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ESG Performance, Debt Financing, and R&D Output: Evidence From the Healthcare Sector

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ABSTRACT

Amid growing calls for sustainability in the healthcare sector, this study examines how and under what conditions environmental, social, and governance (ESG) performance influences research and development (R&D) output. Although existing studies suggest that ESG performance enhances R&D output, the financial mechanisms that enable or constrain this relationship remain underexplored. We address this gap by theorizing and testing the dual role of debt financing as both a mediator and a moderator in the ESG performance and R&D output relationship within the healthcare sector, where innovation is highly capital-intensive and socially consequential. Integrating stakeholder theory and agency theory, we argue that ESG performance promotes R&D output through improved access to reputational and financial resources, whereas high debt levels weaken this effect due to agency conflicts. Using panel data from 2016 to 2022 on healthcare firms in Europe and the United States, we estimate our main models using OLS and applying instrumental variable and system GMM techniques as robustness checks to address endogeneity. Our findings show that debt financing partially mediates the ESG–R&D link and negatively moderates it, revealing its ambivalent role. Compared to existing studies, our findings indicate that the effects of ESG performance on R&D output are conditional and context specific, with stronger impacts observed in Europe than in the United States, reflecting institutional conditions such as stricter European Union sustainability reporting frameworks, notably the Corporate Sustainability Reporting Directive (CSRD), along with robust policy incentives and longer term investment horizons. We also find pronounced effects in the biotechnology and pharmaceutical subsectors. This study contributes to theory by bridging competing views on ESG performance and offering a more nuanced understanding of how debt financing shapes the ESG–R&D output relationship.

1 | Introduction

The sustainability of firms has become a major global concern under the United Nations' 2030 Agenda for Sustainable Development (United Nations 2015) and the European Green Deal, which targets climate neutrality by 2050 (European Green Deal 2019). These frameworks emphasize the urgent need for industries to align their operations with sustainability goals. However, the prevailing economic and social development models continue to exert substantial pressure on natural resources, posing risks to both public health and social care (Fiksel 2012). In this context, the healthcare sector has emerged as a significant contributor to environmental degradation, driven by its reliance on energy-intensive infrastructure, complex supply chains, high resource consumption, and waste generation (Hensher and McGain 2020; Eckelman et al. 2020). Notably, the sector is responsible for 4.4% of global greenhouse gas emissions, equivalent to the fifth-largest emitter if it were considered a country (Healthcare Without Harm Europe 2019). The United States and the European Union, the world's largest healthcare spenders relative to GDP, together account for nearly 40% of this environmental footprint

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(Eckelman et al. 2020). This environmental toll poses a paradox in which a sector intended to protect human health is simultaneously undermining the ecological systems that sustain it.

Besides the environmental impact, social sustainability in this context includes issues related to equity in access to care, affordability, employee well-being, and ethical treatment of stakeholders (e.g., Chiarini et al. 2017; Paolone et al. 2022). Market-driven practices such as price discrimination and aggressive competition, although often aimed at maximizing financial returns, can unintentionally restrict access to essential healthcare services, particularly for marginalized populations. These dynamics highlight the sector's need to balance economic imperatives with societal responsibilities. Furthermore, governance-related practices such as board diversity, transparent leadership, and labor rights are increasingly scrutinized as part of firms' broader sustainability initiatives (Dixit 2020; Uyar et al. 2021). As such, healthcare firms are expected to integrate these social and governance considerations alongside environmental concerns to build resilient, equitable, and sustainable business models (Mehra and Sharma 2021).

Moreover, human health outcomes create interdependencies with social and environmental sustainability (e.g., Park et al. 2022; Montiel et al. 2022). Health shocks such as communicable disease outbreaks disproportionately burden vulnerable populations through reduced access to care, income loss, and widened inequities, thereby intensifying the social dimension of sustainability (Park et al. 2025). At the same time, surges in acute and infection-control services during health emergencies increase resource use, medical waste, and energy demand across healthcare supply chains, aggravating the sector's environmental footprint (Eckelman et al. 2020). The cross-border nature of disease transmission further illustrates how global business systems mediate these effects (Montiel et al. 2022). This interplay underscores the importance of adopting a holistic, systems-oriented perspective on sustainability in healthcare.

Together, these dynamics highlight why the healthcare sector must increasingly balance its mission to promote public health with the imperative to reduce its environmental footprint and enhance operational efficiency. This dual objective has shifted sustainability from a peripheral concern to a central pillar of strategic and operational decision-making in the sector (Uyar et al. 2021). This shift is particularly relevant from a management perspective, as it reflects not only growing regulatory and reputational pressures but also the need to foster innovation and ensure long-term competitiveness (Panda and Sangle 2020). As healthcare systems increasingly contribute to environmental deterioration, they are now recognized as key actors in advancing the Sustainable Development Goals (SDGs) (Acharya et al. 2018). To address environmental challenges, healthcare firms must institutionalize sustainability across clinical, managerial, and strategic levels by adopting practices such as socially responsible accounting (Bonollo 2015), outcome-based performance metrics (Wenzel et al. 2014), and low-emission innovations such as telemedicine (Purohit et al. 2021). These initiatives must align with the values of both internal and external stakeholders, such as patients, healthcare workers, insurers, and regulators (Freeman et al. 2018; Dixit 2020). Embedding

such practices into core decision-making processes enables healthcare managers to respond to growing environmental and social expectations while maintaining institutional legitimacy, accountability, and performance.

Although sustainability dimensions are inherent to the healthcare sector (e.g., Cardinaels and Soderstrom 2013; Uyar et al. 2021), the role of ESG performance in driving R&D output remains relatively underexplored. Existing ESG literature has largely concentrated on emissions-intensive industries such as mining, energy, and automotive, whereas the healthcare sector has received comparatively limited scholarly attention despite its growing sustainability challenges (Belkhir and Elmeligi 2019; Paolone et al. 2022). This is especially relevant given the sector's reliance on stakeholder trust, regulatory oversight, and ethical governance practices (Dixit 2020). Increasing market competition, declining drug pipelines, and growing demands for outcomes-based evidence have further intensified the need for healthcare firms to integrate ESG principles into their core strategies (Wenzel et al. 2014). Yet ESG performance as a catalyst for R&D output in healthcare remains insufficiently theorized and empirically examined.

ESG performance has gained prominence as a key mechanism through which firms operationalize their sustainability objectives, particularly in ways that influence R&D output (e.g., McWilliams and Siegel 2001; Chen et al. 2023; Baek and Lee 2024). ESG performance serves as a platform for signaling commitment to sustainable practices and aligning with stakeholder expectations, enhancing legitimacy and access to critical resources (Kemper et al. 2013; Baek and Lee 2024). This alignment fosters the development of dynamic capabilities and innovation agility, enabling firms to remain competitive in fast-evolving markets. Consequently, firms leveraging ESG dimensions effectively can accelerate technological advancement (Padgett and Galan 2010; Panda and Sangle 2020). It cultivates distinctive capabilities and knowledge that are difficult for competitors to replicate over time, providing firms with a sustainable competitive edge and contributing directly to enhanced R&D output (Chen et al. 2023). Although ESG performance has been widely associated with positive R&D outcomes through enhanced stakeholder trust and long-term competitiveness (e.g., McWilliams and Siegel 2001; Baek and Lee 2024), recent literature has questioned the consistency and material impact of ESG performance (Eccles and Klimenko 2019; Berg et al. 2022). These concerns have emerged around greenwashing (Christensen et al. 2022), inconsistencies in ESG ratings (Berg et al. 2022), and the challenge of linking ESG disclosures to measurable outcomes (Eccles and Klimenko 2019). These debates highlight the need for more context-specific research to understand the conditions under which ESG performance yields tangible value. Our study responds to this call by exploring how ESG performance contributes to R&D output in the healthcare sector, a setting where innovation is both resource dependent and capital intensive.

This sectoral context is particularly relevant given that firms competing through innovation require substantial long-term financing, such as debt financing, to sustain R&D activities (e.g., Scellato and Ughetto 2010; Brown et al. 2012; Muhammad et al. 2022). However, the inherent uncertainty,

long investment horizons, high risk, and intangible nature of R&D output create significant challenges for debt holders in effectively monitoring these activities. These issues increase information asymmetry and agency costs (Sharfman and Fernando 2008; Ali et al. 2024). Moreover, the divergence between resource consumption and lower short-term financial gains in developing R&D output further leads to inadequate financial support, thereby stifling a firm's motivation to engage in R&D output activities (Hoffmann et al. 2019). By framing ESG performance within these financing constraints, our study offers new insights into its role in shaping R&D outcomes in the healthcare sector.

As firms navigate financial and sustainability imperatives, the healthcare sector has increasingly implemented a range of initiatives aimed at environmental and social responsibility (Mehra and Sharma 2021). These include the adoption of green building standards, energy-efficient technologies, sustainable procurement policies, and waste reduction practices designed to optimize operations and reduce environmental impact. ESG performance, in this context, plays a central role in advancing clean technologies, improving treatment outcomes, and lowering the environmental footprint of healthcare delivery (Bade et al. 2024). Despite these developments and the sector's heavy dependence on R&D investments (Eurostat 2024), there remains a significant gap in our understanding of how ESG performance influences R&D output in healthcare. As an innovation-driven and capital-intensive sector, healthcare requires long-term R&D investment in areas such as pharmaceuticals, biotechnology, and medical technologies, making it theoretically relevant to explore the debt financing mechanism, particularly debt financing, through which ESG performance may influence R&D output. This study aims to address this gap by empirically examining the mechanisms through which ESG performance affects R&D output, with a specific focus on the mediating and moderating roles of debt financing. Accordingly, we pose two research questions:

RQ1. How does ESG performance influence R&D output in the healthcare sector?

RQ2. What are the mediating and moderating roles of debt financing in the relationship between ESG performance and R&D output in the healthcare sector?

In doing so, we aim to provide valuable insights into the interplay between ESG performance, debt financing, and R&D output within the healthcare sector. Our analysis utilizes a sample of 1211 firm-year observations from Europe and the United States covering the period 2016–2022. We employ a series of panel data tests, incorporating both mediation and moderation mechanisms. Specifically, we use the ordinary least squares (*OLS*) regression model to test the primary hypotheses, supplemented by instrumental variable (*IV*) and system generalized method of moments (*SGMM*) regression models to address potential endogeneity concerns. Finally, we conduct heterogeneity analysis to explore regional and industry-specific variations in the ESG performance-R&D output relationship.

Although previous research has examined the relationship between ESG performance and innovation outcomes

primarily in manufacturing and energy sectors (e.g., Demirel and Kesidou 2019; Pinheiro et al. 2023), studies addressing the healthcare context have largely focused on hospital settings (e.g., Cardinaels and Soderstrom 2013; Dixit 2020). Our study offers an incremental yet meaningful contribution in three key ways. First, we broaden the scope by focusing on the healthcare sector as a whole, encompassing a diverse set of subindustries including biotechnology, healthcare equipment and supplies, healthcare providers and services, life sciences, and pharmaceuticals. This provides a theoretically rich context for examining the ESG–R&D output relationship, given the sector's unique blend of societal responsibility, regulatory complexity, and innovation intensity (Hensher and McGain 2020; Rezaee et al. 2023). Unlike other high-tech industries, healthcare firms face heightened public scrutiny, stricter compliance obligations, and elevated ethical expectations in service delivery and governance (Paolone et al. 2022; Uyar et al. 2021). This sector-specific perspective enhances our understanding of how ESG performance influences R&D output in contexts where social legitimacy and technological advancement are deeply interconnected (e.g., Cardinaels and Soderstrom 2013).

Second, unlike most studies that overlook the financial mechanisms linking ESG performance to R&D output (e.g., Padgett and Galan 2010; Amel-Zadeh and Serafeim 2018), we examine both the mediating and moderating roles of debt financing in the ESG–R&D output relationship. This dual focus provides a more nuanced understanding of how ESG performance translates into R&D output under varying financial constraints. Third, whereas previous studies rely on a single-country perspective (e.g., Chen et al. 2023; Baek and Lee 2024), we adopt a cross-regional approach that examines healthcare firms in Europe and the United States. This design captures institutional differences, such as regulatory environments and sustainability reporting frameworks, which shape the ESG–R&D output relationship and enhance the theoretical relevance and generalizability of our findings.

The remainder of the paper is structured as follows: Section 2 outlines the theoretical framework and develops hypotheses. Section 3 details the research methodology. Section 4 presents the empirical results and discussion. Section 5 conducts a series of robustness checks, whereas Section 6 explores the heterogeneity analysis. Finally, Section 7 concludes with key findings and discusses theoretical and practical implications.

