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ESG-linked Executive Compensation and Firm Value: The Mediating Role of Environmental Innovation and Moderating Role of ESG Training

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ABSTRACT

This study examines whether environmental, social, and governance (ESG)-linked executive compensation influences firm value and the channels through which its effects emerge. Using panel data of listed firms from STOXX Europe 600 during 2015–2023, the study employs Tobin's Q and price-to-book value to assess firm value and robustness, respectively. The empirical analysis uses firm- and year-fixed–effects models complemented by system-generalized method of moments (GMM) and an event-study difference-in-differences design to address endogeneity. The results show that ESG-linked compensation is positively associated with environmental innovation. In the baseline fixed-effects estimates, moving from no ESG-linked pay to ESG-linked pay is associated with a 7.6-point increase in the environmental innovation score, equivalent to approximately 14% of its sample mean, and approximately 5.2% higher firm value. However, the association with firm value is not robust under system-GMM and event-study specifications. ESG-related training conditions the ESG-linked pay–environmental innovation relation; governance variables do not show consistent moderating effects. The mediation analysis does not support a statistically significant indirect effect. Overall, ESG-linked pay appears to influence firm behavior more consistently compared with immediate financial outcomes.

1 | Introduction

The link between executive compensation and company performance was initially examined by Jensen and Murphy (1990), whose study highlighted the need for linking CEO pay with the firm's financial performance. Since then, companies have increasingly incorporated financial targets in CEOs' compensation contracts to incentivize them to maximize shareholder wealth (Cohen et al. 2023). Theoretically, this initiative aims to reduce agency issues that could arise from the lack of monitoring of self-interested executives' behaviors (Cregan et al. 2025; Petrou and Procopiou 2016). However, the literature also highlights the potential issues associated with CEO-linked compensation contracts, as executives could manipulate the firm's financial resources to increase their own wealth (Cregan et al. 2025). According to Frydman and Jenter (2010, 9), "any form of incentive compensation entails the danger that managers may manipulate the performance measure." Existing literature has also shed light on some manipulation methods adopted by CEOs. Gopalan et al. (2017) highlighted the CEO practice of managing reported earnings by increasing revenues or postponing certain expenditures. Ringlee et al. (2023) pointed to CEOs' aggressive capital expenditure strategies designed to increase returns on assets and equity. CEOs have adopted many other strategies, such as the release of negative news before the reward date. These strategies are intended to decrease share prices and increase the number of shares awarded under a set value of share options (Cregan et al. 2025; Faulkender et al. 2010).

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These views on manipulations are not only borne of scholarly hypotheses but also have been the trigger for several real-world scandals, such as the Enron scandal and accounting malpractices. Recently, many large companies have begun linking executive compensation to environmental, social, and governance (ESG) performance. ESG-related executive compensation has become a popular governance tool for handling pressure from corporate stakeholders who are committed to simultaneously meeting ESG goals and achieving sustainability and sound financial performance. The Global ISS Executive Compensation Analytics database reports that as key financial indicators, the significance of ESG metrics rose tenfold from 3% in 2010 to 30% in 2021 (Cohen et al. 2023). Firms have traditionally used financial metrics, such as earnings or returns on investment, to reward executives, but the use of nonfinancial metrics is on the rise. Companies adopt ESG-based compensation policies to demonstrate their commitment to meeting the expectations of different stakeholders (Ben Ali and Chouaibi 2024; Veltri et al. 2025) and achieve robust financial performance (Cohen et al. 2023).

However, compared with financial performance, the conceptual ambiguity of ESG performance suggests substantial opportunities for its manipulation. The lack of standardized ESG measurements raises the potential for agency issues. Because of these complications, Bebchuk and Tallarita (2022) argued whether ESG-linked compensation may be effective for S&P 500 companies. Dell'Erba and Ferrarini (2024) also reached the same conclusion for European firms. Similar results were found across industries by Temple-West and Xiao (2023), who reported ESG-linked pay as "very subjective, fluffy, and easily gamed." Firms are refining their ESG performance to mitigate agency issues by providing clear goals and meaningful context that is understood by all the company stakeholders (Bebchuk and Tallarita 2022). Owing to the special nature of ESG-linked compensation, technical knowledge and monitoring are necessary for avoiding manipulation, thereby highlighting the role of effective corporate governance and objectivity. This gap brings the following research questions to the fore: Does CEO ESG-linked pay improve firm value? What monitoring factors and outcomes are necessary to make it more effective?

