ESG reporting verified by authoritative organizations can reduce information asymmetry between a company's internal and external stakeholders and enhance the credibility of enterprises in the eyes of government agencies (Chen *et al.*, 2020). Consequently, enterprises excelling in ESG performance are in a stronger position to obtain government subsidies and achieve more efficient resource allocation, thereby improving their innovation efficiency.

Government subsidies also have a signalling effect. When selecting subsidy recipients, governments often prefer innovative enterprises that align with industrial policies and maintain transparent internal governance (Feldman & Kelley, 2006; Guo, 2018). This preference implicitly assures the broader investor community of the innovative capabilities and competitiveness of these enterprises (Meuleman & Maeseneire, 2012; Li *et al.*, 2019). Despite the risk of strategic innovation behaviours, where companies may focus on the quantity of non-invention patent applications rather than genuine innovation performance, subsidised enterprises are subject to continuous and stringent regulatory oversight by government agencies. This external supervision ensures that funding is directed towards legitimate R&D initiatives, rather than low-effort or non-existent activities (Nishimura & Okamuro, 2018). Therefore, the combined impact of governmental support and regulations curtails strategic innovation practices and provides enterprises with essential financial support, enhancing the efficiency of their innovation efforts. In light of this understanding, we propose our second hypothesis (H2):

Hypothesis 2 (H2): ESG performance can promote firms' innovation efficiency by increasing government subsidies.

3) The mechanism role of financing constraints

Business growth is driven by corporate innovation, yet external financing constraints consistently pose challenges. A robust financial foundation is essential for innovation projects due to their unique characteristics, such as higher risks, extended payback periods, and significant sunk costs, distinguishing them from conventional investments (Ascioglu *et al.*, 2008; Savignac, 2008; Yu *et al.*, 2021). However, due to the non-exclusive nature of knowledge, companies leading in innovation often keep R&D activities as trade secrets to prevent information leakage (Hall, 2002; Ge *et al.*, 2020). This secrecy exacerbates the "lemon problem" between capital seekers and providers (Ju *et al.*, 2013), reducing the willingness of financial institutions to provide loans and amplifying the challenges associated with financing constraints and market frictions (Beladi *et al.*, 2021). Small, young innovative enterprises often encounter financial hurdles when seeking external funds for their promising innovations (Audretsch *et al.*, 2020).

Addressing this issue involves leveraging the benefits of ESG performance. The research of Kim and Park (2023) demonstrates that ESG practices are effective in reducing information asymmetry between enterprises and external investors. Specifically, companies that actively engage in ESG initiatives tend to disclose high-quality, trustworthy information. This transparency sends a clear message to financial institutions and external stakeholders about firms' operational performance, assisting them in making informed investment decisions (Chen & Xie, 2022). Alleviating financial constraints ensures a steady and adequate flow of capital throughout the innovation process, ultimately enhancing innovation efficiency. Therefore, we propose our third hypothesis (H3):

Hypothesis 3 (H3): ESG performance can promote firms' innovation efficiency by alleviating financing constraints.

4) The mechanism role of corporate governance

Sustained competitiveness and value generation increasingly depend on the role of innovation. Nevertheless, innovation acts as a double-edged sword, necessitating the sacrifice of immediate gains for future prosperity. This presents challenges for managers who strive to enhance financial performance through R&D achievements within a short period (Griffin *et al.*, 2021). The urgent need to meet financial targets, coupled with concerns about the consequences of failure, often deters management from investing in projects with innovation risks (Porter, 1992). This situation is further complicated by the opportunistic behaviours of publicly traded companies, driven by market-sensitive investors who frequently trade based on short-term market fluctuations, creating obstacles to the progress of corporate innovation (Benner & Zenger, 2016; Jia & Menon, 2023). For instance, under the pressure of blockholders who disregard the complexities and long timeframes of innovation activities, managers may feel compelled to manipulate earnings and reduce R&D spending. This can result in fewer patent applications, a decrease in influential patents, and a decline in overall innovation efficiency (Bereskin *et al.*, 2018). Business owners often turn to short-term incentives to align their interests with those of managers. However, if these typical incentives are insufficient to alleviate managers' concerns about reputation and career risks (such as dismissal due to poor financial performance), they might prioritize actions that inflate short-term reported results, hindering the pursuit of long-term innovations (Ongsakul *et al.*, 2022).

ESG establishes a pathway for companies to optimize governance capability while ensuring that the interests of various stakeholders are considered in corporate decision-making. Firstly, incorporating ESG principles into executive incentive plans acts as a remedy for short-sighted management thinking. Fatemi *et al.* (2018) and Chen and Xie (2022) demonstrate that ESG disclosure is more effective than financial data in reflecting a company's commitment to long-term value. Executives with ESG-driven incentives are obliged to provide transparent information rather than engage in selective reporting. Secondly, ESG initiatives redefine the traditional concept of shareholder wealth maximization by broadening the focus to include all stakeholders, significantly enhancing enterprises' social capital. As Khan *et al.*, (2016)

and Alsayegh *et al.,* (2020) suggest, aligning interests across different parties contributes to developing a balanced and sustainable business strategy, positively impacting both financial success and non-financial aspects. Thirdly, firms with strong ESG performance attract professional investors who are aware of sustainability. Hong *et al.*, (2022) posit that firms committed to ESG initiatives in their efforts to reduce governance risks not only adhere to ethical standards but also offer institutional shareholders an investment framework that minimizes relevant risk exposure. Given ESG practices' risk management effects, institutional investors are increasingly aligning their investment strategies with the ESG approaches of firms (Sakawa & Watanabel, 2020). Similar to government departments, institutional investors can play a role in external corporate governance surveillance, using their expertise to seek reliable information for investment decisions. With strong governance, companies can reduce the risk of internal conflicts and opportunistic behaviours. Even when facing challenges in innovation, external stakeholders are more likely to attribute these to uncontrollable factors rather than managerial shortcomings. This high level of trust and credibility encourages stakeholders to be more understanding and supportive, providing managers with a buffer to confidently pursue innovation (Sakaki & Jory, 2019). Therefore, our fourth hypothesis (H4) is proposed:

Hypothesis 4 (H4): ESG performance can promote firms' innovation efficiency by improving corporate governance.

The theoretical model of this research is shown in Fig. 1. These tests include the H1 baseline test, the H2, H3, and H4 mediating tests, and the heterogeneity tests.

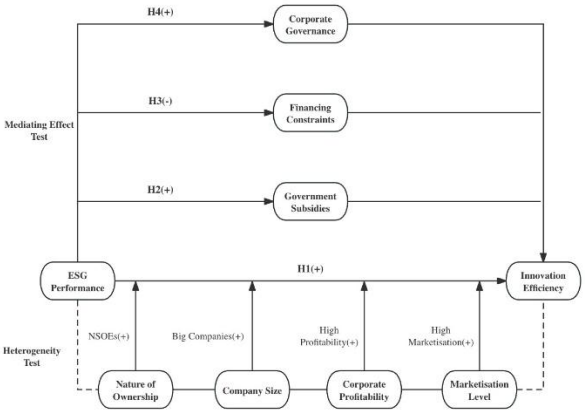

Fig. 1. Theoretical framework. Notes: [+] positive relationships.

III. Research Design

A. Sample Selection and Data Source

The initial sample includes all firms listed on the Shanghai and Shenzhen Stock Exchanges from 2009 to 2020. Following the methodology of Tang (2022), this research constructs the sample as follows: (1) exclude firms under special treatment (ST) or particular transfer (PT); (2) eliminate samples with missing values; and (3) exclude financial services firms due to the differences in financial statement structures and business models between financial and non-financial sectors. Considering the sample coverage and the relevant period, the Sino-Securities Index (SNSI) ESG rating has been used as a proxy for enterprises' ESG performance. This rating has assessed the ESG performance of A-share listed companies since 2009 and includes all A-share listed companies in Shanghai and Shenzhen. The SNSI ESG rating and innovation patent data are sourced from the WIND database, while additional relevant firm-level financial and industry characteristic data are obtained from the CSMAR database. All continuous variables are winsorized at the top and bottom 1% levels to reduce the impact of extreme values on the empirical results. The final sample consists of 24,879 firm-year observations.