2 | Theoretical Framework and Hypotheses Development

Consistent with recent studies (e.g., Chen et al. 2023; Pinheiro et al. 2023; Ali et al. 2024), we discuss stakeholder theory (Freeman 1984; Baek and Lee 2024) to comprehend the impact of ESG performance on R&D output. Then, we incorporate agency theory to explain the role of debt financing in the ESG–R&D relationship (Jensen and Meckling 1976; Brown et al. 2012). Specifically, we argue that debt financing may mediate this relationship by enabling ESG-performing firms to access financial capital and may also moderate it by constraining or facilitating managerial discretion over R&D investments. This layered theoretical framing allows us to examine

not only how ESG performance drives R&D output but also under what financial conditions this relationship strengthens or weakens. Figure 1 illustrates the conceptual model of the proposed relationships.

Specifically, stakeholder theory suggests that firms with superior ESG performance are better positioned to meet the expectations of key stakeholders such as investors, regulators, patients, and employees, thus gaining legitimacy, reputational capital, and support for long-term strategic decisions, including those related to R&D output (Cornell and Shapiro 2021). This theory extends the focus beyond shareholder value and encourages managerial actions that promote sustainable development and environmental protection, thus benefiting all stakeholders (Pinheiro et al. 2023; Baek and Lee 2024). Recent developments in stakeholder theory further emphasize that firms create sustained value by addressing shareholder demands and actively aligning with the evolving expectations of a broader set of stakeholders (Freeman et al. 2018). ESG performance, in this view, becomes a strategic lever through which firms demonstrate accountability, foster trust, and attract resources critical to long-term innovation. Moreover, ESG performance acts as a credibility-enhancing signal embedded in stakeholder relationships. It communicates accountability and risk mitigation, thereby attracting external capital and reinforcing trust (e.g., Fu et al. 2022; Valentinov 2023). Rather than treating signaling as a separate theoretical lens, we conceptualize it as a functional mechanism within stakeholder engagement.

Furthermore, agency theory contends that conflicts of interest often emerge between shareholders, managers, and debt holders, especially in the context of long-term and high-risk investments such as R&D (Jensen and Meckling 1976). Specifically, managers acting on behalf of shareholders may initiate R&D projects that benefit equity holders while imposing disproportionate risk on creditors, thereby leading to potential expropriation of wealth (Aghion et al. 2004; Ali et al. 2024). These conditions give rise to agency problems such as moral hazard, where firms may pursue riskier projects once funding is secured, and adverse selection, in which information asymmetry prevents creditors from accurately assessing the risk profile of R&D investments (Brown et al. 2012). Such issues increase the cost of monitoring and reduce lenders' willingness to finance R&D activities. Bah and Dumontier (2001) further argue that the agency costs associated with debt can significantly undermine the efficiency and effectiveness of R&D

investment. The excessive use of debt financing constrains managerial flexibility and reduces a firm's capacity to sustain innovation over time (Prasad et al. 2022), underscoring the fragility of debt financing in supporting R&D initiatives.

Together, stakeholder theory and agency theory provide a robust foundation for examining how ESG performance influences R&D output. Whereas stakeholder theory highlights the role of external legitimacy and resource access, agency theory emphasizes internal conflicts that may constrain the impact of ESG performance on R&D output. In the following sections, we formulate hypotheses based on our theoretical framework to explore the complex relationships between ESG performance, debt financing, and R&D output.

2.1 | ESG Performance and R&D Output

Extant literature shows the significant impact of ESG performance on a firm's R&D output (e.g., McWilliams and Siegel 2001; Amel-Zadeh and Serafeim 2018; Baek and Lee 2024). Kemper et al. (2013) argue that ESG performance enhances R&D output by developing a firm's resources and aligning innovation with market needs, thus fostering unique knowledge and capabilities. Additionally, ESG performance promotes knowledge absorption and interorganizational learning capacity, facilitating R&D output (Panda and Sangle 2020). Similarly, Amel-Zadeh and Serafeim (2018) suggest that ESG performance not only assesses environmental impact but also strengthens stakeholder oversight, propelling amplified R&D allocations. Research shows that ESG performance promotes stakeholder engagement in R&D activities and strengthens strategic communication with all stakeholders (Tidd and Bessant 2018; Wan et al. 2024). Firms disclosing ESG information can reduce information asymmetry, increase transparency, foster stakeholder involvement, and mitigate the risk of managerial opportunism (Hanson et al. 2017; Bolognesi and Burchi 2023). Thus, stakeholder theory suggests that ESG performance enables firms to recognize the need for strategic adaption, ultimately improving the quality and reliability of R&D output to benefit consumers and society (Pinheiro et al. 2023).

Prior empirical studies consistently show a positive relationship between ESG performance and R&D output (e.g., Padgett and Galan 2010; Demirel and Kesidou 2019; Baek and Lee 2024).
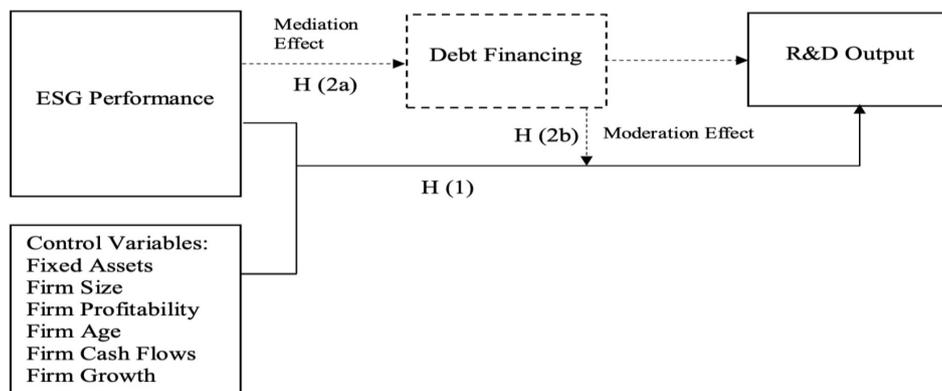

FIGURE 1 | Conceptual model.

The resource-based view (RBV) posits that ESG performance can generate critical and inimitable resources such as internal capabilities, knowledge, and collaborative networks that support a firm's innovation capacity (Barney 2018). R&D fosters creativity, technology transfer, and operational efficiency (Padgett and Galan 2010; Uyar et al. 2023) but requires substantial resources (Kemper et al. 2013), making resource availability a critical factor in R&D decision-making (Bartoloni 2013). In this context, for instance, Padgett and Galan (2010) suggest that firms with strong ESG performance are more likely to innovate due to greater stakeholder involvement and resource access. Similarly, Demirel and Kesidou (2019) find that ESG performance enhances a firm's ability to acquire technological resources for R&D output, based on a survey of UK firms. Panda and Sangle (2020) also argue that ESG practices improve organizational learning and capabilities, increasing R&D output.

Although ESG performance is often recognized as a key driver of R&D output by enhancing stakeholder trust and resource access, recent studies also raise critical concerns about its reliability and strategic effectiveness (e.g., Berg et al. 2022; dos Reis Cardillo and Basso 2025; Zhu et al. 2025). For instance, Berg et al. (2022) postulate that the inconsistency of ESG ratings across providers reduces comparability and creates ambiguity around the reliability of ESG metrics, potentially weakening their role in improving R&D outcomes. Similarly, Zhu et al. (2025) highlight that divergent ESG scores can generate investor uncertainty and elevate the perceived financial risk associated with ESG performance initiatives. Consequently, the uncertainty surrounding ESG performance evaluations undermines its signaling power to drive R&D output.

Moreover, ESG initiatives can divert managerial attention and financial resources from core R&D activities, particularly in firms facing capital constraints or external pressure to meet short-term ESG performance metrics (Eccles and Klimenko 2019). dos Reis Cardillo and Basso (2025) emphasize that ESG performance may be partially driven by managerial self-interest, leading to agency costs and a misalignment with shareholder interests. Furthermore, the financial returns from ESG engagement tend to be unevenly distributed, disproportionately benefiting firms operating in highly regulated environments or those subject to greater stakeholder scrutiny (Garcia et al. 2017). ESG initiatives largely depend on execution, as poorly designed or implemented efforts can lead to inefficient resource allocation and weaken their support for R&D outcomes (Kalia and Aggarwal 2023).

The existing literature generally supports our integrated theoretical framework and highlights a positive and significant relationship between ESG performance and R&D output. However, recent studies also indicate divergent perspectives, underscoring that the effectiveness of ESG performance in driving R&D output may vary across contexts. Despite growing scholarly attention, there remains a limited understanding of how ESG performance influences R&D outcomes within the healthcare sector, which is characterized by high resource intensity, stringent regulations, and long-term R&D horizons. This study aims to address this gap by examining the nuanced impact of ESG performance on R&D output in healthcare firms. Accordingly, we propose the following hypothesis:

Hypothesis 1. *ESG performance is positively and significantly associated with R&D output in the healthcare sector.*

2.2 | Debt Financing Mechanisms in the ESG-R&D Context

Although existing research primarily establishes a direct relationship between ESG performance and R&D output (e.g., Demirel and Kesidou 2019; Pinheiro et al. 2023), we argue that this connection is contingent upon the firm's financing decisions, particularly debt financing, which plays a crucial role in supporting R&D initiatives in the healthcare context (Wenzel et al. 2014; Prasad et al. 2022; Asimakopoulos et al. 2023). Notably, firms often require sufficient debt financing to fund R&D activities, which can either facilitate or constrain R&D decision-making processes (Brown et al. 2012; Hoffmann et al. 2019). However, the role of debt financing in shaping the ESG–R&D output relationship has been largely overlooked in the literature. In this context, extant studies on R&D output decisions focus on the agency model of managerial opportunism, which suggests that financing and R&D decisions are interdependent processes (Jensen and Meckling 1976; Brown et al. 2012; Muhammad et al. 2022). These studies posit that firm owners typically exhibit greater optimism about the potential success of R&D projects than external lenders. This optimism often stems from the firm's management having more information about the projects and a vested interest in their success. However, external lenders, such as banks or bondholders, generally lack the same level of insight and are more cautious about the risks involved. Thus, lenders tend to focus on the firm's ability to generate stable cash flows to service debt, leading to a potential misalignment in expectations between owners and lenders.

Previous research highlights the complex relationship between ESG performance and debt financing, influencing a firm's strategic decisions, such as R&D output (Sharfman and Fernando 2008; Murè et al. 2021; Asimakopoulos et al. 2023). However, the findings on this relationship remain mixed. For instance, Raimo et al. (2021) and Huang et al. (2023) show that firms with strong ESG performance can secure debt financing under more favorable terms by enhancing transparency through ESG disclosures, which in turn boosts lenders' confidence and lowers borrowing costs. Similarly, Henisz and McGlinch (2019) find that firms prioritizing ESG practices face fewer risks (e.g., regulatory and litigation) and attract more media coverage, government support, and investor backing, which helps lower debt financing costs (Murè et al. 2021).

In contrast, Sharfman and Fernando (2008) argue that ESG initiatives often require a long-term commitment to environmental and social goals, introducing greater uncertainty and risk without immediate financial returns. This makes it difficult for lenders to effectively monitor ESG performance, thereby increasing the agency's cost of debt. Asimakopoulos et al. (2023) suggest that firms with strong ESG performance may focus more on long-term growth, reducing their reliance on debt financing to avoid potential issues such as debt overhang and high switching liquidation costs. Christensen et al. (2022) further underscore that ESG ratings often rely on subjective and inconsistent methodologies, which reduce their credibility and comparability.

This ambiguity can distort stakeholder perceptions and heighten financing uncertainty, ultimately limiting the effectiveness of ESG performance in facilitating access to external debt capital. Whereas some studies highlight the beneficial effects of ESG performance on debt financing, others caution that the inherent complexity and long-term orientation of ESG initiatives may pose challenges for both firms and lenders.

Building on the preceding discussion, we argue that the relationship between ESG performance and R&D output is critically shaped by the firm's financing structure, particularly its reliance on debt financing. ESG performance may provide firms with reputational capital and stakeholder trust, enabling access to external financing (Padgett and Galan 2010). However, the inherently uncertain, long-term, and intangible nature of R&D projects makes them difficult for creditors to evaluate, especially given limited collateral and unpredictable returns (Carpenter and Petersen 2002; Brown et al. 2012; Muhammad et al. 2022). This often results in constrained debt availability, dampening the ability of ESG-performing firms to translate sustainability efforts into R&D output (Hoffmann et al. 2019).

We further theorize that debt financing serves not only as a transmission channel (i.e., mediator) but also as a boundary condition (i.e., moderator) in the ESG–R&D output linkage. On one hand, ESG-oriented firms may be better positioned to attract debt financing by reducing lender risk perceptions (Raimo et al. 2021; Huang et al. 2023), thereby mediating the ESG–R&D relationship. On the other hand, drawing on agency theory (Jensen and Meckling 1976), we argue that excessive debt may constrain managerial discretion, induce risk-averse behavior, and increase external monitoring that limits flexibility and suppresses R&D output (Brown et al. 2012; Muhammad et al. 2022). Thus, although ESG performance may enhance a firm's access to external capital, high debt financing may ultimately weaken its positive influence on R&D output.