In terms of monitoring, recent studies on corporate governance use the presence of women on corporate boards as a proxy for effective governance and tight monitoring (Srinidhi et al. 2020; Velte 2017). Their presence on corporate boards plays a significant role in shaping corporate policies (Chen et al. 2019), including the design of executive compensation (Benkraiem et al. 2017; Ullah et al. 2020). The inclusion of women on corporate boards reportedly brings more benefits to corporations, such as boosting financial performance (Alahdal et al. 2024; Xie et al. 2024), environmental performance (Mallidis et al. 2024; Zahid et al. 2025), and green innovation (Chu 2024; Jin et al. 2024). Women board members are also observed to be more sensitive toward ethical issues and show community-oriented behavior (Cook and Glass 2018). Therefore, the role of gender diversity in the relation between ESG-based pay and firm value merits examination. Similarly, board independence plays an important role in ESG-based compensation. Liao et al. (2025) documented that it supports ESG-based compensation. Similarly, Homroy et al. (2023) concluded that an effective governance mechanism is more likely to support the sustainability metric in executive compensation.

Beyond its role as a governance mechanism, ESG-linked executive compensation can shape how firms translate sustainability commitments into concrete value-relevant outcomes. Linking CSR or ESG objectives to executive pay has been shown to help mitigate agency problems by encouraging managers to prioritize long-term stakeholder-oriented investments (Focke 2022; Hou et al. 2025). However, to be effective, such incentive structures must guide managerial attention toward actions that are both observable and impactful. Drawing on the attention-based view, managerial behavior is influenced by how attention is directed and allocated within the firm, and compensation contracts play a central role in this process (Zhang et al. 2026). In this context, ESG-linked incentives are likely to channel managerial focus toward sustainability-oriented activities, among which environmental innovation represents a relevant and measurable pathway.

Environmental innovation reflects firms' efforts to reduce waste, improve energy efficiency, and adopt environmentally responsible processes (Tang et al. 2018). These efforts improve environmental performance, enhance operational efficiency, and support the development of new business models, thereby contributing competitive advantages (Dwekat et al. 2025; Traversi et al. 2024). Thus, environmental innovation provides a tangible channel through which ESG-driven managerial incentives can translate into economic outcomes. Moreover, because such initiatives are relatively visible and measurable, they allow stakeholders to better assess whether ESG-linked compensation leads to substantive organizational change.

Environmental innovation is also associated with several challenges. It is often costlier, riskier, and more uncertain than conventional forms of innovation (Del Río et al. 2016; Dwekat et al. 2025), with additional concerns such as the risk of failure, employee dissatisfaction, and uncertain financial returns (Farza et al. 2022). These complexities may discourage managers from pursuing environmental innovation in the absence of adequate support. Thus, ESG-related training is particularly important. Training equips managers and employees with the knowledge and skills necessary to understand environmental issues and implement effective sustainability practices (Khatib and Al Amosh 2024). Such knowledge enhances their ability to interpret ESG objectives and reduces the uncertainty associated with environmental decision-making, leading to more informed and practical approaches. Training plays a critical role in improving environmental performance and facilitating the successful implementation of sustainability initiatives (Elsayih et al. 2021; Gedam et al. 2021).

As such, ESG training can strengthen the relation between ESG-linked compensation and environmental innovation by enhancing a firm's capacity to respond to sustainability-oriented incentives. In firms where such training is offered, managers are better equipped to translate ESG-linked pay into meaningful innovation outcomes. Together, these arguments suggest that environmental innovation acts as a key mediating mechanism through which ESG-linked executive compensation influences

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firm value, whereas ESG training further reinforces this relation by enabling more effective implementation of sustainability-driven strategies.

Thus, our study aims to elucidate the impact of ESG-based compensation policies on firm value by considering the roles of corporate governance (board gender diversity and board independence), environmental innovation, and ESG training. Using the STOXX Europe 600 Index, this study contributes to the literature by empirically investigating the following questions: Does ESG-based compensation directly contribute to firm value? Do board gender diversity and independence moderate the relation between ESG-based compensation and firm value? Does environmental innovation mediate the relation between ESG-based compensation and firm value? Does ESG training moderate the relation between ESG-based compensation and environmental innovation?

Agency issues in the pay-setting process have encouraged European policymakers to work on both the structure and process of executive compensation settings. This has led to the implementation of the Shareholder Rights Directive (SHRD), which attempts to promote a long-term approach to the variable part of remuneration. In this process, independent directors, SHRD II, and corporate governance codes help reduce agency costs and select optimal pay-setting processes. Article 9a (6) of SHRD I, as amended in SHRD II, clearly outlines that remuneration should contribute to the company's sustainability, and when variable pay is awarded, the company should "indicate the financial and non-financial performance criteria, including, where appropriate, criteria relating to corporate social responsibility." Despite this explicit reference to the inclusion of sustainability, serious doubts about ESG remain. This motivated the current study on the European context and the use of the STOXX Europe 600 Index.