B. Variable Definition

1) Innovation efficiency

According to the Patent Law of the People's Republic of China, three distinct types of patents are officially defined and registered with the State Intellectual Property Office (SIPO): invention patents, utility model patents, and appearance design patents. Of these, invention patents are considered the most innovative, encompassing new technical solutions or improvements to production processes. To assess how efficiently an enterprise converts innovation input (typically represented by R&D expenditure) into innovation output (measured by patent applications), we employ the method outlined by Hirshleifer *et al.,* (2013). This method involves constructing a measurement called 'Innovation Efficiency' (*InnoEff1*), which reflects a firm's ability to generate patents or patent citations per unit of R&D investment. *InnoEff1* is calculated by dividing the number of inventions, utility model, and design patents generated by the firm's R&D investment from the previous year.

$$InnoEff1_{i,t+1} = \frac{ln\left(patent1_{i,t} + patent2_{i,t} + patent3_{i,t} + 1\right)}{ln\left(R\&D_{i,t} + 1\right)} \quad (1)$$

where i index firms, and t denotes years. $InnoEff1_{i,t+1}$ represents the innovation efficiency, the numerator from $patent1_{i,t}$ to $patent3_{i,t}$ stands for invention patents, utility model patents, and appearance design patents respectively, and the denominator $R\&D_{i,t}$ represents the innovation inputs. *InnoEff2*, on the other hand, assigns weights of 3:2:1to the three types of patents:

$$InnoEff2_{i,t+1} = \frac{\ln\left(patent1_{i,t} + \frac{2}{3} * patent2_{i,t} + \frac{1}{3} * patent3_{i,t} + 1\right)}{\ln\left(R\&D_{i,t} + 1\right)} \quad (2)$$

These two measurements evaluate innovation efficiency through the lens of innovation quantity and quality, respectively. The higher the value of innovation efficiency, the greater the innovation outcome the enterprise derives from its R&D investment.

2) ESG performance

In this paper, the core explanatory variable is represented by the SNSI ESG rating. The United Nations Environment Program established the Principles for Responsible Investment (UN PRI) in 2006, making ESG ratings a vital indicator of corporate ESG performance (Gibson *et al.,* 2022). The SNSI ESG rating aligns with the international mainstream ESG evaluation framework, standardizing indicators and offering a range of nine ratings from "AAA" to "C". The data sources include sustainability reports,

annual filings, proxy statements, corporate governance reports, supplemental releases, and company websites. For ease of computation, this paper assigns a score of 9 to an "AAA" ESG rating, 8 to "AA", and so on.

Alternatively, Bloomberg's ESG rating provides a viable substitute for the SNSI ESG rating. Bloomberg, a globally recognized financial information and news rating agency, employs a bottom-up, model-driven approach. It uses self-reported and publicly available data to create a transparent, parametric scoring system ranging from 0 to 100. A score close to 100 denotes excellent ESG performance, whereas a lower score indicates a lesser performance.

3) Mechanism variables

We examine the following mechanisms to understand potential causality: government subsidies, financing constraints, and corporate governance, which is also the focus of this article. The variables *Subsidy* and *TaxRebate* serve as proxies for government subsidies. Enterprises exhibiting strong ESG performance are likely to receive policy support from the government to enhance innovation efficiency (Meuleman & Maeseneire, 2012). We categorize the funding received from government departments into two types: government subsidies (*Subsidy*) and tax rebates (*TaxRebate*). Both types represent forms of government incentives for innovation (Zhang & Song, 2022). Information on government innovation subsidies is derived from the "Government Subsidy Details" section under "Non-operating Income" in the financial statements notes within the CSMAR database. Due to the absence of a unified disclosure format, this paper utilizes a "Keyword Search" method to identify specific items related to government subsidies. This approach aids in determining the eligible projects. These amounts were then summed to calculate the total innovation subsidies (*Subsidy*) granted to each company annually. In a similar manner, the total amount of tax refunds (*TaxRebate*) is ascertained by aggregating all the relevant tax rebate items.

Financing constraints are an indicator of whether enterprises encounter difficulties and high costs in securing funding (Kaplan & Zingales, 1997). Enterprises with robust ESG performance may gain easier access to capital and incur a lower cost of capital for innovation investments. Following Hadlock and Pierce (2010), this paper employs the Kaplan and Zingales (KZ) index and the Whited and Wu (WW) index as indicators of financing constraints. The KZ index assesses an enterprise's dependence on external financing. Higher scores on this index suggest a greater probability of facing financial challenges in adverse economic conditions. According to Lamont *et al.*, (2001), the KZ index is given by:

$$-1.001909CF_{i,t} + 3.139193TLTD_{i,t} - 39.36780TDIV_{i,t} - 1.314795CASH_{i,t} + 0.2826389Q_{i,t} \quad (3)$$

where $CF_{i,t}$ is the ratio of cash flow to total assets; $TLTD_{i,t}$ is the ratio of the long-term debt to total assets; $TDIV_{i,t}$ is the ratio of total dividends to assets; $CASH_{i,t}$ is the ratio of liquid assets to total assets; and $Q_{i,t}$ is Tobin's q. Similarly, the alternative indicator of financing constraints, the WW index, constructed as a linear combination of six empirical factors which quantifies the degree to which a firm's investment decisions are constrained by its financial position. Whited and Wu (2006) give the formula of the WW index:

$$-0.091CF_{i,t} - 0.062DIVPOS_{i,t} + 0.021TLTD_{i,t} - 0.044LNTA_{i,t} + 0.102ISG_{i,t} - 0.035SG_{i,t} \quad (4)$$

where $DIVPOS_{i,t}$ is a dividend payer dummy that takes the value of 1 if the firm pays cash dividends, and 0 otherwise; $LNTA_{i,t}$ is the natural log of total assets; $ISG_{i,t}$ is the firm's industry sales growth; and $SG_{i,t}$ is the firm's sales growth.

One of the indicators in measuring corporate governance is discretionary accruals, which imply management's accounting decisions and the private information they possess. Recent research conducted by Hong *et al.*, (2022) discovered that implementing rigorous ESG standards in management can limit the opportunity for managers to manipulate discretionary accruals and help allot more resources for innovation. To calculate the discretionary accruals, the measure of the modified Jones model is given by Dechow *et al.* (1995):

$$NA_{i,t} = \alpha_0 + \alpha_1 \times \frac{1}{A_{i,t-1}} + \alpha_2 \times \frac{\Delta SALE_{i,t} - \Delta AR_{i,t}}{A_{i,t-1}} + \alpha_3 \times \frac{PPEGT_{i,t}}{A_{i,t-1}} + \epsilon_{i,t}$$
$$DA_{i,t} = \frac{TA_{i,t}}{A_{i,t-1}} - NA_{i,t} \quad (5)$$

where $NA_{i,t}$ is the normal accruals for firm i in year t; $A_{i,t-1}$ stands for the total assets for firm i in year t-1; $TA_{i,t-1}$ is the total accruals; $\Delta SALE_{i,t}$ indicates the changes in sales; $PPEGT_{i,t}$ represents the total gross plant property and equipment; and $DA_{i,t}$ is the discretionary accruals for firm i in year t. As determined by Dechow *et al.* (1995), the absolute value of $DA_{i,t}$—*AbsDA*, is the estimate for the modified Jones discretionary accruals.

The other metric of corporate governance is institutional holdings. Currently, enterprises' ESG performance tends to be a critical factor in attracting institutional shareholders, as they are motivated by both financial and social returns. By engaging with institutional investors, enterprises can obtain the necessary financial support to drive innovation development (Dyck *et al.*, 2019). As important stakeholders, institutional investors have strong motivations to protect their investments, thus intensifying the external monitoring of enterprises through oversight activities and requiring credible information (Burns *et al.*, 2010). In this paper, Institutional Ownership (*InsHold*) refers to the overall percentage of outstanding shares held by institutional investors for firm i in year t.

4) Control variables

We control for confounding factors that could potentially affect the relationship between the explained and explanatory variables to isolate and assess their specific effect. The control variables include *Size*, computed as the natural logarithm of total assets, accounting for the influence of firm size on outcomes; *ROA*, the ratio of operating income to total assets, controlling for profitability; *Lev,* representing the ratio of total liabilities to total assets, measures leverage and solvency; *Cashflow*, expressed as the ratio of operating net cash flow to total assets, accounts for liquidity; *Growth*,

capturing the rate of incremental operating income in the current year relative to that of the previous year, controls for operational performance; *FirmAge*, calculated as the natural logarithm of the listing period, controls for the life cycle of enterprises; and the Herfindahl index (*HHI1*) and its square term *(HHI2*) are derived as the sum of the fractions of sales of the firms within the same industry, used to control for industry competition. Additionally, we have incorporated variables related to corporate governance. To address potential issues of omitted variables and enhance the robustness of our analysis, industry fixed effects (Ind FE) based on the China Securities Regulatory Commission (CSRC) 2012 industry classification and year fixed effects (Year FE) have been included.