To better understand this dynamic, we examine the dual roles of debt financing as both a mediator and moderator. This dual perspective highlights the critical role of debt financing in determining how ESG performance can effectively translate into enhanced R&D output, making it essential for firms to strategically manage both ESG performance and debt financing. Thus, we aim to test the following hypothesis:

Hypothesis 2a. *Debt financing significantly mediates the relationship between ESG performance and R&D output in the healthcare sector.*

Hypothesis 2b. *Debt financing significantly moderates the relationship between ESG performance and R&D output in the healthcare sector.*

3 | Research Methodology

3.1 | Sample

In this study, we used a panel dataset based on publicly listed healthcare firms from Europe and the United States, spanning 2016–2022. This period was chosen following the 2015 launch of the United Nations SDGs, which catalyzed firms' integration of ESG factors into strategic decision-making (Pinheiro et al. 2023). The healthcare sector, a significant source of industrial waste and environmental pollution (Eckelman et al. 2020), faces substantial sustainability challenges, making ESG practices indispensable for mitigating environmental impact (Fiksel 2012; Hensher and McGain 2020). Our initial sample consisted of 258 healthcare firms. To ensure the validity and rationality of the sample, we refined our panel dataset by removing duplicate firms and firms with missing data. We also winsorized all continuous variables at the 1% and 99% levels to mitigate the effect of outliers.

After screening, our final sample comprised 1211 firm-year observations from 173 healthcare firms. We extrapolated ESG performance scores and financial data from the *LSEG workspace* (formerly known as *Refinitiv*) using the Global Industry Classification System (*GICS*) to identify healthcare firms. This database has been validated and consistently used in recent studies for its reliability in providing comprehensive ESG performance metrics (e.g., Murè et al. 2021; Pinheiro et al. 2023). We also complemented the reliability of the Global Patent Index (*GPO*), developed by the European Patent Office (*EPO*) and US Patent and Trademark Office (*USPTO*), for the collection of patent-related information consistent with recent studies (e.g., Vincent et al. 2017; Dicuonzo et al. 2022).

Table 1 shows the distribution of our sample by industry and country. Our sample includes six industries in the healthcare sector: biotechnology, healthcare equipment and supplies, healthcare providers and services, healthcare technology, life sciences tools and services, and pharmaceuticals. The industries with the highest representation are biotechnology (29.48%), healthcare equipment and supplies (23.70%), and pharmaceuticals (23.70%), accounting for (76%) of the total sample. On the other hand, the industries with the lowest representation are life sciences tools and services (12.14%), healthcare providers and services (6.94%), and healthcare technology (4.94%). Moreover, our final sample comprises (47%) of firms from European countries and (53%) from the United States.

3.2 | Measures

Consistent with prior research on firm innovation capabilities, we contend that the conversion of R&D input into innovation output is complex and often subject to overestimation due to the high-risk characteristics of innovation (e.g., Aghion et al. 2004; Chen et al. 2023). As such, R&D output, measured by the number of patent applications, more accurately reflects a firm's technological capabilities and provides a more comprehensive disclosure than traditional R&D input measures (Ernst 2001; Li et al. 2023). Following previous studies (e.g., Aghion et al. 2004; Dicuonzo et al. 2022; Chen et al. 2023), we measure our dependent variable, R&D output (*R&D_Output)*, as the natural logarithm of the number of patent applications plus one, to reduce the patent count deviation among firms. This measure captures total R&D output rather than exclusively sustainable R&D. Although the environmental pillar of ESG includes eco-innovation, our patent-based measure reflects general R&D outcomes. Thus, we

TABLE 1 | Sample description.

Panel A: Distribution of observations by industry

Industry	Firms	Percentage	Observations	Percentage
Biotechnology	51	29.48	357	29.48
Health care equipment & supplier	41	23.70	287	23.70
Health care providers & services	12	6.94	84	6.94
Health care technology	7	4.05	49	4.05
Life sciences tools & services	21	12.14	147	12.14
Pharmaceuticals	41	23.70	287	23.70
Total	173	100.00	1211	100.00

Panel B: Distribution of observations by country

Country	Firms	Percentage	Observations	Percentage
Belgium	6	3.47	42	3.47
Denmark	8	4.62	56	4.62
France	7	4.05	49	4.05
Germany	12	6.94	84	6.94
Italy	4	2.31	28	2.31
Netherlands	3	1.73	21	1.73
Spain	6	3.47	42	3.47
Sweden	12	6.94	84	6.94
Switzerland	14	8.09	98	8.09
United Kingdom	8	4.62	56	4.62
United States of America	93	53.76	651	53.76
Total	173	100.00	1211	100.00

retain the broader label of R&D output while recognizing that ESG performance may influence its sustainability orientation through channels such as eco-innovation.

Our key explanatory variable is the *ESG* performance (*ESG*), measured on a score ranging from 0 (lowest) to (100 highest), reflecting a firm's involvement in sustainability activities across environmental (E), social (S), and governance (G) dimensions. This measure is derived from the ESG rating provided by the *LSEG workspace* database, which has been widely used and validated in the literature (e.g., Pinheiro et al. 2023; Uyar et al. 2023). the ESG mechanism is composed of three pillars, each with several themes. Specifically, the environmental pillar score (*EPS*) includes resource use, emissions, and innovation. The social pillar score (*SPS*) covers the workforce, human rights, community, and product responsibility. Finally, the governance pillar score (*GPS*) addresses management, shareholders, and corporate social responsibility strategies.

Moreover, our mediating and moderating variable of interest is debt financing (*DF*), measured as the ratio of total debt to total assets (e.g., Aghion et al. 2004; Hoffmann et al. 2019). Consistent with existing literature on ESG performance and R&D output, we control for several firm-level variables that significantly influence

R&D output (Dicuonzo et al. 2022; Demirel and Kesidou 2019; Uyar et al. 2023). Fixed asset (*FA*) is measured as the ratio of total fixed assets to total assets (Chen et al. 2023), as a higher proportion of fixed assets enables firms to cover the substantial upfront costs of R&D output. Firm size (*FS*) is the natural logarithm of total assets (Alam et al. 2019), as larger firms are typically better positioned to allocate resources and are more conducive to R&D output. Firm performance (*ROA*) is measured as net income scaled by total assets (Dicuonzo et al. 2022), reflects profitability, and influences the firm's ability to finance and sustain R&D initiatives. Firm age (*Age*) is the natural logarithm of the years since the firm's establishment (Bartoloni 2013). Whereas mature firms leverage past experience and established capabilities to innovate, younger firms tend to excel at knowledge-sharing with external networks and managing uncertainty, which can enhance their R&D output. Firm cash flow (*CF*) is the net cash flow from operations scaled by total assets (Wan et al. 2024). A stable cash flow is critical for financing R&D activities, which are characterized by long investment cycles, high risk, and lower comparability. Finally, firm growth (*FG*) is the annual percentage change in total sales (Demirel and Kesidou 2019). Firms with stronger growth prospects nurture their ability to allocate resources toward R&D initiatives.

3.3 | Model Specifications

In this study, we employ the three-step procedure outlined by Muller et al. (2005) to test our research hypotheses. In the first step, we regress *ESG* on *R&D_Output* (Model 1) to draw inferences regarding Hypothesis 1. In the second step, we regress *ESG* on *DF* (Model 2). In the third step, we regress both *ESG* and *DF* as determinants of *R&D_Output* (Model 3). We examine the mediating effect of debt financing to better understand the path mechanism through which ESG performance affects R&D output across these three steps (e.g., Baron and Kenny 1986). To support Hypothesis 2a, *ESG* should significantly impact *R&D_Output* (Step 1) and *DF* (Step 2). Additionally, the inclusion of *DF* (Step 3) should reduce the explanatory power of *ESG* on *R&D_Output*. The insignificant coefficient of *ESG* (Step 3) indicates a full mediation. However, the significant coefficient of *ESG* (Step 3) with reduced magnitude indicates a partial mediation. Finally, we create an interaction term between *ESG* and *DF* (Model 4) to examine whether *DF* strengthens or weakens the direct effect of *ESG* on *R&D_Output*:

$$R\&D\_Output_{it} = \alpha + \beta_1 ESG_{it} + \Sigma Control_{it} + Country_i$$
$$+ Industry_i + Year_t + \varepsilon_{it} \quad (1)$$

$$DF_{it} = \alpha_0 + \beta_1 ESG_{it} + \Sigma Control_{it} + Country_i + Industry_i + Year_t + \varepsilon_{it} \quad (2)$$

$$R\&D\_Output_{it} = \alpha_0 + \beta_1 ESG_{it} + \beta_2 DF_{it} + \Sigma Control_{it}$$
$$+ Country_i + Industry_i + Year_t + \varepsilon_{it} \quad (3)$$

$$R\&D\_Output_{it} = \alpha_0 + \beta_1 ESG_{it} + \beta_2 DF_{it} + \beta_3 (ESG \times DF)_{it}$$
$$+ \Sigma Control_{it} + Country_i + Industry_i + Year_t + \varepsilon_{it} \quad (4)$$

where the subscript (*i*) refers to the individual firm, (*t*) refers to the time, and (*ε*) refers to the error term. *Control* denotes a set of control variables that affect R&D output. We also include *country*, *industry*, and *years* to account for fixed effects. Although we include contemporaneous ESG performance and debt financing in the benchmark specification, we acknowledge that these variables may have lagged effects on R&D investment decisions. However, we do not include lagged terms in the main regressions to maintain model parsimony and avoid potential multicollinearity. Instead, we test for temporal dynamics and address reverse causality in the robustness checks, where we introduce lagged ESG performance and debt ratio variables. These extensions allow us to capture both the immediate and delayed effects of ESG performance on R&D output. All variables are defined in Table A1.

4 | Empirical Results and Discussion

4.1 | Descriptive Statistics and Correlations

Table 2 reports the descriptive statistics for all variables. The mean ESG performance score is 53.389, with a standard deviation of 20.664, indicating a moderate level of compliance and significant variations in ESG scores across the sample firms. The mean R&D output is 2.579, with a standard deviation of

TABLE 2 | Descriptive statistics of the variables.

Variables	Obs.	Mean	SD	Min	Max
ESG	1211	53.389	20.664	1.175	95.912
R&D_Output	1211	2.579	2.064	0.000	8.475
DF	1211	0.244	0.209	0.000	1.535
FA	1211	0.481	1.427	0.002	20.191
FS	1211	21.495	1.965	16.389	26.008
ROA	1211	0.027	0.566	−3.143	10.464
Age	1211	3.018	0.997	0.000	4.804
CF	1211	0.081	0.677	−1.601	12.334
FG	1211	−0.026	1.802	−15.273	14.742

Note: This table reports descriptive statistics of the variables used in this study. All variables are defined in Table 1. All variables are defined in Table A1.
Abbreviations: Max, maximum; Min, minimum; Obs., observations; SD, standard deviation.

2.064, reflecting substantial variations in patent applications among firms. The average debt financing ratio is 0.244, with a standard deviation of 0.209, meaning firms fund 24.4% of their total assets through debt financing. Regarding control variables, the average fixed assets ratio is 48%, indicating the firms hold nearly half of their assets in fixed assets. The mean firm size is 21.495, with a return on assets of 2.7%. Firms have an average age of 3.018 years, a net operating cash flow to asset ratio of 8%, and an average revenue growth rate of −2.6%.

Table A2 presents the Pearson correlation for all variables. It shows that both ESG performance and debt financing are significantly associated with R&D output. Noticeably, the correlation coefficients among all variables are below 0.8, suggesting that multicollinearity is not a concern for the subsequent regression analysis. To further assess potential multicollinearity, we compute the variance inflation factor (VIF) for each variable. Field (2013) states that a VIF value greater than 10 indicates problematic multicollinearity. In our analysis, all VIF values are below 2, confirming that multicollinearity is not an issue in our model.

4.2 | Baseline Regression Results

Table 3 presents regression estimates of the direct impact of ESG performance on R&D output as stated in (Model 1). In Columns (1) and (2), the coefficient for ESG performance is positive and statistically significant ($\beta = 0.0284$, at 1%). Although the magnitude of this relationship decreases after controlling for firm-level variables, the impact is still positive and highly significant ($\beta = 0.0148$, at 1%), indicating that ESG performance significantly enhances R&D output.

Table 4 presents the regression results for the mediating and moderating effects of debt financing. In Column (1), we find a positive and significant relationship between ESG performance and debt financing ($\beta = 0.0018$, $p < 0.01$), indicating that stronger

TABLE 3 | ESG performance and R&D output.

Dependent variables → Explanatory variables ↓	R&D_Output (1)	R&D_Output (2)
ESG	0.0284***	0.0148***
	(0.0027)	(0.0045)
FA		0.1639***
		(0.0399)
FS		0.2281***
		(0.0435)
ROA		−0.8842***
		(0.2724)
Age		0.1227*
		(0.0578)
CF		0.1600
		(0.1265)
FG		0.0155
		(0.0400)
Constant	2.1141***	−1.8206**
	(0.3480)	(0.7971)
Country fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
No. of observations	1211	1211
R squared	0.2637	0.3130
F statistic	19.34***	18.55***

Note: This table presents the baseline regressions of the study. Column (1) shows the direct impact of ESG performance (*ESG*) without control variables on R&D output (*R&D_Output*). Column (2) shows the direct impact of ESG performance (*ESG*) including control variables on R&D output (*R&D_Output*). All variables are defined in Table A1. Standard errors are in parentheses.

*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

ESG performance improves firms' access to external debt financing. In Column (2), when debt financing is included in the ESG performance-R&D output model, both ESG performance and debt financing remain highly significant at 1%. Although the coefficient for ESG performance decreases slightly from 0.0148 to 0.0140, it remains positive and significant, suggesting that debt financing partially mediates the ESG performance-R&D output link without eliminating the positive and significant impact of ESG performance. We also perform postestimation tests, including the Sobel and Monte Carlo tests, to validate the significance of the indirect effect of debt financing in the ESG-R&D output relationship.[1] The results confirm that approximately 32% of the effect of ESG performance on R&D output is mediated by debt financing. Notably, this indirect effect is 0.2 times the magnitude of the direct effect, underscoring the importance of debt financing as a significant mechanism through which ESG

performance drives R&D output decisions. In the moderation analysis presented in Table 4, we find a negative and significant effect of debt financing on R&D output. Specifically, Column (3) reveals that the interaction term between ESG performance and debt financing ($ESG \times DF$) has a negative and significant impact on R&D output (i.e., $\beta = -0.0244$, at 10%).

4.3 | Discussion

This study examined the relationship between ESG performance and R&D output in the healthcare sector and the dual role of debt financing as both a mediator and a moderator. Whereas the prior section presented the empirical findings, this section consolidates those findings and clarifies their theoretical implications, contributions, and the novelty of our research context. Our findings support the notion that ESG performance positively affects R&D output. This result corroborates our theoretical lenses and prior studies (e.g., Freeman 1984; Padgett and Galan 2010; Pinheiro et al. 2023), reinforcing the idea that ESG initiatives enhance firm legitimacy, attract stakeholder support, and foster strategic learning and organizational capabilities. ESG performance enables firms to align innovation efforts with stakeholder expectations, reducing reputational risks and increasing access to strategic resources. This strengthens the theoretical linkage between ESG performance and R&D output, suggesting that ESG performance is not merely symbolic but plays a strategic role in enhancing R&D output. Thus, our conjecture in Hypothesis 1 is confirmed.

In addition, we find that ESG performance indirectly promotes R&D output through improved access to debt financing, supporting Hypothesis 2a. This mediating effect provides empirical validation for recent arguments that ESG performance can act as a signal of firm quality and long-term orientation, thereby reducing information asymmetries in financial markets (e.g., Murè et al. 2021; Huang et al. 2023). This contribution extends stakeholder theory by illustrating how ESG initiatives not only build reputational capital but also enable access to tangible financial resources. These findings suggest that ESG performance, when perceived as credible, functions as a financing enabler for R&D output.

Our results also reveal that debt financing negatively moderates the relationship between ESG performance and R&D output. Drawing on agency theory (Jensen and Meckling 1976; Brown et al. 2012), this indicates that high levels of debt may constrain managerial discretion and innovation flexibility, even for ESG-engaged firms. R&D activities inherently involve high uncertainty, long payback periods, and limited collateral, making them riskier from a lender's perspective (e.g., Scellato and Ughetto 2010; Hoffmann et al. 2019). This risk aversion amplifies agency costs, particularly when financial leverage is high. Our findings suggest that although ESG performance enhances R&D output, the benefits may be limited or reversed in highly leveraged firms. Thus, debt financing can act as both a conduit and constraint, highlighting the need for alignment in the relationship between a firm's ESG performance and financing mechanism. The discrepancies in ESG disclosures across different rating agencies further exacerbate information asymmetry,

TABLE 4 | The mediating and moderating effects of debt financing.

Dependent variables → Explanatory variables ↓	DF (1)	R&D_Output (2)	R&D_Output (3)
ESG	0.0018***	0.0140***	0.0224***
	(0.0005)	(0.0042)	(0.0040)
DF		−1.8860***	−1.4912***
		(0.3579)	(0.2869)
ESG × DF			−0.0244*
			(0.0147)
FA	−0.0013	0.1501***	0.1511***
	(0.0046)	(0.0404)	(0.0378)
FS	0.0058	0.2271***	0.1699***
	(0.0050)	(0.0434)	(0.0398)
ROA	−0.0444	−0.8573***	−0.9919***
	(0.0314)	(0.2722)	(0.2858)
Age	−0.0219***	0.1046*	0.0411
	(0.0066)	(0.0583)	(0.0570)
CF	0.0288**	0.1423	0.0952
	(0.0146)	(0.1266)	(0.1319)
FG	0.0056	0.0194	0.0078
	(0.0046)	(0.0400)	(0.0417)
Constant	0.0706	−1.9694**	3.2387***
	(0.0919)	(0.7986)	(0.1473)
Sobel test		−2.97***	
Monte Carlo test		−3.02***	
Ratio of indirect effect to total effect		0.32	
Ratio of indirect effect to direct effect		0.24	
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
No. of observations	1211	1211	1211
R squared	0.1070	0.3158	0.3215
F statistic	5.06***	18.16***	18.02***

Note: This table presents the mediation and moderating effects of debt financing. Column (1) presents the impact of ESG performance (*ESG*) with control variables on debt financing (*DF*). Column (2) reports the mediating effects of debt financing (*DF*) on R&D output (*R&D_Output*). Column (3) shows the interaction effect between ESG performance (*ESG*) and debt financing (*DF*) on R&D output (*R&D_Output*). All variables are defined in Table A1. Standard errors are in parentheses.
*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

making it difficult for lenders to effectively assess and monitor ESG activities. This increases agency costs and, in turn, impedes R&D output. Thus, our findings support the reasonability of Hypothesis 2b, demonstrating that debt financing significantly moderates and attenuates the positive effect of ESG performance on R&D output.

Finally, unlike prior research that examines ESG–R&D relationships across manufacturing samples (e.g., Demirel and Kesidou 2019; Pinheiro et al. 2023), we provide insight into the healthcare sector where innovation is highly sensitive, regulatory complexity is high, and public accountability is critical (e.g., Belkhir and Elmeligi 2019; Uyar et al. 2021). The healthcare

sector serves as an ideal setting to observe the complex nexus between ESG performance, debt financing, and R&D output. Moreover, our study advances the literature by demonstrating that ESG performance enhances R&D output directly and indirectly through debt financing, while also showing that debt financing can suppress this positive relationship under certain conditions. These findings contribute to the integrated theoretical framework based on stakeholder theory and agency theory and offer novel insights into the financial mechanisms through which ESG performance influences R&D output.

5 | Robustness Checks

We introduce several alternative methods to test the robustness of our results. First, in line with previous research (e.g., Hall et al. 2005; Jung et al. 2008), we use an alternative measure for R&D output (*R&D_Output2*), which is based on the number of patent citations received by the firms. Table 5 shows that our results remain consistent when re-examining the baseline regressions using *R&D_Output2* as the alternative measure of R&D output.

TABLE 5 | Alternative measure of R&D output.

Dependent variables →	*R&D_Output2*	*DF*	*R&D_Output2*	*R&D_Output2*
Explanatory variables ↓	(1)	(2)	(3)	(4)
ESG	0.0161***	0.0018***	0.0142***	0.0190***
	(0.0042)	(0.0005)	(0.0034)	(0.0039)
DF			−2.6050***	−1.1366***
			(0.3314)	(0.2882)
ESG × DF				−0.0256*
				(0.0147)
FA	0.1244***	−0.0013	0.0910**	0.0199
	(0.0374)	(0.0046)	(0.0374)	(0.0381)
FS	0.2505***	0.0058	0.2480***	0.1372***
	(0.0407)	(0.0050)	(0.0402)	(0.0398)
ROA	−0.2942	−0.0444	−0.2293	−0.4406
	(0.2552)	(0.0314)	(0.2520)	(0.2880)
Age	0.0648	−0.0219***	0.0210	−0.0369
	(0.0542)	(0.0066)	(0.0540)	(0.0569)
CF	−0.0357	0.0288**	−0.0786	−0.1387
	(0.1186)	(0.0146)	(0.1172)	(0.1322)
FG	0.0496	0.0056	0.0590	0.0491
	(0.0375)	(0.0046)	(0.0370)	(0.0420)
Constant	−2.7685***	0.0706	−3.1276***	2.9879***
	(0.7468)	(0.0919)	(0.7393)	(0.1442)
Country fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
No. of observations	1211	1211	1211	1211
R squared	0.325	0.107	0.344	0.329
F statistic	19.61***	5.05***	20.60***	18.69***

Note: This table presents regression results using an alternative measure of R&D output (*R&D_Output2*). Column (1) shows the direct impact of ESG performance (*ESG*) with control variables on the alternative measure of R&D output (*R&D_Output2*). Column (2) presents the direct impact of ESG performance (*ESG*) with control variables on debt financing (*DF*), whereas Columns (3) and (4) report the mediation and moderation effects of debt financing (*DF*) in the relationship between ESG performance (*ESG*) and R&D output (*R&D_Output2*). Standard errors are in parentheses. All variables are defined in Table A1.
*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

Second, we re-estimate our models using the long-term debt to total-assets ratio (*LTD*) as an alternative measure of debt financing. This refinement addresses the limitation of our baseline measure, total debt to total assets (*DF*), which does not differentiate between short- and long-term debt financing. Given that R&D projects typically involve extended timelines and higher uncertainty, *LTD* could serve as an alternative proxy for evaluating long-term financing constraints associated with R&D investments. As shown in Table 6, the mediation analysis using *LTD* continues to show consistent results, confirming that ESG performance is positively associated with *LTD* and that *LTD*

acts as a transmission channel (i.e., partial mediation) in the ESG–R&D output linkage. This supports the robustness of our proposed mediating mechanism. Furthermore, the moderating effect of ESG performance on R&D output through *LTD* remains directionally consistent with our main model, although the interaction effect is statistically insignificant. This may reflect that the influence of ESG performance on R&D output is more sensitive to a firm's total debt financing than long-term debt financing alone, particularly in the healthcare sector, where firms often rely on a mix of debt financing sources due to high capital intensity and regulatory complexity. Overall, these

TABLE 6 | Alternative measure of debt financing.

Dependent variables →	*LDT*	*R&D_Output*	*R&D_Output*
Explanatory variables ↓	(1)	(2)	(3)
ESG	0.0026***	0.0136***	0.0138**
	(0.0006)	(0.0045)	(0.0056)
LDT		−0.4699**	−1.3581***
		(0.2205)	(0.2836)
ESG × LDT			−0.0043
			(0.0143)
FA	0.0190***	0.1746***	0.1638***
	(0.0053)	(0.0405)	(0.0400)
FS	0.0062	0.2234***	0.2287***
	(0.0058)	(0.0439)	(0.0435)
ROA	−0.0754**	−0.8610***	−0.8770***
	(0.0362)	(0.2752)	(0.2735)
Age	0.0083	0.1555***	0.1191*
	(0.0077)	(0.0581)	(0.0591)
CF	0.0494***	0.1452	0.1611
	(0.0168)	(0.1280)	(0.1266)
FG	−0.0011	0.0077	0.0157
	(0.0053)	(0.0404)	(0.0401)
Constant	0.2735**	−1.7852**	3.6377***
	(0.1062)	(0.8068)	(0.3288)
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
No. of observations	1211	1211	1211
R squared	0.126	0.300	0.313
F statistic	6.07***	17.43***	17.92***

Note: This table presents the robustness of mediation and moderating effects of an alternative measure of debt financing (*LDT*). Column (1) reports the impact of ESG performance (*ESG*) on an alternative measure of debt financing (*LDT*). Column (2) presents the mediating effects of an alternative measure of debt financing (*LDT*) on R&D output (*R&D_Output*). Column (3) shows the interaction effect between ESG performance (*ESG*) and an alternative measure of debt financing (*LDT*) on R&D output (*R&D_Output*). All variables are defined in Table A1. Standard errors are in parentheses.
*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

findings reinforce the robustness of our proposed mechanisms and lend credibility to the theoretical relationship between ESG performance, debt financing, and R&D output.

Third, examining the relationship between ESG performance, debt financing, and R&D output raises concerns about omitted variable bias, reverse causality, and unobserved heterogeneity. To address these endogeneity issues, we employ an instrumental variable (*IV*) approach, as presented in Table 7. This estimation strengthens the robustness of our results by mitigating bias from simultaneity and omitted variables (Angrist and Krueger 2001). Consistent with previous research (e.g., Chen et al. 2023; Doni and Fiameni 2024; Wan et al. 2024), we use the 2-year lag of ESG performance (i.e., *^ESG*) as an instrument in our *IV* estimation. This lag is plausibly correlated with current

TABLE 7 | ESG performance and R&D output: Instrumental variable (IV) regression.