C. Model Specification

To test the impact of ESG performance on enterprises' innovation efficiency, we construct the regression model (6) as follows:

$$InnoEff1_{i,t+1} = \alpha_0 + \beta_1 ESG1_{i,t} + \beta_2 \sum Controls_{i,t} + \sum Ind + \sum Year + \epsilon_{i,t} \quad (6)$$

where i indicates firms and t denotes years. The explained variable $InnoEff1_{i,t+1}$ represents the innovation efficiency. $ESG1_{i,t}$ is the explanatory variable which represents the ESG score given by the SNSI ESG rating. $Controls_{i,t}$ stands for the control variables included in the model; $\epsilon_{i,t}$ is the error item; and β is the coefficient. This paper has lagged the explanatory and control variables by one year to control for the lagged effect of ESG performance on enterprise innovation efficiency as well as the plausible endogeneity issues caused by reverse causality. Besides, robust standard errors are clustered at the firm level to adjust for the impact of heteroscedasticity and time-series-related problems on the estimation coefficient.

IV. Empirical Analysis

A. Descriptive Statistics

The descriptive statistics results are presented in Table 1. The variable for innovation efficiency (*InnoEff1*) among the sample companies shows an average value of 0.154, with a standard deviation of 0.110. Interestingly, the maximum value for this variable is four times the average, indicating significant variation among the observations. Regarding ESG performance (*ESG1*), the average score is 4.114, ranging from a minimum of 1 to a maximum of 7. This range suggests that the companies in the sample achieve ESG grades varying from C (the lowest) to A (the highest), demonstrating a notable diversity in ESG ratings. In terms of company size, the mean value surpasses the median, indicating a prevalence of larger companies within the dataset. The statistics for return on total assets (*ROA*) display a minimum value of -0.387 and a maximum of 0.244, reflecting diverse profitability across the sample. Given the varied stages of life cycles among the sample companies, the revenue growth rate (*Growth*) shows significant fluctuation, with values ranging from −0.657 to 4.330. Additionally, the data indicates that 35.3% of the sample comprises state-owned enterprises (*SOE=1*), while 64.7% are non-state-owned enterprises (*SOE=0*), with private enterprises constituting the majority. This distribution is reflective of the current structure of China's capital market. The descriptive statistical results for the other control variables align with findings from previous studies.

Table 1. Descriptive statistics of the main variables

VarName	Obs	Mean	SD	Min	Median	Max
InnoEff1	24879	0.154	0.110	−0.959	0.168	0.721
ESG1	24879	4.114	1.075	1.000	4.000	7.000
Size	24879	22.161	1.281	19.350	21.971	26.395
Lev	24879	0.421	0.203	0.028	0.414	0.925
ROA	24879	0.043	0.064	−0.387	0.040	0.244
Cashflow	24879	0.049	0.068	−0.224	0.047	0.283
Growth	24879	0.173	0.410	−0.657	0.110	4.330
FirmAge	24879	2.828	0.360	1.099	2.890	3.555
Top1	24879	0.345	0.148	0.084	0.325	0.758
Mshare	24879	0.142	0.202	0.000	0.007	0.709
Indep	24879	0.375	0.053	0.273	0.333	0.600
SOE	24879	0.353	0.478	0.000	0.000	1.000
BM	24879	0.983	1.089	0.051	0.639	9.946
Fixed	24879	0.219	0.157	0.002	0.188	0.769
HHI_1	24879	0.084	0.099	0.015	0.050	0.932
HHI_2	24879	0.017	0.060	0.000	0.003	0.868

Table 1 reports summary descriptive statistics for all the variables used to estimate. The sample size is 24879. All continuous variables are winsorized at 1% and 99%.

B. Baseline Regression Results

We conduct multivariate regressions, controlling for industry and year fixed effects, to examine the impact of ESG performance on corporate innovation efficiency. Table 2 presents the baseline regression results of Equation (6). Column (1) reports the baseline regression results without covariates, while column (2) includes control variables. The coefficient of *ESG1* in column (1) is 0.0132, which is positive at the 1% significance level, demonstrating that the improvement in ESG performance by one notch (e.g., from BBB to A) has significantly enhanced enterprises' innovation efficiency by 1.32%. Column (2) shows the coefficient of *ESG1* is 0.005, which is slightly smaller but still significantly positive at the level of 1%, confirming the same conclusion given the covariates controlled.

The coefficients of the control variables align with those reported in relevant studies (Liu & Lyu, 2022; Tang, 2022). Notably, the positive relationships between firm size (*Size*), profitability (*ROA*), and management shareholding (*Mshare*) on innovation efficiency are all significant at the 1% level. This suggests that larger, profitable companies with effective stewardship are particularly adept at enhancing innovation efficiency. However, the coefficient for the fixed asset ratio (*Fixed*) is significantly negative, potentially due to a 'crowding-out' effect where traditional capital investment competes with and possibly suppresses innovation investment (Huang *et al.*, 2020). Economically, a one standard deviation increase in a firm's ESG performance corresponds to a 4.8% rise in the number of patent applications per unit of R&D input, other factors being constant. This implies that firms are motivated to strengthen

their ESG practices, both as a positive signal of their commitment to sustainability to stakeholders and as a means of improving their corporate image and long-term value. These improvements could be driven by external factors such as industry regulations or internal factors like management characteristics. Therefore, Hypothesis 1 (H1) is supported.

Table 2. Regression results of ESG performance on corporate innovation efficiency.

Dependent variable:	*InnoEff1*	*InnoEff1*
	(1)	(2)
ESG1	0.012***	0.005***
	(11.32)	(5.54)
Size		0.026***
		(15.63)
Lev		0.013
		(1.57)
ROA		0.075***
		(4.74)
Cashflow		−0.015
		(−0.93)
Growth		−0.001
		−0.03)
FirmAge		−0.003
		(−0.60)
Top1		−0.011
		(−1.02)
Mshare		0.016***
		(2.59)
Indep		−0.039*
		(−1.80)
SOE		0.009**
		(2.18)
BM		−0.003
		(−1.62)
Fixed		−0.029**
		(−2.12)
HHI_1		0.061
		(0.85)
HHI_2		−0.123
		(−1.16)
Constant	0.104***	−0.427***
	(22.11)	(−11.32)
Year FE	Yes	Yes
Industry FE	Yes	Yes
N	24879	24879
Adjusted R^2	0.171	0.239

Table 2 reports the regression results for the firm's ESG score on its innovation efficiency. Column (1) reports the results without control variables and column (2) reports the results with control variables. Year fixed effects and industry fixed effects are included in the models. Robust standard errors clustered at the firm level are used to compute t-statistics. *, ** and *** indicates a significance level at 10%, 5% and 1% respectively.

C. Robustness Checks

1) Replacing the measures of core variables

a) Replacing the measures of the core explanatory variable

As previously mentioned, constructing robust ESG profiles aids listed companies in establishing a responsible social reputation and earning investor trust. However, there is a risk that some companies may embellish their ESG performance for self-interest, leading to inconsistencies in ratings from different agencies. To address this issue related to ESG disclosure quality, our study includes the Bloomberg ESG rating as an alternate explanatory variable, denoted *ESG2*.

The Bloomberg ESG rating, globally recognized for its reliability, assigns scores from 0 to 100 to assess a company's ESG performance. It is crucial to note, however, that Bloomberg's coverage extends back only to 2011, thereby limiting the sample size compared to the SNSI ESG rating data. As Table 3 shows, column (1) of Panel A reveals that the coefficient associated with *ESG2* is 0.001, which is positively significant at the 1% level. This result reinforces the robustness of our baseline regression findings.

b) Replacing the measures of explained variable

In the initial regression model, our study utilizes patent applications as the explained variable in the regression model. It is important to recognize that the development of ESG performance may influence not only the quantity but also the quality of innovation. A prevalent belief is that invention patents typically demonstrate a higher level of originality and innovation quality compared to utility model and appearance design patents. With this in mind, we calculate a weighted summation of these three patent categories using a 3:2:1 ratio. To gauge the scale of patent output, we apply the natural logarithm, following the approach of Quan and Yin (2017). Regression outcomes in column (2) show a coefficient of 0.006 when replacing the explained variable with *InnoEff2*, which is significantly positive at the 1% level. This finding corroborates the conclusion that ESG performance positively affects innovation efficiency in the subsequent year, maintaining the robustness of the baseline regression results.

2) Changes in the model fixed effects

Our analysis primarily examines the relationship between corporate ESG performance and innovation efficiency using a multiple linear regression method with a two-way fixed effects model, controlling for industry and year fixed effects. However, there may be time-invariant heteroscedasticity at the firm level, potentially influencing result estimations. To address potential issues from firm-level unobservable variables, this paper replaces industry fixed effects with firm fixed effects in the model (6). As shown in Panel B, the estimated coefficient of *ESG1* in column (1) is positively significant at the 1% level, with a value of 0.002. Moreover, we implement a triple fixed effects model encompassing firm, industry, and year fixed effects, to simultaneously control for omitted variable issues across three dimensions. The results in column (2) display a significant positive coefficient of 0.002 at the 1% level, affirming the consistency of our findings with the baseline regression.

Table 3. Results of the robustness test

Panel A: Results of replacing explanatory variable and explained variable		
Dependent variable:	*InnoEff1*	*InnoEff2*
	(1)	(2)
ESG2	0.001***	
	(2.80)	
ESG1		0.006***
		(5.36)
Constant	−0.401***	−0.423***
	(−7.90)	(−9.61)
Control variables	Yes	Yes
Industry FE	Yes	Yes
N	8588	24879
Adjusted R^2	0.388	0.211
Panel B: Results of changing the model fixed effects		
Dependent variable:	*InnoEff1*	*InnoEff1*
	(1)	(2)
ESG1	0.002**	0.002**
	(2.46)	(2.44)
Constant	−0.229***	−0.237***
	(−4.10)	(−4.35)
Control variables	Yes	Yes
Industry FE	No	Yes
Firm FE	Yes	Yes
N	24629	24629
Adjusted R^2	0.649	0.655

Panel A column (1) reports the regression results with ESG2 as the explanatory variable, and column (2) reports the results with InnoEff2 as explained variable. Panel B column (1) reports the regression results with year fixed and firm fixed effects and column (2) reports the results with year, industry, and firm fixed effects. Robust standard errors clustered at the firm level are used to compute t-statistics. *, ** and *** indicates a significance level at 10%, 5% and 1% respectively.

3) Endogeneity test: Instrumental variable method

A central issue in related studies is the potential for endogeneity, arising from factors such as omitted variables, reverse causality, and measurement errors (Benlemlih & Bitar, 2018). In our research, we attempt to mitigate omitted variable issues by including firm, industry, and year fixed effects. Nonetheless, the possibility remains that certain excluded variables simultaneously influence corporate innovation efficiency and ESG performance, leading to reverse causality. To address this challenge, we implement a two-stage least squares (2SLS) instrumental variables approach. Following Breuer *et al.* (2018), we select the average ESG score of other firms within the same industry (*ESGOther*) as the instrumental variable. This selection rests on two pillars: (1) firms within an industry are generally subject to similar external influences, regulatory environments, and market dynamics, rendering their ESG ratings pertinent; and (2) the ESG performance of other firms within the same industry is unlikely to directly affect a company's innovation efficiency, thereby satisfying the exogeneity requirement (Zheng *et al.*, 2022). Introducing this instrumental variable allows us to generate an exogenous variation in the endogenous variable (*ESG1*), enabling the identification of the causal effect of ESG practices on corporate innovation efficiency.

The results of the second-stage regression, presented in Table 6, column (1), reinforce our earlier findings. They indicate that enhancing ESG performance significantly fosters enterprise innovation efficiency, evidenced by a coefficient of 0.032 at the 5% significance level. Moreover, the robust Kleibergen-Paap RK Wald F statistic of 54.56 effectively addresses the concern regarding a weak instrument variable. As shown in column (2), the coefficient of the instrumental variable is positively significant at the 1% level, affirming the validity of our conclusions even after accounting for endogeneity.

4) Endogeneity test: Difference-in-differences with multiple time periods

Policymakers and agencies have implemented various mechanisms, including ESG reporting, to monitor ESG progress. The disclosure of ESG performance potentially influences innovation in two ways: Firstly, it may lead to changes in the innovation efficiency of the same enterprise before and after disclosure. Secondly, it may introduce disparities among enterprises that have and have not disclosed within the same timeframe. To accurately measure the net effect of ESG disclosure on firm innovation efficiency, we adopt a difference-in-differences (DiD) approach that considers these variations. This methodology enables the isolation of the impact of other concurrent policies and pre-existing differences across firms. In addition to the well-known SNSI ESG rating and Bloomberg ESG rating, Syntao Green Finance (STGF) launched China's inaugural ESG rating system in 2015, progressively expanding its scope annually. Given the staggered disclosure of the STGF ESG rating by different companies, we utilize a quasi-natural experiment, following the methodology proposed by Beck et al. (2010). This approach allows us to construct a DiD model with multiple time periods, offering a nuanced exploration of the impact of ESG disclosure on innovation efficiency. The model is as follows:

$$InnoEff1_{i,t+1} = \alpha_0 + \beta_1 ESGDisclosure_{i,t} + \beta_2 \sum Controls_{i,t} + \sum Ind + \sum Year + \epsilon_{i,t} \quad (7)$$

where $ESGDisclosure_{i,t}$ is a dummy variable, assigned the value of 1 if company i discloses the STGF ESG report in year t, and 0 otherwise. β_1 represents the estimated coefficient. The other variables retain their symbolic meanings as defined in Model (6).

The results, as detailed in Table 4, column (3), reveal that the coefficient of *ESGDisclosure* is significantly positive at the 1% level. This finding indicates that firms engaging in ESG disclosure significantly enhance their innovation efficiency compared to those that do not, after accounting for other relevant factors. Complementing our results, the empirical study by Chen *et al.* (2023) supports our findings, suggesting that ESG disclosure notably accelerates overall technological innovation in corporations, particularly in the context of voluntary disclosure. This is attributed to the fact that companies voluntarily sharing information demonstrate a forward-thinking approach and a commitment to transparency. Such actions help in building a responsible external reputation and attract socially conscious investors, potentially providing resources that fuel innovative pursuits (Shen *et al.*, 2020).

In applying the DiD methodology with multiple time periods, it is imperative to assume a parallel trend between enterprises that disclose ESG performance and those that do not. This presupposes that, prior to disclosure, the trend in innovation efficiency should be comparable for both groups. To validate this assumption, we employ the event study

method proposed by Jacobson *et al.,* (1993). Given the sample interval from 2009 to 2010 in our study, we consider the five-year periods both before and after the initial STGF ESG disclosure, with the fifth year preceding the initial disclosure serving as the baseline. The results of the parallel trend test, depicted in Fig. 2, show that the coefficients for each period prior to the initial ESG disclosure are not significant. However, from the second year post-disclosure onwards (acknowledging the lagged effect), these coefficients become significantly positive. The absence of notable differences in innovation efficiency among enterprises before the initial ESG disclosure supports the parallel trend hypothesis.