Dependent variables →	R&D_Output	R&D_Output
Explanatory variables ↓	(1)	(2)
$^{\wedge}ESG$	0.0329***	0.0240***
	(0.0041)	(0.0098)
FA_{t-1}		0.1158***
		(0.0412)
FS_{t-1}		0.1504**
		(0.0702)
ROA_{t-1}		−1.3584***
		(0.4078)
Age_{t-1}		0.0870*
		(0.0676)
CF_{t-1}		0.3806
		(0.3494)
FG_{t-1}		0.0261
		(0.0461)
Constant	−0.5623	−3.0771***
	(0.4332)	(1.1209)
Country fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
No. of observations	865	865
R squared	0.2791	0.3172

Note: This table presents the robustness of our baseline results using instrumental variable technique. Column (1) shows the direct impact of ESG performance (*^ESG*) instrumented with two years lags (without including control variables) on R&D output (*R&D_Output*). Column (2) shows the direct impact of ESG performance (*^ESG*) instrumented with 2-year lags (including control variables) on R&D output (*R&D_Output*). All control variables are lagged by 1 year to reduce simultaneity issues. All variables are defined in Table A1. Standard errors are in parentheses.
*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

ESG performance due to the path-dependent nature of ESG reporting, whereas it is unlikely to be correlated with the current error term (Wan et al. 2024). The exclusion restriction holds under the assumption that ESG performance typically evolves gradually, shaped by firm routines and long-term sustainability initiatives. Therefore, ESG commitments from 2 years prior influence current R&D output only indirectly through their effects on current ESG practices rather than via any direct impact of past performance (Doni and Fiameni 2024). Moreover, prior literature suggests that ESG investments signal firm quality and reduce long-term risk (Behl et al. 2022), but these benefits are recognized gradually, reinforcing the logic of a time lag in ESG's effects. Stakeholders respond to accumulated ESG signals rather than isolated actions (Luo et al. 2015), further supporting the temporal separation. To further mitigate simultaneity bias, all control variables are lagged by 1 year. Collectively, this approach justifies the use of lagged ESG performance as a valid instrument that satisfies both relevance and exclusion requirements.

Table 8 reports the mediation and moderation effects of debt financing on the link between ESG performance and R&D output, estimated using *IV*. In line with Yan (2006), we instrument debt financing (*^DF*) using its 2-year lag to isolate the indirect pathway through which ESG performance (*^ESG*) affects R&D output. Our findings remain robust relative to the baseline results, indicating that the effects of ESG performance on R&D output are not significantly driven by endogeneity issues. This robustness strengthens the validity of our conclusions and underscores the reliability of the proposed mechanisms by which ESG influences R&D output through the channel of debt financing.

To further address potential endogeneity bias, we re-examine our baseline models by capturing the dynamic relationships that explain the R&D output path over time, employing a system generalized method of moments (*SGMM*) regression (e.g., Blundell and Bond 1998; Roodman 2009; Ali et al. 2024). *SGMM* utilizes internal instruments, with the lagged dependent variable (i.e., *R&D_Output_{(t−1)}* in our case) serving as a regressor alongside other explanatory variables. This dynamic approach controls the assumption in static regression that firms immediately adjust their R&D output based on ESG performance metrics or other firm-level characteristics. Based on previous studies (e.g., Uyar et al. 2023; Ali et al. 2024; Baek and Lee 2024), we assert that the R&D adjustment process occurs over a longer investment horizon, rather than immediately in response to short-term changes in ESG performance. Table 9 demonstrates that our main findings remain robust under the alternative *SGMM* specification, even after incorporating the lag of the dependent variables (i.e., *R&D_Output_{(t−1)}*). To further ensure the reliability of our results, we conduct several postestimation tests, including the Hansen and Arellano–Bond tests, to address autocorrelation and overidentification concerns (Roodman 2009).[2] These tests show that the instruments are valid and fall within the recommended threshold. Overall, the use of both *IV* and *SGMM* techniques provides robust assurance that our findings regarding the nexus between ESG performance, debt financing, and R&D output hold firm, even in the presence of endogeneity arising from omitted variable bias and reverse causality.

Finally, we examine the persistence of the ESG-R&D output relationship by introducing 1- to 4-year lags of ESG

TABLE 8 | The mediating and moderating effects of debt financing: Instrumental variable (IV) regression.

Dependent variables → Explanatory variables ↓	DF (1)	R&D_Output (2)	R&D_Output (3)
$^\wedge ESG$	0.0013*	0.0199***	0.0237***
	(0.0007)	(0.0090)	(0.0064)
$^\wedge DF$		−2.8287***	−2.2502***
		(0.8082)	(0.4807)
$^\wedge ESG \times {}^\wedge DF$			−0.0718*
			(0.0314)
FA_{t-1}	−0.0019	0.0985*	0.1109***
	(0.0047)	(0.0425)	(0.0385)
FS_{t-1}	0.0109*	0.1936***	0.2624***
	(0.0064)	(0.0724)	(0.0566)
ROA_{t-1}	−0.0034	−1.1368***	−1.3021***
	(0.0376)	(0.4211)	(0.4248)
Age_{t-1}	−0.0222***	0.0446	−0.1219*
	(0.0069)	(0.0711)	(0.0691)
CF_{t-1}	0.0268*	0.2308	0.2705
	(0.0147)	(0.3606)	(0.3577)
FG_{t-1}	−0.0014	0.0325	0.0168
	(0.0050)	(0.0469)	(0.0478)
Constant	0.0169	−3.6127***	1.5041***
	(0.1082)	(1.1574)	(0.1696)
Country fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
No. of observations	865	865	865
R squared	0.1064	0.3016	0.2585

Note: This table presents the robustness of mediation and moderating effects of Debt financing ($^\wedge DF$) using instrumental variable estimation. ESG performance ($^\wedge ESG$) and debt financing ($^\wedge DF$) are instrumented with 2-year lags. Column (1) reports the impact of ESG performance ($^\wedge ESG$) with control variables on debt financing (*DF*). Column (2) reports the mediating effects of debt financing ($^\wedge DF$) on R&D output (*R&D_Output*). Column (3) shows the interaction effect between ESG performance ($^\wedge ESG$) and debt financing ($^\wedge DF$) on R&D output (*R&D_Output*). All control variables are lagged by 1 year to reduce simultaneity issues. All variables are defined in Table A1. Standard errors are in parentheses.
*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

performance. As presented in Table 10, all lagged coefficients remain positive, though their magnitudes progressively decline. Notably, the ESG coefficient at $t-1$ is significant, aligning with the idea that prior ESG performance signals a firm's credibility and lowers perceived risk, thereby attracting investor capital that supports R&D output. However, the relationship becomes statistically insignificant at the 3- and 4-year lags, suggesting that the influence of ESG performance on R&D output is strongest in the short term. These results indicate that the innovation benefits associated with ESG are relatively immediate and may diminish over time. This finding is consistent with prior research (e.g., Ernst 2001; Rezaee

et al. 2023) and may reflect a signaling mechanism in which strong ESG performance initially boosts investor confidence and facilitates capital access, thereby enabling R&D output. However, as time passes, the strength of this signal may fade. This highlights the importance of sustained ESG engagement to maintain stakeholder trust and resource mobilization.

6 | Heterogeneity Analysis

Although our baseline regression results and robustness checks indicate a positive and significant relationship between ESG

TABLE 9 | ESG performance, debt financing and R&D output: Two-step system (*SGMM*) regression.

Dependent variables → Explanatory variables ↓	R&D_Output (1)	DF (2)	R&D_Output (3)	R&D_Output (4)
$R\&D\_Output_{(t-1)}$	0.8347***		0.8470***	0.8390***
	(0.0326)		(0.0307)	(0.0318)
$DF_{(t-1)}$		0.7378***		
		(0.0162)		
ESG	0.0043***	0.0010**	0.0039**	0.0039**
	(0.0016)	(0.0005)	(0.0015)	(0.0016)
DF			−0.3084***	−0.4221***
			(0.0874)	(0.0895)
ESG × DF				−0.0165***
				(0.0059)
FA	0.0118***	−0.0024	0.0120**	0.0113*
	(0.0044)	(0.0015)	(0.0056)	(0.0058)
FS	0.0186	−0.0067	0.0242	0.0332**
	(0.0156)	(0.0068)	(0.0157)	(0.0160)
ROA	−0.4741***	−0.0105	−0.4502***	−0.4416***
	(0.1261)	(0.0200)	(0.1200)	(0.1229)
Age	0.0030	−0.0113***	−0.0092	−0.0284
	(0.0207)	(0.0032)	(0.0211)	(0.0226)
CF	0.0892*	0.0156	0.0933*	0.1123**
	(0.0484)	(0.0119)	(0.0478)	(0.0499)
FG	0.0265	0.0356***	0.0457*	0.0356
	(0.0236)	(0.0036)	(0.0241)	(0.0244)
Year, country, and industry effects	Yes	Yes	Yes	Yes
Observations	1038	1038	1038	1038
AR(2) (*p* value)	0.078	0.366	0.077	0.069
Hansen (*p* value)	0.223	0.440	0.182	0.231

Note: This table presents the two step (*SGMM*) regression results. Column (1) shows the direct impact of ESG performance (*ESG*) with control variables on R&D output (*R&D_Output*). Column (2) presents the direct impact of ESG performance (*ESG*) with control variables on debt financing (*DF*), whereas Columns (3) and (4) report the mediation and moderation effects of debt financing (*DF*) in the relationship between ESG performance (*ESG*) and R&D output (*R&D_Output*). Standard errors are in parentheses. All variables are defined in Table A1.
*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

performance and R&D output, this relationship may exhibit significant heterogeneity across geographical regions (i.e., the United States and Europe) and within different healthcare industries. Such heterogeneity arises from distinct regulatory environments, market dynamics, and institutional frameworks across regions and industries (e.g., Paolone et al. 2022; Rezaee et al. 2023). To explore this further, we split our sample into two subsamples representing healthcare firms in the United States and Europe, allowing us to examine the regional heterogeneity in the impact of ESG performance and its individual pillars on R&D output. Additionally, we determine industrial

heterogeneity within the healthcare sector by classifying firms using the LSEG workspace GICS framework, enabling a detailed analysis of how industry-specific factors influence the ESG-R&D output relationship.

As shown in Columns (1) and (5) of Table 11, ESG performance is positively and significantly associated with R&D output for both US and European healthcare firms. However, the estimated coefficient of ESG performance for European firms is larger and more statistically significant than that for US firms, implying a stronger impact of ESG performance

TABLE 10 | The persistence of the ESG IMPACT on R&D output.

Dependent variables → R&D_Output Explanatory variables ↓	(1) t−1	(2) t−2	(3) t−3	(4) t−4
$ESG_{(t-1)}$	0.0146**			
	(0.0047)			
$ESG_{(t-2)}$		0.0111*		
		(0.0050)		
$ESG_{(t-3)}$			0.0095	
			(0.0052)	
$ESG_{(t-4)}$				0.0068
				(0.0059)
FA	0.1457***	0.1366***	0.1253***	0.1107*
	(0.0413)	(0.0430)	(0.0478)	(0.0616)
FS	0.2249***	0.2488***	0.2645***	0.2734***
	(0.0477)	(0.0522)	(0.0565)	(0.0653)
ROA	−0.7774**	−0.5031	−0.4553	−0.2949
	(0.3180)	(0.3455)	(0.3612)	(0.3974)
Age	0.1323**	0.0954	0.0578	0.0438
	(0.0643)	(0.0721)	(0.0818)	(0.0963)
CF	0.0863	−0.2617	−0.0872	0.1053
	(0.3108)	(0.3887)	(0.4067)	(0.4290)
FG	−0.0181	−0.0296	−0.0371	−0.0315
	(0.0428)	(0.0448)	(0.0461)	(0.0515)
Constant	−2.0001**	−2.4507**	−4.5916***	−4.5414***
	(0.8887)	(0.9825)	(1.0763)	(1.2488)
Year, country, and industry effects	Yes	Yes	Yes	Yes
Observations	1038	865	692	519
R squared	0.3154	0.3165	0.3281	0.3217
F statistic	16.60***	14.358***	12.488***	9.353***

Note: This table presents the baseline regression results. Columns (1–4) show the direct impact with inclusion of lags of ESG performance (*ESG*) by 1, 2, 3, and 4 years (with control variables) on R&D output (*R&D_Output*). All variables are defined in Table A1. Standard errors are in parentheses.
*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

on R&D output in Europe. This regional disparity suggests that sustainability is more deeply embedded in corporate strategy among European firms, largely due to stricter ESG disclosure requirements and stronger policy incentives (e.g., European Green Deal 2019). These institutional supports contribute to a more pronounced impact of ESG performance on R&D output in Europe. In contrast, US firms operate under less stringent ESG regulations and face fewer policy-driven incentives to prioritize sustainability (Cicchiello et al. 2023; Rezaee et al. 2023), resulting in a weaker and less consistent ESG–R&D relationship. Moreover, institutional and regulatory differences between the two regions further explain this variation. European firms are subject to more comprehensive

ESG disclosure frameworks, including the EU Non-Financial Reporting Directive (NFRD) and the Corporate Sustainability Reporting Directive (CSRD), which aim to improve ESG transparency and comparability (European Commission 2025; KPMG 2022). These frameworks not only heighten stakeholder scrutiny but also encourage the integration of ESG performance into R&D output decisions. Conversely, the US ESG landscape is more market-driven, characterized by voluntary and fragmented disclosure practices (US Securities and Exchange Commission 2022). This variability contributes to less standardized sustainability efforts. In terms of capital market structures, European markets often adopt longer term investment horizons, supporting ESG-aligned R&D activities,

TABLE 11 | ESG performance and R&D output: US and Europe subsample.