Table 4. Results of the endogeneity test

	Second Stage	First Stage	
Dependent variable:	*InnoEff1*	*ESG1*	*InnoEff1*
	(1)	(2)	(3)
ESG1	0.032**		
	(2.28)		
ESGOther		0.454***	
		(7.39)	
ESGDisclosure			0.006***
			(3.30)
Size	0.019***	0.271***	0.027***
	(4.40)	(19.77)	(36.19)
Lev	0.036**	−0.846***	0.010***
	(2.53)	(−11.05)	(2.83)
ROA	0.001	2.738***	0.083***
	(0.02)	(15.56)	(6.32)
Cashflow	−0.011	−0.191	0.009
	(−0.65)	(−1.48)	(0.90)
Growth	0.003	−0.129***	0.002
	(1.24)	(−7.53)	(1.19)
FirmAge	−0.001	−0.035	−0.005***
	(−0.28)	(−0.89)	(−3.02)
Top1	−0.014	0.108	−0.015***
	(−1.29)	(1.27)	(−3.99)
Mshare	0.001	0.569***	0.014***
	(0.02)	(8.46)	(4.95)
Indep	−0.075***	1.369***	−0.018*
	(−2.58)	(7.06)	(−1.83)
SOE	0.003	0.218***	0.010***
	(0.59)	(6.74)	(7.85)
BM	−0.003	−0.003	−0.002**
	(−1.52)	(−0.21)	(−2.30)
Fixed	−0.034**	0.231**	−0.023***
	(−2.37)	(2.46)	(−5.08)
HHI_1	0.058	0.159	0.097
	(0.81)	(0.43)	(1.54)
HHI_2	−0.116	−0.289	−0.232
	(−1.11)	(−0.65)	(−1.40)
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
N	24879	24879	21685
Adjusted R^2	0.025	0.186	0.331

To address the potential impact of unobserved omitted variables, our study conducts a placebo test, inspired by the methodology of Cai *et al.,* (2016). In this test, the treated enterprises are substituted with a pseudo treatment group composed of 1,165 randomly selected enterprises, and a pseudo control group consisting of the remaining enterprises in the sample.[3] The regression is replicated 1,000 times to generate estimated coefficients and p-values. As illustrated in Fig. 3, the distribution of these regression coefficients and p-values forms a normal distribution around 0, with most proving insignificant at the 10% level. Significantly, the baseline regression coefficient lies outside the kernel density distribution formed by the coefficients from the spurious regressions. This discrepancy suggests that the actual regression coefficient markedly differs from those generated in the placebo tests, a divergence unlikely due to random chance. Therefore, we can reasonably exclude the influence of unobserved omitted variables on our baseline regression outcomes.

Column (1) and column (2) report 2SLS regression results. The result of the first-stage weak instrument test (F-value) is 54.56. Column (1) reports the results of the second-stage regression and column (2) reports the results of the first stage. Column (3) reports the regression results of the method of DiD with multiple time periods. Year fixed effects and industry fixed effects are included in the models. Robust standard errors clustered at the firm level are used to compute t-statistics. *, ** and *** indicates a significance level at 10%, 5% and 1% respectively.

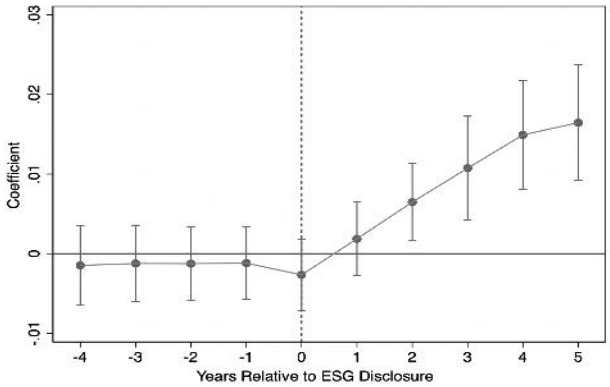

Fig. 2. Parallel trend test. Note: The solid points represent the estimated coefficients, and the short vertical lines are the 95% confidence intervals.

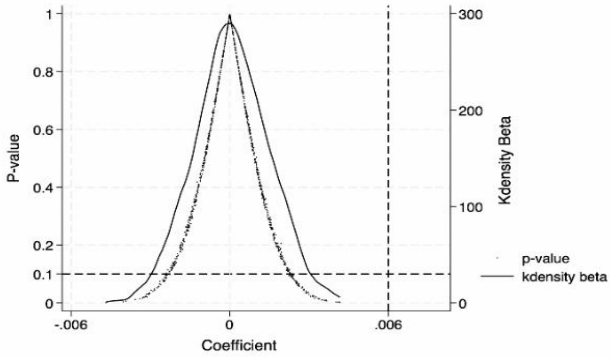

Fig. 3. Placebo test. Note: the horizontal dashed line represents the 10% significance level, and the vertical dashed line is the real baseline regression coefficient.

[3] By 2020, the STGF ESG rating has covered 1165 listed companies. Therefore, we selected 1165 companies from the sample to keep the consistency in the placebo test.

V. Economic Mechanism

As previously established, our study identifies a direct and positive correlation between ESG performance and innovation efficiency. A notable aspect of this relationship is the parallel rise in ESG ratings and the increase in patent applications per unit of RMB invested in R&D. In the subsequent section, we will methodically explore this causality from three perspectives: government subsidies, financing constraints, and corporate governance. This multifaceted approach is designed to deepen the understanding of how ESG performance influences corporate innovation efficiency.

A. Government Subsidies

Table 5. Mechanism test: Government subsidies

Dependent variable:	*Subsidy*	*TaxRebate*
	(1)	(2)
ESG1	0.746***	0.251***
	(3.21)	(3.33)
Size	2.676***	2.196***
	(9.36)	(23.71)
Lev	−0.682	0.212
	(−0.43)	(0.41)
ROA	−14.979***	−4.744***
	(−3.28)	(−3.21)
Cashflow	−2.577	5.923***
	(−0.67)	(4.73)
Growth	0.141	−0.841***
	(0.24)	(−4.38)
FirmAge	−2.630***	−0.526**
	(−3.36)	(−2.08)
Top1	−14.639***	−0.039
	(−8.71)	(−0.07)
Mshare	2.633*	0.871*
	(1.87)	(1.91)
Indep	−3.283	−0.880
	(−0.76)	(−0.63)
SOE	2.543***	0.400**
	(4.15)	(2.02)
BM	−2.340***	−0.255**
	(−7.41)	(−2.49)
Fixed	−8.900***	−4.026***
	(−4.62)	(−6.45)
HHI_1	6.407	−3.723
	(0.55)	(−0.98)
HHI_2	−17.047	4.837
	(−1.10)	(0.97)
Constant	−22.508***	−37.252***
	(−3.40)	(−17.38)
Year FE	Yes	Yes
Industry FE	Yes	Yes
N	24749	24749
Adjusted R^2	0.118	0.115

Table 5 reports the regression results for the effect of firms' ESG performance on government subsidies. Year fixed effects and industry fixed effects are included in the models. Robust standard errors clustered at the firm level are used to compute t-statistics. *, ** and *** indicates a significance level at 10%, 5% and 1% respectively.

Government incentives play a crucial role in addressing market failures, offering financial motivation for businesses to engage in sustainable practices. Organizations committed to ESG practices often exhibit a strong focus on long-term goals, which reduces information asymmetry and enhances their ability to gain trust from government entities. To examine the mediating role of government subsidies in the link between ESG performance and corporate innovation efficiency, we adopt the methodology proposed by Wen and Ye (2014). We include government innovation grants and tax rebates as proxies for government subsidies in Eq. (6). The results, presented in Table 5, column (1), show a positive association between ESG performance and innovation subsidies, with a coefficient of 0.746 at the 1% significance level. Furthermore, column (2) reveals a coefficient of 0.251 for tax rebates, another proxy for government subsidies, also significant at the 1% level. These findings suggest that effective ESG performance can attract government grants.

In terms of the link between government subsidies and corporate innovation efficiency, empirical research by Li *et al.,* (2021) views government subsidies as an instrumental policy tool for supporting corporate innovation, enhancing innovation efficiency. Similarly, Yang *et al.,* (2021) argue that companies benefiting from government aid exhibit improved innovation efficiency. Thus, our findings confirm that government subsidies act as a conduit through which ESG performance boosts corporate innovation efficiency. Hypothesis 2 (H2) is therefore supported.

B. Financing Constraints

Theoretical analysis suggests that ESG performance fosters innovation efficiency by easing corporate financing constraints. Specifically, companies championing ESG performance can diminish information asymmetry among various stakeholders and foster relations with socially responsible investors by committing to long-term value creation. This access to external financing allows for the allocation of more resources to innovative endeavours. Our empirical investigation, detailed in Table 6, utilizes the KZ and WW indices to assess financing constraints faced by firms. We find that the coefficients in both columns (1) and (2) are negative and significantly at the 1% level, indicating that enhanced ESG performance reduces barriers to financing for enterprises.

Table 6. Mechanism test: Financing constraints

Dependent variable:	*KZ*	*WW*
	(1)	(2)
ESG1	−0.093***	−0.002***
	(−8.70)	(−8.16)
Size	−0.256***	−0.047***
	(−15.29)	(−136.29)
Lev	6.343***	0.021***
	(69.46)	(10.91)
ROA	−4.959***	−0.218***
	(−22.00)	(−34.67)
Cashflow	−15.121***	−0.095***
	(−92.90)	(−23.39)
Growth	−0.163***	−0.045***
	(−6.26)	(−44.80)
FirmAge	0.188***	0.003***
	(4.27)	(3.34)
Top1	−0.790***	−0.011***
	(−8.18)	(−5.54)
Mshare	−1.146***	−0.008***
	(−14.02)	(−5.09)
Indep	1.004***	0.010**
	(4.47)	(2.04)
SOE	0.056	0.001
	(1.63)	(0.41)
BM	−0.080***	−0.003***
	(−5.12)	(−6.31)
Fixed	2.191***	0.005**
	(22.72)	(2.35)
HHI_1	−0.791	−0.044*
	(−1.58)	(−1.85)
HHI_2	0.826	0.112*
	(1.18)	(1.83)
Constant	4.491***	0.034***
	(11.57)	(4.37)
Year FE	Yes	Yes
Industry FE	Yes	Yes
N	25700	22704
Adjusted R^2	0.746	0.849

Table 6 reports the regression results for the effect of firms' ESG performance on financing constraints. Year-fixed effects and industry-fixed effects are included in the models. Robust standard errors clustered at the firm level are used to compute t-statistics. *, ** and *** indicates a significance level at 10%, 5% and 1% respectively.

Concerning the influence of financing constraints on corporate innovation efficiency, prior studies such as those by Savignac (2008) and Garcá-Quevedo *et al.* (2018) empirically demonstrate that easing financing constraints increases firms' propensity and capacity to undertake innovative activities, thereby contributing to innovation efficiency. This perspective is further corroborated by Yu *et al.,* (2021) and Wang *et al.,* (2022), who present a negative correlation between financing constraints and innovation efficiency among China's listed companies in the green energy and manufacturing sectors, respectively. Therefore, by alleviating financing constraints, enterprises excelling in ESG performance can secure external capital to drive innovation efficiency. Hypothesis 3 (H3) is corroborated.

C. Corporate Governance

The interplay between ESG practices and innovation efficiency is significantly influenced by the quality of corporate governance. Primarily, firms adhering to ESG principles are often perceived as having robust corporate governance that provides reliable reporting, championing sustainability, and fostering responsible innovation. Given the severe implications of jeopardizing this trust, managers generally find the cost of engaging in opportunistic behaviour prohibitively high. Secondly, companies demonstrating exemplary ESG performance tend to attract institutional investors who are mindful of long-term impacts. These investors typically undertake extensive due diligence before and after investments, ensuring that corporate practices are in harmony with their investment criteria. Thus, they play dual roles as both financiers and overseers. Our analysis of corporate governance involves using the absolute value of discretionary accruals to gauge the extent of earnings management, as illustrated in Table 7, column (1). At a 1% significance level, the regression results exhibit a negative sign, suggesting that robust ESG performance mitigates earnings management. In column (2), we introduce institutional shareholdings as an alternative indicator of corporate governance efficacy. Here, the noted coefficient of 0.482 is statistically significant at the 1% level, reinforcing the impact of enhanced ESG performance on corporate governance.

Turning our attention to the nexus between corporate governance and innovation efficiency, recent empirical research, including studies by Scherer and Voegtlin (2020), underscores that organizations with strong corporate governance structures are more adept at fostering effective and efficient innovation activities. Furthermore, Jia *et al.,* (2019) observe that improvements in governance not only reduce agency risks but also enhance the efficiency of resource allocation in innovation processes. In summary, superior ESG performance acts as a bulwark against managerial short-sightedness by minimizing discretionary accruals and bolstering institutional shareholdings. The mechanism of corporate governance serves as an integral mediator, through which ESG practices boost corporate innovation efficiency. Thus, Hypothesis 4 (H4) is verified.

Table 7. Mechanism test: Corporate governance.

Dependent variable:	*AbsDA* (1)	*InsHold* (2)
ESG1	−0.001***	0.482***
	(−3.75)	(3.05)
Size	−0.001***	4.756***
	(−2.67)	(18.96)
Lev	0.039***	−0.954
	(14.02)	(−0.74)
ROA	0.015	62.520***
	(1.04)	(15.36)
Cashflow	−0.119***	6.541***
	(−12.19)	(2.86)
Growth	0.016***	3.033***
	(10.56)	(7.38)
FirmAge	0.001	−4.533***
	(0.50)	(−6.09)
Top1	0.001	62.795***
	(0.19)	(41.14)
Mshare	0.004*	−79.262***
	(1.77)	(−57.88)
Indep	0.015**	−18.617***
	(2.02)	(−4.99)
SOE	−0.003***	0.310
	(−3.29)	(0.62)
BM	−0.009***	−2.879***
	(−11.92)	(−8.90)
Fixed	−0.036***	0.808
	(−10.92)	(0.50)
HHI_1	−0.048	27.084*
	(−1.08)	(1.78)
HHI_2	0.165	−79.322*
	(1.37)	(−1.95)
Constant	0.090***	−55.099***
	(7.29)	(−9.40)
Year FE	Yes	Yes
Industry FE	Yes	Yes
N	26591	26185
Adjusted R^2	0.109	0.683

Table 7 reports the regression results for the effect of firms' ESG performance on corporate governance. Year fixed effects and industry fixed effects are included in the models. Robust standard errors clustered at the firm level are used to compute t-statistics. *, ** and *** indicates a significance level at 10%, 5% and 1% respectively.

VI. Heterogeneity Analyses

ESG considerations, acknowledged as a pivotal element in shaping a company's innovative capacity, demonstrate a varied relationship with corporate innovation efficiency across different business characteristics and geographical regions. We undertake a detailed exploration of this complex interplay through heterogeneity analysis, examining how factors such as the ownership structure of listed companies, company size, profitability, and regional marketization levels interact with the influence of ESG performance on innovation efficiency. Our objective is to uncover the diverse impacts ESG practices have on innovation.

A. Ownership of Listed Companies

Disparities in corporate ownership structures can give rise to varying effects of ESG performance on firms' innovation endeavours. In the case of SOEs in China, there exists a dual focus on both political and economic objectives. However, ESG practices in SOEs tend to prioritize political goals, often due to intense institutional pressure. This situation can exacerbate agency problems and increase risk aversion in R&D activities, as pointed out by Xu (2011) and Zhang *et al.,* (2020). SOEs typically operate in less competitive industries,

and the lack of market-driven innovation incentives can lead to complacency. Such an environment, combined with redundant governance structures, may dampen the enthusiasm for innovation among R&D personnel (Shi & Zhang, 2018). In contrast, Non-State-Owned Enterprises (NSOEs) are mainly motivated by profit. Lacking political connections for government and bank support, NSOEs tend to adopt socially and environmentally responsible practices to support their long-run operations. Lian *et al.,* (2023) note that ESG practices in NSOEs foster a sustainable, innovation-oriented business model, which helps reduce agency problems and enhances the impacts of ESG performance on innovation efficiency. Consequently, we hypothesize a more pronounced impact of ESG performance on innovation efficiency in NSOEs. For our analysis, sample enterprises were categorized based on the ownership characteristics of their primary controlling shareholder, distinguishing between government-majority-owned SOEs and privately or publicly traded NSOEs.

Our results, as shown in columns (1) and (2) of Table 8, Panel A, reveal a significant difference in the impact of ESG practices between these two ownership types. The coefficient for *ESG1* in the NSOE group is notably positive, standing at 0.006 at the 1% significance level. Conversely, the coefficient in the SOE group is not statistically significant. To confirm this disparity, we applied the Suest test, which affirmed the statistical significance of the difference at the 1% level. These findings suggest that NSOEs, which are not hindered by bureaucratic decision-making constraints, are more adept at leveraging ESG practices to enhance innovation efficiency and more responsive to market changes due to their entrepreneurial approach. However, SOEs are often restricted by political agendas, limiting their ability to effectively use ESG practices for innovation. Thus, our research indicates that ESG performance in NSOEs is more conducive to boosting innovation efficiency than in SOEs.