Dependent variables →	R&D_Output							
	US				*Europe*			
Explanatory variables ↓	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
ESG	0.0111*				0.0207***			
	(0.0059)				(0.0070)			
EPS		0.0062				−0.0006		
		(0.0041)				(0.0043)		
SPS			0.0109***				0.0155***	
			(0.0043)				(0.0054)	
GPS				−0.0018				0.0135***
				(0.0043)				(0.0042)
FA	−1.0797**	−0.7937*	−0.8342*	−0.8696*	0.1509***	0.1505***	0.1515***	0.1446***
	(0.4478)	(0.4530)	(0.4511)	(0.4509)	(0.0364)	(0.0367)	(0.0364)	(0.0364)
FS	0.1433**	0.2025***	0.2246***	0.2788***	0.4778***	0.6089***	0.5094***	0.5505***
	(0.0612)	(0.0637)	(0.0564)	(0.0449)	(0.0611)	(0.0545)	(0.0547)	(0.0465)
ROA	−0.1500	−0.4881	−0.4855	−0.4257	2.1091	2.4729*	2.1940	2.4167*
	(0.3717)	(0.3697)	(0.3701)	(0.3689)	(1.4026)	(1.4112)	(1.4012)	(1.3954)
Age	0.2759***	0.3121***	0.3135***	0.3297***	−0.0032	0.0068	0.0006	0.0368
	(0.0962)	(0.0924)	(0.0924)	(0.0976)	(0.0693)	(0.0714)	(0.0692)	(0.0698)
CF	−1.0061**	−0.2093	−0.1585	−0.2194	0.3017**	0.3138**	0.2975**	0.3061**
	(0.4639)	(0.4735)	(0.4766)	(0.4753)	(0.1306)	(0.1317)	(0.1307)	(0.1303)
FG	0.0118	0.0020	0.0041	0.0074	−0.0290	−0.0232	−0.0277	−0.0108
	(0.0527)	(0.0515)	(0.0515)	(0.0517)	(0.0639)	(0.0647)	(0.0639)	(0.0639)
Industry and year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	651	651	651	651	560	560	560	560
R squared	0.1853	0.2287	0.2282	0.2261	0.3999	0.3902	0.3994	0.4018
F statistic	9.01***	9.85***	9.82***	9.70***	18.94***	18.19***	18.90***	19.09***

Note: This table presents the regression results of the impact of combined ESG performance (*ESG*) score and individual pillars score (i.e., environmental pillar score [*EPS*], social pillar score [*SPS*], and governance pillar score [*GPS*] on R&D output [*R&D_Output*]). Columns (1–4) show the direct impact of ESG performance (*ESG*) and its individual pillars score on R&D output (*R&D_Output*) for the firms in the United States (*US*). whereas Columns (5) and (8) report the direct impact of ESG performance (*ESG*) and its individual pillars score on R&D output (*R&D_Output*) for the firms in the European countries (*Europe*). All variables are defined in Table A1. Standard errors are in parentheses.

*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

whereas US firms operate under greater short-term investor pressure, potentially weakening ESG's impact on R&D output (Jackson and Apostolakou 2010). These institutional and market dynamics help contextualize the regional heterogeneity observed in our results.

Table 11 further shows that the estimated coefficient for the social pillar of ESG is positive and statistically significant across both the United States and Europe, whereas the environmental pillar of ESG is insignificant, indicating that healthcare firms place greater emphasis on social factors,

such as product access and affordability, product quality and safety, and employee well-being, to drive R&D output (Paolone et al. 2022). Surprisingly, despite the healthcare sector's significant environmental impact and relatively more stringent environmental regulations in Europe (Healthcare without Harm Europe 2019), firms are less likely to prioritize the environmental pillar concerning R&D output. Additionally, the governance pillar of ESG is only significant for European healthcare firms, suggesting that governance factors play a more influential role in fostering R&D within the European context. These findings highlight the importance of tailoring

TABLE 12 | ESG performance and R&D output: Industry subsample.

Dependent variables →	R&D_Output					
Explanatory variables ↓	Biotechnology (1)	Healthcare equipment & supplies (2)	Health care providers & services (3)	Health care technology (4)	Life sciences tools & services (5)	Pharmaceuticals (6)
ESG	0.0259***	0.0213***	0.0169***	0.0204***	0.0238***	0.0127***
	(0.0045)	(0.0047)	(0.0045)	(0.0045)	(0.0047)	(0.0047)
$ESG*D_{ind}$	−0.0245***	−0.0079	0.0035	−0.0045	−0.0087	0.0297***
	(0.0066)	(0.0066)	(0.0095)	(0.0187)	(0.0094)	(0.0054)
D_{ind}	1.8200***	0.7514*	−1.5857***	−0.3835	0.1793	−1.7671***
	(0.3335)	(0.3995)	(0.5496)	(0.8159)	(0.5832)	(0.3185)
FA	0.1749***	0.1471***	0.1552***	0.1524***	0.1531***	0.1614***
	(0.0405)	(0.0410)	(0.0403)	(0.0410)	(0.0410)	(0.0406)
FS	0.1602***	0.1286***	0.1792***	0.1208***	0.1053**	0.0979**
	(0.0422)	(0.0424)	(0.0424)	(0.0424)	(0.0428)	(0.0430)
ROA	−0.7503***	−1.0008***	−0.9383***	−1.0041***	−0.9529***	−0.8773***
	(0.2787)	(0.2800)	(0.2764)	(0.2809)	(0.2802)	(0.2774)
Age	0.1067*	0.0932	0.0771	0.0981*	0.1033*	0.0564
	(0.0585)	(0.0588)	(0.0584)	(0.0590)	(0.0594)	(0.0587)
CF	0.2062	0.0545	0.1142	0.1023	0.0971	0.1211
	(0.1283)	(0.1299)	(0.1271)	(0.1293)	(0.1292)	(0.1278)
FG	0.0194	0.0240	0.0142	0.0163	0.0210	0.0360
	(0.0406)	(0.0412)	(0.0405)	(0.0412)	(0.0412)	(0.0409)
Country & year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	1211	1211	1211	1211	1211	1211
R squared	0.291	0.269	0.292	0.268	0.268	0.284
F statistic	18.685	16.793	18.784	16.657	16.699	18.097

Note: This table presents the subsample regression results using industry dummies (D_{ind}). Columns (1–6) show the impact of ESG performance (*ESG*) on R&D output (*R&D_Output*) using the interaction between ESG performance (*ESG*) and industry dummies (D_{ind}). Industry dummies (D_{ind}) obtain the value of 1 if a firm is in the industry indicated on the top row and 0 otherwise. All variables are defined in Table A1. Standard errors are in parentheses.
*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.

ESG strategies to regional sustainability priorities and regulatory environments (Cicchiello et al. 2023).

Building on these findings, we argue that there are broader contextual factors that explain why ESG performance has a stronger impact on R&D output in Europe than in the United States. One important reason is the institutional setting. European firms face mandatory and harmonized sustainability reporting rules that provide more structured incentives to integrate ESG practices into long-term strategies, including R&D investments.

These requirements are reinforced by policy initiatives and financial markets that encourage longer investment horizons and stronger stakeholder accountability, conditions that naturally support R&D activities. However, the situation in the United States is different. Although there has been progress toward ESG disclosure, overall sustainability reporting frameworks remain narrower, more contested, and influenced by political polarization. Firms there operate under greater short-term market pressure and less certainty about the long-term benefits of ESG commitments, which makes the link to R&D output weaker.

We believe these contrasts help explain why ESG performance shows up more strongly in European R&D outcomes.

Table 12 presents the results of the industry subsample analysis. As shown in Columns (1–6), ESG performance is positively and significantly associated with R&D output across all industries, confirming the previous findings. However, there is little evidence of industry-specific moderating effects, as the interaction terms (*ESG × Dind*) are mostly statistically insignificant. The exceptions are the biotechnology and pharmaceutical industries. In biotechnology, the interaction term is negative and significant, suggesting that ESG performance has a weaker impact on R&D output in this sector. In contrast, the interaction term for pharmaceuticals is positive and significant, indicating a particularly strong effect of ESG performance on R&D output. These findings highlight that although ESG performance generally promotes R&D across industries, its impact is more pronounced in the pharmaceutical sector, where R&D is critical for innovation. In the biotechnology industry, ESG factors may face other challenges that limit their direct influence on R&D output.

7 | Conclusion

The growing emphasis on ESG performance has garnered widespread attention from scholars, investors, and regulators, particularly following the launch of the UN's 2030 Agenda for Sustainable Development. However, there is a lack of prior evidence examining the interplay between ESG performance, debt financing, and R&D output within the healthcare sector. The healthcare sector plays a significant role in global well-being, making substantial R&D investments to improve access to life-saving medications and enhance public health. However, this sector has considerable environmental, ethical, and social implications, particularly in production processes and supply chains. These include the generation of large amounts of waste and emissions, as well as ethical concerns related to practices in manufacturing and distribution. Consequently, the sector is increasingly scrutinized by various stakeholders, particularly environmentalists, regarding the legitimacy of its business practices (e.g., Eckelman et al. 2020; European Academies' Science Advisory Council 2021). Given these challenges, the healthcare sector is under the spotlight in addressing ESG issues due to the integration of its business models and the main goals of the UN's 2030 Agenda. For instance, Goal 3 aims to "ensure healthy lives and promote well-being for all ages" (United Nations 2015), further emphasizing the sector's responsibility to contribute to global sustainability efforts.

As the global narrative on ESG continues to evolve, our study explores the impact of ESG performance on R&D output, examining the dual roles of debt financing as both a mediator and moderator. Using a sample of 1211 firm-year observations from Europe and the United States over the period 2016–2022, we first demonstrate a positive and statistically significant impact of ESG performance on R&D output. Notably, the social dimension of ESG has a more prominent role than the environmental and governance dimensions in both regions. However, the ESG impact on R&D output is more significant in Europe. Additionally, we find no substantial evidence of industry-specific variations in the ESG-R&D output link, with the exception of

the biotechnology and pharmaceutical industries. Second, our analysis reveals that debt financing partially mediates the relationship between ESG performance and R&D output. Finally, we find that debt financing moderates the positive impact of ESG performance on R&D output, attenuating its effect. This provides new empirical evidence that the relationship between ESG performance and R&D output is not direct. We conclude that firms should not only focus on enhancing their ESG performance but also strategically manage their debt financing mechanisms to optimize R&D outcomes.

7.1 | Theoretical Implications

From a theoretical viewpoint, the extant literature continues to debate the direct role of ESG performance in driving R&D output. Whereas previous studies predominantly highlight the positive influence of ESG performance on R&D output, our research extends the current stream of literature by examining the role of debt financing mechanisms in shaping the relationship between ESG performance and R&D output in three key ways. First, our findings affirm the relevance of insights drawn from stakeholder theory. We demonstrate that healthcare firms with more stakeholder engagement tend to exhibit superior ESG performance, which, in turn, fosters increased R&D output. These firms are more likely to cultivate a positive corporate image and achieve better strategic coordination with stakeholders, facilitating the development and integration of critical resources that support R&D activities. Second, our study builds on agency theory to offer a more nuanced understanding of the mechanism through which ESG performance is internalized into firm debt financing decisions to drive the R&D output process. Specifically, we show that debt financing challenges the conventional understanding of a direct, positive relationship between ESG performance and R&D output, suggesting that the dynamics of debt financing play a significant role in driving this relationship.

In this regard, our results endorse the basis of the agency theory, suggesting that ESG activities enhance a firm's debt financing position by providing critical information to external parties, allowing them to assess sustainability performance. This, in turn, helps alleviate issues related to information asymmetry and moral hazard problems. Our findings also confirm the negative moderating effect of debt financing on the relationship between ESG performance and R&D output. This effect arises from the long-term, strategic nature of R&D initiatives, which involve high risk, uncertain returns, and complex scientific and technical challenges. Moreover, significant variations in ESG performance metrics across healthcare firms in Europe and the United States make it difficult for lenders to accurately assess the prospects of ESG performance. As a result, healthcare firms face challenges in securing adequate external debt financing for their R&D activities.

7.2 | Practical Implications

From a practical viewpoint, our findings underscore the critical role of ESG performance in R&D output decision-making, suggesting that firms in the healthcare sector should adopt policies addressing sustainability issues to promote R&D output. Our

study indicates that the direct link between ESG performance and R&D output may be spurious. Therefore, policymakers should consider the role of debt financing alongside ESG performance in shaping R&D outcomes. To mitigate the negative moderating effect of debt financing, regulators should enhance ESG reporting requirements, thereby reducing the adverse impact of debt financing on the ESG performance-R&D output relationship. This would leverage ESG reporting as a strategic tool for firms to facilitate access to debt financing, overcome financial constraints, and address information asymmetry, ultimately enhancing R&D output. Our evidence highlights the need to strengthen the supervisory role of debt financing to foster R&D output. In this regard, healthcare firms should allow banks and other financial institutions to conduct comprehensive, systematic evaluations of the firm's R&D processes. This improves communication and transparency, ultimately reducing the agency costs associated with debt financing.

Our study also suggests that the ESG evaluation system should be standardized and internationally harmonized to reduce divergence and accurately reflect a firm's ESG performance situation (Berg et al. 2022). This would, in turn, minimize variations in ESG performance scores, particularly among healthcare firms, which are often provided by different rating agencies. In this context, our findings support the implementation of contemporary sustainability initiatives, such as the EU's NFRD and CSRD reporting frameworks, and the US SEC's climate disclosure regulations to ensure consistent, comparable, and reliable ESG information. Following the adoption of these directives, the data reported under both the EU CSRD and US SEC should be aligned and made publicly accessible. Moreover, the weak and insignificant impact of the environmental pillar score highlights the urgent need to enhance stakeholder perspectives on Environmental Risk Assessment (ERA) regulations (Zinken et al. 2024). Whereas ERA revisions aim to reduce the environmental impact of medicines, current risk mitigation measures remain insufficient for identifying environmental risks. Therefore, ERA legislation must be refined and expanded to strengthen healthcare firms' ability to address emerging environmental challenges.

7.3 | Limitations and Future Research Avenues

This study has several limitations that offer useful directions for future research. First, our sample is limited to healthcare firms in Europe and the United States. Although these regions are highly data-rich, our findings may not be generalizable to emerging economies with distinct institutional structures, stakeholder expectations, and capital market conditions. Second, our analysis measures total R&D output based on patent applications and patent citations, without differentiating sustainability-oriented R&D from general R&D output. Future research could build on our findings by employing patent classifications that specifically capture sustainable R&D. Furthermore, the absence of a standardized methodology for measuring ESG performance introduces variability across ESG ratings, which may affect the interpretation of our results. Future research could move beyond quantitative metrics to explore the qualitative nature of ESG disclosures, for instance, analyzing how narrative ESG reporting and third-party ESG rating assurance influence R&D outcomes.

Third, although we use both total debt and long-term debt to total assets as proxies for debt financing, these measures have inherent limitations. Although the direction and mediation effects remain consistent when substituting *LTD* for our baseline measure, the moderating effect of *LTD* is statistically insignificant. This suggests that debt structure may influence the ESG–R&D output link differently depending on the temporal horizon of financing. Future studies could explore other debt financing dimensions such as direct indicators of weighted average cost of debt and interest coverage ratios for their potential influence on R&D output.

Fourth, our sample period (2016–2022) covers several key developments in ESG policy and practice, including the COVID-19 pandemic years (2020–2021), which may have temporarily influenced firm behavior in areas such as ESG disclosure, R&D prioritization, and capital allocation. Although we retain these years to capture the full trajectory of post-SDG ESG engagement, we acknowledge that the pandemic may introduce context-specific effects. Future research could explore how COVID-19-related shocks differentially shaped the ESG–R&D relationship across healthcare sectors in different regions. Finally, expanding the geographical scope of analysis could provide deeper insight into how country-specific ESG regulations and institutional environments impact R&D output. Longitudinal studies, in particular, could examine how sustained ESG performance over time influences innovation trajectories such as product pipelines, patent activity, and R&D internationalization in the healthcare sector.

Conflicts of Interest

The authors declare no conflicts of interest.

Endnotes

[1] We follow the approach proposed by Zhao et al. (2010) and Mehmetoglu (2018), using the "medsem" package in STATA 17 to estimate indirect effects through structural equation modeling (SEM) command. The significance of both direct and indirect effects is assessed using Sobel and Monte Carlo tests.

[2]The Arellano–Bond and Hansen tests are essential diagnostics in *SGMM* estimation. The Arellano–Bond test checks for second-order autocorrelation in the first-differenced residuals, whereas the Hansen test assesses instrument validity through overidentification testing. Together, these tests enhance the robustness and reliability of the estimated parameters (Arellano and Bond 1991; Roodman 2009).

References

Acharya, S., V. Lin, and N. Dhingra. 2018. "The Role of Health in Achieving the Sustainable Development Goals." *Bulletin of the World Health Organization* 96, no. 9: 591.

Aghion, P., S. Bond, A. Klemm, and I. Marinescu. 2004. "Technology and Financial Structure: Are Innovative Firms Different?" *Journal of the European Economic Association* 2, no. 2–3: 277–288.

Alam, M. S., M. Atif, C. Chien-Chi, and U. Soytaş. 2019. "Does Corporate R&D Investment Affect Firm Environmental Performance? Evidence From G-6 Countries." *Energy Economics* 78: 401–411.

Ali, S., H. Muhammad, and S. Migliori. 2024. "R&D Investment and SMEs Performance: The Role of Capital Structure Decisions." *EuroMed Journal of Business* 20: 1029–1051.

Amel-Zadeh, A., and G. Serafeim. 2018. "Why and How Investors Use ESG Information: Evidence From a Global Survey." *Financial Analysts Journal* 74, no. 3: 87–103.

Angrist, J. D., and A. B. Krueger. 2001. "Instrumental Variables and the Search for Identification: From Supply and Demand to Natural Experiments." *Journal of Economic Perspectives* 15, no. 4: 69–85.

Arellano, M., and S. Bond. 1991. "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations." *Review of Economic Studies* 58, no. 2: 277–297.

Asimakopoulos, P., S. Asimakopoulos, and X. Li. 2023. "The Role of Environmental, Social, and Governance Rating on Corporate Debt Structure." *Journal of Corporate Finance* 83: 102488.

Bade, C., A. Olsacher, P. Boehme, H. Truebel, L. Bürger, and L. Fehring. 2024. "Sustainability in the Pharmaceutical Industry—An Assessment of Sustainability Maturity and Effects of Sustainability Measure Implementation on Supply Chain Security." *Corporate Social Responsibility and Environmental Management* 31, no. 1: 224–242.

Baek, S., and D. H. Lee. 2024. "Can R&D Investment Be a Key Driver for Sustainable Development? Evidence From Korean Industry." *Corporate Social Responsibility and Environmental Management* 31, no. 2: 838–853.

Bah, R., and P. Dumontier. 2001. "R&D Intensity and Corporate Financial Policy: Some International Evidence." *Journal of Business Finance & Accounting* 28, no. 5–6: 671–692.

Barney, J. B. 2018. "Why Resource-Based Theory's Model of Profit Appropriation Must Incorporate a Stakeholder Perspective." *Strategic Management Journal* 39, no. 13: 3305–3325.

Baron, R. M., and D. A. Kenny. 1986. "The Moderator–Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations." *Journal of Personality and Social Psychology* 51, no. 6: 1173–1182.

Bartoloni, E. 2013. "Capital Structure and Innovation: Causality and Determinants." *Empirica* 40, no. 1: 111–151.

Behl, A., P. R. Kumari, H. Makhija, and D. Sharma. 2022. "Exploring the Relationship of ESG Score and Firm Value Using Cross-Lagged Panel Analyses: Case of the Indian Energy Sector." *Annals of Operations Research* 313, no. 1: 231–256.

Belkhir, L., and A. Elmeligi. 2019. "Carbon Footprint of the Global Pharmaceutical Industry and Relative Impact of Its Major Players." *Journal of Cleaner Production* 214: 185–194.

Berg, F., J. F. Koelbel, and R. Rigobon. 2022. "Aggregate Confusion: The Divergence of ESG Ratings." *Review of Finance* 26, no. 6: 1315–1344.

Blundell, R., and S. Bond. 1998. "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models." *Journal of Econometrics* 87, no. 1: 115–143.

Bolognesi, E., and A. Burchi. 2023. "The Impact of the ESG Disclosure on Sell-Side Analysts' Target Prices: The New Era Post Paris Agreements." *Research in International Business and Finance* 64: 101827.

Bonollo, E. 2015. "Disclosures in Local Healthcare Organizations' Social Reports. 'What?' And 'Why?' An Empirical Analysis of the Italian National Healthcare System." *Financial Reporting* 1: 41–75.

Brown, J. R., G. Martinsson, and B. C. Petersen. 2012. "Do Financing Constraints Matter for R&D?" *European Economic Review* 56, no. 8: 1512–1529.

Cardinaels, E., and N. Soderstrom. 2013. "Managing in a Complex World: Accounting and Governance Choices in Hospitals." *European Accounting Review* 22, no. 4: 647–684.

Carpenter, R. E., and B. C. Petersen. 2002. "Capital Market Imperfections, High-Tech Investment, and New Equity Financing." *Economic Journal* 112, no. 477: F54–F72.

Chen, L., M. U. Khurram, Y. Gao, M. Z. Abedin, and B. Lucey. 2023. "ESG Disclosure and Technological Innovation Capabilities of the Chinese Listed Companies." *Research in International Business and Finance* 65: 101974.

Chiarini, A., A. Opoku, and E. Vagnoni. 2017. "Public Healthcare Practices and Criteria for a Sustainable Procurement: A Comparative Study Between UK and Italy." *Journal of Cleaner Production* 162: 391–399.

Christensen, D. M., G. Serafeim, and A. Sikochi. 2022. "Why Is Corporate Virtue in the Eye of the Beholder? The Case of ESG Ratings." *Accounting Review* 97, no. 1: 147–175.

Cicchiello, A. F., F. Marrazza, and S. Perdichizzi. 2023. "Non-Financial Disclosure Regulation and Environmental, Social, and Governance (ESG) Performance: The Case of EU and US Firms." *Corporate Social Responsibility and Environmental Management* 30, no. 3: 1121–1128.

Cornell, B., and A. C. Shapiro. 2021. "Corporate Stakeholders, Corporate Valuation and ESG." *European Financial Management* 27, no. 2: 196–207.

Demirel, P., and E. Kesidou. 2019. "Sustainability-Oriented Capabilities for Eco-Innovation: Meeting the Regulatory, Technology, and Market Demands." *Business Strategy and the Environment* 28, no. 5: 847–857.

Dicuonzo, G., F. Donofrio, S. Ranaldo, and V. Dell'Atti. 2022. "The Effect of Innovation on Environmental, Social and Governance (ESG) Practices." *Meditari Accountancy Research* 30, no. 4: 1191–1209.

Dixit, S. K. 2020. "A New Multiperspective Emphasis on the Public Hospital Governance." *International Journal of Healthcare Management* 13: 1–9.

Doni, F., and M. Fiameni. 2024. "Can Innovation Affect the Relationship Between Environmental, Social, and Governance Issues and Financial Performance? Empirical Evidence From the STOXX200 Index." *Business Strategy and the Environment* 33, no. 2: 546–574.

dos Reis Cardillo, M. A., and L. F. C. Basso. 2025. "Revisiting Knowledge on ESG/CSR and Financial Performance: A Bibliometric and Systematic Review of Moderating Variables." *Journal of Innovation & Knowledge* 10, no. 1: 100648.

Eccles, R. G., and S. Klimenko. 2019. "The Investor Revolution." *Harvard Business Review* 97, no. 3: 106–116.

Eckelman, M. J., K. Huang, R. Lagasse, E. Senay, R. Dubrow, and J. D. Sherman. 2020. "Health Care Pollution and Public Health Damage in the United States: An Update: Study Examines Health Care Pollution and Public Health Damage in the United States." *Health Affairs* 39, no. 12: 2071–2079.

Ernst, H. 2001. "Patent Applications and Subsequent Changes of Performance: Evidence From Time-Series Cross-Section Analyses on the Firm Level." *Research Policy* 30, no. 1: 143–157.

European Academies' Science Advisory Council. 2021. "Decarbonisation of the Health Sector: A Commentary by EASAC and FEAM." https://easac.eu/fileadmin/PDF_s/reports_statements/Health_Decarb/EASAC_Decarbonisation_of_Health_Sector_Web_9_July_2021.pdf.pdf.

European Commission. 2025. "Corporate Sustainability Reporting." European Commission. https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en.

European Green Deal. 2019. "Communication on the European Green Deal." https://commission.europa.eu/publications/communication-european-green-deal_en.

Eurostat. 2024. "High-Tech Industry and Knowledge-Intensive Services (HTEC)." https://ec.europa.eu/eurostat/cache/metadata/en/htec_esms.htm.

Field, A. 2013. *Discovering Statistics Using IBM SPSS Statistics*. Sage.

Fiksel, J. 2012. "A Systems View of Sustainability: The Triple Value Model." *Environmental Development* 2: 138–141.