B. *Enterprise Size*

Our exploration into the influence of ESG practices on corporate innovation efficiency reveals distinct differences when analysed through the lens of enterprise size. Innovation activities, characterised by extended development cycles and inherent risks, require support from extensive resources in terms of funds and talent. Companies with large assets typically have the strategic advantage of financial capital, human capital, and technology, enabling them to invest in ESG practices to meet the diverse expectations of stakeholders (Zumente & Lāce, 2021). Their substantial assets allow them to engage in ESG investments without facing the trade-offs often encountered by smaller firms, enabling them to pursue both ESG and innovation agendas concurrently (Youn *et al.,* 2015). Therefore, large companies can effectively use their ESG performance as a driver to enhance innovation efficiency (Andries & Stephan, 2019). In contrast, small enterprises, limited by financial constraints and narrower business scopes, often struggle to effectively engage in ESG practices, thus limiting the impact of their ESG efforts on innovation efficiency compared to their larger counterparts (D'Amato & Falivena, 2020). Taking into account these size-based disparities, we hypothesize that the enhancing effect of ESG performance on innovation efficiency is more pronounced in larger enterprises. To test this, we divided the sample into two groups based on total assets: large companies and small companies.[4]

Table 8. Results of heterogeneity analysis.

Panel A: Tests of the ownership		
	SOE	NSOE
Dependent variable:	*InnoEff1*	*InnoEff1*
	(1)	(2)
ESG1	0.002	0.006***
	(1.32)	(5.91)
Constant	−0.451***	−0.427***
	(−6.09)	(−10.17)
Control variables	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
Mean-diff	−0.003**	
N	8790	16089
Adjusted R^2	0.242	0.278
Panel B: Tests of the firm size		
	Small Company	Large Company
Dependent variable:	*InnoEff1*	*InnoEff1*
	(1)	(2)
ESG1	0.004*	0.010***
	(1.94)	(7.28)
Constant	0.163***	0.111***
	(6.07)	(4.09)
Control variables	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
Mean-diff	−0.062***	
N	7869	8616
Adjusted R^2	0.171	0.255
Panel C: Tests of the enterprise profitability		
	Low Profitability	High Profitability
Dependent variable:	*InnoEff1*	*InnoEff1*
	(1)	(2)
ESG1	0.001	0.006***
	(1.11)	(5.46)
Constant	−0.222*	−0.448***
	(−1.93)	(−8.96)
	Low profitability	High profitability
Control variables	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
Mean-diff	−0.008***	
N	12047	12426
Adjusted R^2	0.592	0.254
Panel D: Tests of the level of regional marketisation		
	Low Marketisation extent	High Marketisation extent
Dependent variable:	*InnoEff1*	*InnoEff1*
	(1)	(2)
ESG1	0.002	0.005***
	(1.18)	(3.51)
Constant	−0.343***	−0.405***
	(−5.56)	(−5.91)
Control variables	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
Mean-diff	−0.009***	
N	10824	13639
Adjusted R^2	0.117	0.180

Our regression results, presented in columns (1) and (2) of Panel B, indicate that ESG performance's impact on innovation efficiency in small companies is not significant. For large companies, the coefficient is a substantial 0.010 at the 1% significance level, suggesting a significant positive correlation between ESG performance and innovation

[4] We categorize the sample companies based on the tercile of total assets, with firms larger than the upper tercile as the large company group and firms smaller than the lower tercile as the small company group, excluding the middle group. By doing so, we can mitigate the interference of the middle group on the statistical results and gain clearer insights into how firm size influences this relationship.

efficiency. The Suest test confirms this difference as statistically significant at the 1% level. These results support the notion that large companies exhibit a more substantial positive relationship between ESG performance and innovation efficiency compared to smaller ones.

C. Enterprise Profitability

The relationship between ESG performance and innovation efficiency is also influenced by enterprise profitability. Profitable companies, generating abundant cash flows, possess greater financial flexibility and resilience against market volatility and economic downturns (Safitri & Anggara, 2019). This financial strength enables them to maintain consistent and long-term investments in ESG initiatives. Additionally, enterprises with strong profitability and ESG profiles appeal to socially responsible investors and stakeholders, enhancing both input and output efficiency throughout their innovation process (Aydoğmuş *et al.*, 2022). In contrast, less profitable companies may struggle to effectively conduct their innovative endeavours, constrained by limited internal capital and the external resources necessary for driving ESG activities (Li *et al.*, 2017). Understanding these dynamics, we propose that the impact of ESG practices on innovation efficiency is more significant in highly profitable companies. To examine this hypothesis, we categorized our sample into high-profitability and low-profitability groups based on Return on Assets (ROA) and conducted a regression analysis.[5]

The results, depicted in Panel C, show that the coefficient for the low-profitability group is insignificant. Conversely, the coefficient for the high-profitability group is 0.006, indicating significance at the 1% level. The Suest Test further confirms the significant disparity between these two coefficients at the significance level of 1%. Our findings underscore the pivotal role of profitability in shaping the relationship between ESG performance and innovation efficiency, demonstrating that highly profitable companies are more adept at enhancing innovation efficiency through their ESG initiatives.

D. Level of Regional Marketisation

The progression of marketisation in China encompasses comprehensive reforms in economic, social, legal, and political domains (Lian *et al.*, 2023). In areas with advanced marketisation, certain characteristics become prominent: a dynamic market environment, minimal government interference, accessible social capital, and robust legal frameworks (Chen *et al.*, 2021). These factors contribute to a significant reduction in information asymmetry, as they enhance the flow and accessibility of information to investors and other stakeholders (Liu *et al.*, 2021). In such an environment, competition thrives, and uncertainties diminish, allowing businesses to effectively utilize their ESG performance in devising innovative strategies within a clearly defined economic and legal context (Tan *et al*., 2020; Cheng *et al.*, 2023). In contrast, regions with lower levels of marketisation often face challenges such as excessive governmental intervention, limited access to capital, and poor information fluidity. These conditions impede the ability of enterprises to engage in sustainable and socially responsible innovation that is in line with ESG principles (Zhang *et al.*, 2022). Based on these considerations, our study hypothesizes a more pronounced correlation between ESG performance and innovation efficiency in regions with higher marketisation. Extending the work of Wang *et al.* (2017), we stratify our sample into two categories: the high-marketisation group and the low-marketisation group, with the marketisation index of the enterprises' geographical locations as the defining criterion.[6]

The regression results, detailed in Panel D, reveal a notable difference in the impact of ESG performance across these two categories. In low-marketisation regions (column 1), the influence of *ESG1* on innovation efficiency is not statistically significant. However, in high-marketisation areas (column 2), a significant positive coefficient of 0.005 is observed at the 1% level, underscoring a stronger effect of ESG performance. To further substantiate these findings, we employ the Suest method, which confirms the statistical distinction between the coefficients of the two groups at the 1% level. These results decisively suggest that the positive impact of corporate ESG performance on innovation efficiency is more pronounced in regions with a higher degree of marketisation, highlighting a clear heterogeneity based on regional marketisation levels.

Panel A reports the regression results for the effect of ESG performance on firms' innovation efficiency of state-owned enterprises and non-state-owned enterprises, respectively. Panel B reports the results for the effect of ESG performance on firms' innovation efficiency between small companies and large companies. Panel C reports the results for the effect of firms' ESG performance on the innovation efficiency of highly profitable companies and companies with low profitability. Panel D reports the results for the effect of firms' ESG performance on their innovation efficiency in China's provinces, municipalities, and autonomous regions with low marketisation extent and high marketisation extent. Year fixed effects and industry fixed effects are included in the models. Robust standard errors clustered at the firm level are used to compute t-statistics. *, ** and *** indicates a significance level at 10%, 5% and 1% respectively.

VII. Conclusions and Policy Recommendations

This study rigorously examines the interplay between ESG performance and corporate innovation efficiency. We hypothesize that firms exhibiting high ESG performance are likely to demonstrate superior innovation efficiency compared to their lower-scoring counterparts. This is attributed to diminished information asymmetry, enhanced

[5] We divide sample enterprises into high profitable and low profitable companies based on ROA, high profitable enterprises with ROA higher than the median assigned value of 1, otherwise 0 for the following reason: first, ROA provides a quantitative measure of a company's profitability, allowing for comparison and categorization; and secondly, using a median-based classification is objective and less prone to biases or subjectivity.