Freeman, R. E. 1984. *Strategic Management: A Stakeholder Approach*. 1st ed. Pitman/Ballinger.

Freeman, R. E., J. S. Harrison, and S. Zyglidopoulos. 2018. *Stakeholder Theory: Concepts and Strategies*. Cambridge University Press.

Fu, L., D. M. Boehe, and M. O. Orlitzky. 2022. "Broad or Narrow Stakeholder Management? A Signaling Theory Perspective." *Business & Society* 61, no. 7: 1838–1880.

Garcia, A. S., W. Mendes-Da-Silva, and R. J. Orsato. 2017. "Sensitive Industries Produce Better ESG Performance: Evidence From Emerging Markets." *Journal of Cleaner Production* 150: 135–147.

Hall, B. H., A. Jaffe, and M. Trajtenberg. 2005. "Market Value and Patent Citations." *RAND Journal of Economics* 36, no. 1: 16–38.

Hanson, D., T. Lyons, J. Bender, B. Bertocci, and B. Lamy. 2017. "Analysts' Roundtable on Integrating ESG Into Investment Decision-Making." *Journal of Applied Corporate Finance* 29, no. 2: 44–55.

Healthcare without Harm Europe. 2019. "The EU Healthcare Sector Is a Major Contributor to the Climate Crisis." https://noharm-europe.org/articles/press-release/europe/eu-healthcare-sector-major-contributor-climate-crisis.

Henisz, W. J., and J. McGlinch. 2019. "ESG, Material Credit Events, and Credit Risk." *Journal of Applied Corporate Finance* 31, no. 2: 105–117.

Hensher, M., and F. McGain. 2020. "Health Care Sustainability Metrics: Building A Safer, Low-Carbon Health System: Commentary Examines How to Build a Safer, Low-Carbon Health System." *Health Affairs* 39, no.12: 2080–2087.

Hoffmann, A. O., S. Kleimeier, N. Mimiroglu, and J. M. Pennings. 2019. "The American Inventors Protection Act: A Natural Experiment on Innovation Disclosure and the Cost of Debt." *International Review of Finance* 19, no. 3: 641–651.

Huang, G., F. Ye, Y. Li, L. Chen, and M. Zhang. 2023. "Corporate Social Responsibility and Bank Credit Loans: Exploring the Moderating Effect of the Institutional Environment in China." *Asia Pacific Journal of Management* 40, no. 2: 707–742.

Jackson, G., and A. Apostolakou. 2010. "Corporate Social Responsibility in Western Europe: An Institutional Mirror or Substitute?" *Journal of Business Ethics* 94, no. 3: 371–394.

Jensen, M. C., and W. H. Meckling. 1976. "Agency Costs and the Theory of the Firm." *Journal of Financial Economics* 3, no. 4: 305–360.

Jung, D. D., A. Wu, and C. W. Chow. 2008. "Towards Understanding the Direct and Indirect Effects of Ceos' Transformational Leadership on Firm Innovation." *Leadership Quarterly* 19, no. 5: 582–594.

Kalia, D., and D. Aggarwal. 2023. "Examining Impact of ESG Score on Financial Performance of Healthcare Companies." *Journal of Global Responsibility* 14, no. 1: 155–176.

Kemper, J., O. Schilke, and M. Brettel. 2013. "Social Capital as a Microlevel Origin of Organizational Capabilities." *Journal of Product Innovation Management* 30, no. 3: 589–603.

KPMG. 2022. "KPMG Survey of Sustainability Reporting 2022 KPMG International." https://assets.kpmg.com/content/dam/kpmg/se/pdf/komm/2022/Global-Survey-of-Sustainability-Reporting-2022.pdf.

Li, C., S. Ba, K. Ma, Y. Xu, W. Huang, and N. Huang. 2023. "ESG Rating Events, Financial Investment Behavior and Corporate Innovation." *Economic Analysis and Policy* 77: 372–387.

Luo, X., H. Wang, S. Raithel, and Q. Zheng. 2015. "Corporate Social Performance, Analyst Stock Recommendations, and Firm Future Returns." *Strategic Management Journal* 36, no. 1: 123–136.

McWilliams, A., and D. Siegel. 2001. "Corporate Social Responsibility: A Theory of the Firm Perspective." *Academy of Management Review* 26, no. 1: 117–127.

Mehmetoglu, M. 2018. "Medsem: A Stata Package for Statistical Mediation Analysis." *International Journal of Computational Economics and Econometrics* 8, no. 1: 63–78.

Mehra, R., and M. K. Sharma. 2021. "Measures of Sustainability in Healthcare." *Sustainability Analytics and Modeling* 1: 100001.

Montiel, I., J. Park, B. W. Husted, and A. Velez-Calle. 2022. "Tracing the Connections Between International Business and Communicable Diseases." *Journal of International Business Studies* 53, no. 8: 1785–1804.

Muhammad, H., S. Migliori, and S. Mohsni. 2022. "Corporate Governance and R&D Investment: The Role of Debt Financing." *Industrial and Corporate Change* 31, no. 3: 628–653.

Muller, D., C. M. Judd, and V. Y. Yzerbyt. 2005. "When Moderation Is Mediated and Mediation Is Moderated." *Journal of Personality and Social Psychology* 89, no. 6: 852–863.

Murè, P., M. Spallone, F. Mango, S. Marzioni, and L. Bittucci. 2021. "ESG and Reputation: The Case of Sanctioned Italian Banks." *Corporate Social Responsibility and Environmental Management* 28, no. 1: 265–277.

Padgett, R. C., and J. I. Galan. 2010. "The Effect of R&D Intensity on Corporate Social Responsibility." *Journal of Business Ethics* 93: 407–418.

Panda, S. S., and S. Sangle. 2020. "Stakeholder Engagement as a Dynamic Capability." *Business Strategy & Development* 3, no. 2: 204–212.

Paolone, F., N. Cucari, J. Wu, and R. Tiscini. 2022. "How Do ESG Pillars Impact Firms' Marketing Performance? A Configurational Analysis in the Pharmaceutical Sector." *Journal of Business & Industrial Marketing* 37, no. 8: 1594–1606.

Park, J., J. A. Brown, and B. W. Husted. 2025. "Health Is Everyone's Business: Integrating Business and Public Health for Lasting Impact." *Business & Society* 64, no. 3: 423–440.

Park, J., I. Montiel, B. W. Husted, and R. Balarezo. 2022. "The Grand Challenge of Human Health: A Review and an Urgent Call for Business–Health Research." *Business & Society* 61, no. 5: 1353–1415.

Pinheiro, A. B., G. B. Panza, N. L. Berhorst, A. M. M. Toaldo, and A. P. Segatto. 2023. "Exploring the Relationship Among ESG, Innovation, and Economic and Financial Performance: Evidence From the Energy Sector." *International Journal of Energy Sector Management* 18: 500–516.

Prasad, K., S. Kumar, S. Devji, W. M. Lim, N. Prabhu, and S. Moodbidri. 2022. "Corporate Social Responsibility and Cost of Capital: The Moderating Role of Policy Intervention." *Research in International Business and Finance* 60: 101620.

Purohit, A., J. Smith, and A. Hibble. 2021. "Does Telemedicine Reduce the Carbon Footprint of Healthcare? A Systematic Review." *Future Healthcare Journal* 8, no. 1: e85.

Raimo, N., A. Caragnano, M. Zito, F. Vitolla, and M. Mariani. 2021. "Extending the Benefits of ESG Disclosure: The Effect on the Cost of Debt Financing." *Corporate Social Responsibility and Environmental Management* 28, no. 4: 1412–1421.

Rezaee, Z., S. Homayoun, E. Poursoleyman, and N. J. Rezaee. 2023. "Comparative Analysis of Environmental, Social, and Governance Disclosures." *Global Finance Journal* 55: 100804.

Roodman, D. 2009. "How to Do xtabond2: An Introduction to Difference and System GMM in Stata." *Stata Journal* 9, no. 1: 86–136.

Scellato, G., and E. Ughetto. 2010. "The Basel II Reform and the Provision of Finance for R&D Activities in SMEs: An Analysis of a Sample of Italian Companies." *International Small Business Journal* 28, no. 1: 65–89.

Sharfman, M. P., and C. S. Fernando. 2008. "Environmental Risk Management and the Cost of Capital." *Strategic Management Journal* 29, no. 6: 569–592.

Tidd, J., and J. Bessant. 2018. "Innovation Management Challenges: From Fads to Fundamentals." *International Journal of Innovation Management* 22, no. 5: 1840007.

US Securities and Exchange Commission. 2022. "The Enhancement and Standardization of Climate-Related Disclosures for Investors (Release No. 33–11042)." https://www.sec.gov/rules/proposed/2022/33-11042.pdf.

United Nations. 2015. "Transforming Our World: The 2030 Agenda for Sustainable Development A/RES/70/1." https://sustainabledevelopment.un.org/post2015/transformingourworld/publication.

Uyar, A., C. Kuzey, A. M. Gerged, and A. S. Karaman. 2023. "Research and Development Intensity, Environmental Performance, and Firm Value: Unraveling the Nexus in the Energy Sector Worldwide." *Business Strategy and the Environment* 32, no. 4: 1582–1602.

Uyar, A., C. Kuzey, M. Kilic, and A. S. Karaman. 2021. "Board Structure, Financial Performance, Corporate Social Responsibility Performance, CSR Committee, and CEO Duality: Disentangling the Connection in Healthcare." *Corporate Social Responsibility and Environmental Management* 28, no. 6: 1730–1748.

Valentinov, V. 2023. "Sustainability and Stakeholder Theory: A Processual Perspective." *Kybernetes* 52, no. 13: 61–77.

Vincent, C. L., V. Singh, K. Chakraborty, and A. Gopalakrishnan. 2017. "Patent Data Mining in Fisheries Sector: An Analysis Using Questel-Orbit and Espacenet." *World Patent Information* 51: 22–30.

Wan, H., J. Fu, and X. Zhong. 2024. "ESG Performance and Firms' Innovation Efficiency: The Moderating Role of State-Owned Firms and Regional Market Development." *Business Process Management Journal* 30, no. 1: 270–290.

Wenzel, M., N. Henne, and Y. Zöllner. 2014. "Beyond the Pill: The Move Towards Value-Added Services in the Pharmaceutical Industry." *Journal of Medical Marketing* 14, no. 2–3: 91–98.

Yan, A. 2006. "Leasing and Debt Financing: Substitutes or Complements?" *Journal of Financial and Quantitative Analysis* 41, no. 3: 709–731.

Zhao, X., J. G. Lynch Jr., and Q. Chen. 2010. "Reconsidering Baron and Kenny: Myths and Truths About Mediation Analysis." *Journal of Consumer Research* 37, no. 2: 197–206.

Zhu, J., Z. Xiong, X. Lu, and Z. Yao. 2025. "Does ESG Rating Disagreement Impede Corporate Green Innovation?" *Global Finance Journal* 64: 101068.

Zinken, J. F., A. M. Pasmooij, A. G. Ederveen, J. Hoekman, and L. T. Bloem. 2024. "Environmental Risk Assessment in the EU Regulation of Medicines for Human Use: An Analysis of Stakeholder Perspectives on Its Current and Future Role." *Drug Discovery Today* 29: 104213.

Appendix

TABLE A1 | Definition of all variables.

Variables	Notations	Definitions
ESG performance	ESG	The continuous variable score ranging from 0 (lowest ESG performance) to 100 (highest ESG performance)
R&D output	R&D_Output	Natural logarithm of patents application +1
Debt financing	DF	Total debt divided by total assets
Fixed assets	FA	Total fixed assets divided by total assets
Firm size	FS	Natural logarithm of total assets
Firm performance	ROA	Net income scaled by total assets
Firm age	Age	Natural logarithm of the number of years since the firm was established
Firm cash flows	CF	The ratio of the net cash flows from operations to total assets
Firm growth	FG	Percentage change in operating revenue

TABLE A2 | Correlation matrix of variables.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) *ESG*	1								
(2) *R&D_Output*	0.225**	1							
(3) *DF*	0.131***	−0.184***	1						
(4) *FA*	0.062*	0.116***	0.001	1					
(5) *FS*	0.706***	0.238***	0.158***	−0.113	1				
(6) *ROA*	0.277***	0.019	−0.022	0.070*	0.202***	1			
(7) *Age*	0.256***	0.044	−0.099***	0.049	0.140***	0.140***	1		
(8) *CF*	0.103***	0.050	0.035	0.223***	0.036	0.275***	0.047	1	
(9) *FG*	0.030	0.040	0.040	0.007	0.018	−0.012	−0.014	−0.002	1
VIF		1.10	1.05	1.06	1.19	1.15	1.05	1.14	1.01
1/VIF		0.91	0.94	0.94	0.83	0.86	0.95	0.87	0.99

Note: This table reports descriptive statistics of the variables used in this study. All variables are defined in Table A1.
*$p < 0.01$.
**$p < 0.05$.
***$p < 0.01$.