[6] This paper employs the provincial-level NERI Index of Marketisation developed by the National Economic Research Institute of China Reform Foundation. The process of measuring marketisation includes five fields: (1) the relationship between government and the market; (2) the development of the non-state (private) sector; (3) the development of product and factor markets; (4) the development of market intermediaries; and (5) the market-friendly legal environment. When the marketisation index is higher than the sample median, the corresponding enterprise is in a high-marketisation-level region; otherwise, it is in a low-marketisation region.

stakeholder engagement, and increased access to external resources, assuming other factors remain constant. Through an extensive analysis of 24,879 Chinese firm-year observations, and by meticulously controlling for firm-specific, industry, and year-fixed effects, we observe that companies with elevated ESG performance exhibit markedly improved innovation efficiency. The robustness of our empirical findings is further validated through alternative variable replacements, model modifications, the application of the 2SLS method, and the adoption of the DiD model across multiple time periods. Our study delves into the mediating effects, revealing that the proposed channels significantly contribute to innovation efficiency. Notably, improved ESG performance correlates with heightened government incentives, such as innovation subsidies and tax rebates. Additionally, the signalling effect of ESG performance effectively eases financing constraints and bolsters corporate governance by curtailing managerial opportunism and fostering external monitoring by institutional investors. Heterogeneity analysis illuminates that the impact of ESG performance on innovation efficiency is particularly pronounced in firms operating within highly marketized regions, those with sizable assets, high profitability, and non-state ownership. Echoing Shen *et al.* (2023), our study also discerns that ESG disclosure can enhance innovation efficiency. In environments where ESG disclosure is not obligatory, enterprises voluntarily disclosing ESG practices demonstrate an ability to effectively implement these activities and communicate their achievements to stakeholders, thereby garnering essential support for innovation.

Our findings contribute to the ongoing discourse on the role of ESG performance in value creation, demonstrating that enhanced ESG performance can augment corporate innovation efficiency by improving access to external financing and strengthening internal governance capabilities. While prior research primarily focuses on the direct impact of ESG practices on financial performance in developed markets, we underscore the significance of ESG performance in fostering innovation efficiency in emerging market firms, thereby driving long-term value creation that transcends conventional investment and governance approaches.

The practical implications of our findings are manifold. Firstly, it is imperative for management to prioritize boosting technological and business innovation efficiency from an ESG perspective. Traditionally, firms have concentrated solely on the potential financial returns of innovation initiatives. However, it is equally crucial to consider multidimensional factors, such as potential environmental and social impacts. Hence, corporate boards should emphasize the synergy between ESG performance and innovation capacity to embrace the concept of value investment and establish sustainable competitiveness. Secondly, our findings advocate for investors to move beyond a myopic focus on financial reports and to adopt a broader, more sustainable lens when assessing corporate performance. The 2018 revision of the *Governance Standards for Listed Companies* by the CSRC underscores the importance of social and environmental responsibilities, promoting the notion that long-term value creation necessitates attention to ESG issues. Therefore, ESG performance emerges as a vital non-financial metric for investors seeking stable, enduring returns, enabling them to assess the ethicality of a company's actions when selecting investment opportunities. Thirdly, government bodies should intensify their support for ESG development by offering preferential treatment to enterprises demonstrating commendable ESG performance, thus alleviating external capital and talent constraints. Innovative firms, often facing substantial sunk costs, depend on the expertise and commitment of their core employees. However, challenges such as information opacity and imperfect contracts can dampen staff enthusiasm for R&D, a key driver of successful innovation outcomes (Shi & Zhang, 2018; Macchiavello, 2022). As indicated by Chen *et al.* (2018), companies that transform ESG advantages into innovation capabilities are poised to enhance innovation efficiency and generate positive externalities. Policymakers can therefore facilitate this transformation by granting special subsidies and tax incentives to innovative companies that invest in workforce education and training programs, focusing on skills pertinent to innovation and emerging technologies. Such initiatives enable firms to rapidly accumulate innovative human capital and convert ESG advantages into a competitive edge in innovation.

In summary, our study provides a comprehensive theoretical framework and empirical evidence highlighting the criticality of ESG performance in relation to external financing and internal governance for innovation efficiency. However, future research should delve deeper into certain areas. Firstly, while China's status as a leading economy offers representativeness among emerging markets, extending this study to include listed companies in other emerging nations would be insightful. The diverse regulatory landscapes, cultural nuances, and developmental priorities across countries necessitate a broader understanding of ESG challenges in various contexts, especially considering the predominance of literature on developed countries. This would enable businesses and stakeholders to adeptly navigate risks, identify market opportunities, and ensure ethical compliance in an increasingly interconnected global environment. Secondly, exploring alternative metrics for quantifying innovation outcomes, beyond patent applications, could yield further insights. Efficient innovation should not only result in novel products or services but also emphasize their societal and environmental impact. Drawing inspiration from Agostini *et al.* (2020), who underscore the strong correlation between customer feedback and the innovation process, companies can gauge the alignment of their offerings with broader sustainability objectives by assessing customer feedback and satisfaction concerning the eco-social dimensions of their innovations.

APPENDIX A. VARIABLES AND DEFINITION

Dependent variables	Symbol	Description
Innovation efficiency	*InnoEff1*	The natural logarithm of total number of applications for invention patents, utility models and design plus one divided by the natural logarithm of R&D expenditure plus one
Innovation efficiency	*InnoEff2*	The natural logarithm of total number of applications for invention patents, utility models and design patents weighted on 3:2:1

		plus one divided by the natural logarithm of R&D expenditure plus one
Independent variables	**Symbol**	**Description**
	ESG1	The score is assigned as 1–9, from low to high, according to Huazheng ESG rating for firm *i* at the year *t+1*
	ESG2	The score is assigned as 0–100, from low to high, according to Bloomberg ESG rating for firm I at year *t+1*
Control variables	**Symbol**	**Description**
	Size	The natural logarithm of total market value for firm *i* at year *t*
	Lev	Ratio of total liabilities to total assets for firm *i* at the end of year *t*
	ROA	Ratio of the operating income after depreciation to the total assets for firm *i* at year *t*
	Cashflow	The ratio of operating net cashflow to the total assets for firm *i* at year *t*
	Growth	The growth rate of operating income for firm *i* at the end of year *t*
	FirmAge	$\text{FirmAge} = \text{Ln}(year_{i,t} - year_{i,0} + 1)$, in which $year_{i,0}$ stands for the listing year for firm *i*
	Top1	The ratio of the number of shares held by the largest shareholder to the total number of shares for firm *i* at year *t*
	Mshare	The management shareholding ratio for firm *i* at the end of year *t*
	Indep	The proportion of independent directors on the board for firm *i* at year *t*
	SOE	Dummy variable, 1 for state-owned enterprises and 0 for non-state-owned enterprises
	BM	Ratio of book value of equity to the market value of equity for firm *i* at the end of year *t*
	Fixed	The ratio of net fixed assets to the total assets for firm *i* at year *t*
	HHI_1	The Herfindahl index is computed as the sum of the fraction of sales of the firms in an industry in year *t*
	HHI_2	The square term of *HHI_1*
Cross-sectional variables	**Symbol**	**Description**
	ESGOther	The average ESG scores of all enterprises in region *k* except firm *i* at year *t*
	Subsidy	The natural logarithm of innovation subsidies granted by government for firm *i* at year *t*
	TaxRebate	The natural logarithm of tax rebate issued by government for firm *i* at year *t*
	KZ	The *KZ* index is constructed following Lamont, Polk, and Saa-Requejo (2001) as $KZ = 0.283Q - 1.002CF/K + 3.139Debt/Capital - 39.368Div/K - 1.315Cash/K$
	WW	The *WW* index is constructed following Whited and Wu (2006) as $WW = -0.091CF - 0.062DIVPOS + 0.021TLTD - 0.044LNTA + 0.102ISG - 0.035SG$
	AbsDA	The absolute value of discretionary accruals for firm *i* at year *t*
	InsHold	The percentage of shares owned by institutional investors for firm *i* in year *t*
	NSOE	Non-state-owned enterprise
	SOE	State-owned enterprise
	Small company	Enterprises whose size below the lower 33% of the industry
	Big company	Enterprises whose size above the upper 33% of the industry
	Low profitability	Enterprises whose ROA below the median level of the industry
	High profitability	Enterprises whose ROA above the median level of the industry
	Low marketization extent	Enterprises whose marketization index below the median level of the industry
	Low marketization extent	Enterprises whose marketization index above the median level of the industry

CONFLICT OF INTEREST

The author declares no conflict of interest.

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