This study contributes to the literature in multiple ways. First, it moves beyond the traditional focus on the direct relation between ESG-based compensation and firm value by examining a more comprehensive and interconnected framework. Several studies have examined ESG-based compensation along with gender diversity and environmental innovation (Baraibar-Diez et al. 2019; Benkraiem et al. 2017; Dohrmann et al. 2025). This study is primarily motivated by Dohrmann et al.'s (2025) study, which suggests the need for adding more contextual factors that may indirectly (moderate/mediate) the relation between ESG-based compensation and firm value. Studies must go beyond linearity, and our work attempts to fill this gap (Nguyen et al. 2021; Dohrmann et al. 2025). Therefore, we incorporate the role of corporate governance to explain the relation between ESG-linked pay and firm value. Previous research has largely examined ESG-linked pay in isolation from firm value; however, this study introduces governance mechanisms such as board gender diversity and board independence as moderators to examine the relation between ESG-linked pay and firm value. This suggests that ESG-linked compensation may act as a primary alignment mechanism, thereby reducing the incremental influence of traditional governance structures. More broadly, we contribute to the ongoing debate by showing that governance mechanisms do not uniformly enhance firm outcomes and that their effectiveness may be context-dependent.

Second, the study makes a key theoretical contribution by explicitly examining environmental innovation as a mediating mechanism in the ESG-linked pay–firm value relation. Earlier studies suggest that ESG-based incentives can influence firm outcomes, but they have not clarified how these incentives translate into value creation. By introducing environmental innovation as an intervening channel, this study provides a more nuanced explanation of the process through which ESG-linked compensation shapes firms' behaviors. Importantly, the findings offer a more cautious interpretation of this mechanism: Although ESG-linked pay is associated with higher environmental innovation and firm value in the baseline models, the mediation effect is not robust under more rigorous empirical examination. This finding suggests that the link between ESG incentives and firm value may be more complex, indirect, and context-dependent than previously assumed.

Third, this study extends the literature by examining the moderating role of ESG-related training in shaping the relation between ESG-linked compensation and environmental innovation. The results reveal a nuanced dynamic: Although training enhances firms' capacity to engage in environmental innovation over time, its interaction with ESG-linked pay varies according to the estimation approach, suggesting both substitution and complementary effects. This highlights the importance of internal organizational capabilities, particularly human capital, in determining whether ESG incentives translate into meaningful innovation outcomes. Finally, this study makes an important contextual contribution by focusing on European firms and examining the relevance of recent regulatory developments aimed at increasing female representation on boards. By analyzing the role of board gender diversity in the ESG–performance relation, this study provides timely insights into the effectiveness of such policy interventions, particularly in the context of sustainability-oriented governance.

2 | Theoretical Background and Hypotheses Development

Agency theory, proposed by Jensen and Meckling (1976), explains how the interests of agents, such as directors, may diverge from those of principals owing to self-interest. To overcome such agency issues, firms must implement effective and tight monitoring through corporate governance codes. Competent boards that are gender diverse and independent are enabled to act and decide with more transparency, better judgment, and better disclosure procedures (Esterhuyse and du Toit 2023; Khatib and Al Amosh 2024). Consequently, these governance techniques extend beyond financial performance and significantly impact environmental performance. In Europe, these concepts are gradually becoming embedded in regulatory frameworks. By linking ESG with agency theory, firms can bridge the gap between ownership and control by demonstrating sustainability commitments.

The agency framework states that shareholders care only about financial performance and not societal measures, such as ESG. Two schools of thought explain ESG-linked pay. One believes that ESG outcomes are an important indicator of financial growth (Cohen et al. 2023). Proponents argue that ESG-linked pay is

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similar to other nonfinancial variables, such as customer satisfaction and product quality, in managerial incentive contracts (Dutta and Reichelstein 2003; Ittner et al. 1997). ESG-linked pay is gaining popularity, with 92% of large US companies and 72% of large UK companies implementing this concept (PwC 2022). ESG-linked pay improves the value of firms and their ESG goals (Haque and Ntim 2020; Le and Ngo 2024).

The second view, in contrast, criticizes ESG-linked pay. Kaplan and Norton (1992) proposed a balance scorecard that considers the importance of nonfinancial metrics but does not link it with compensation (Edmans 2023). ESG-linked pay also contradicts the traditional view of executive remuneration, which suggests that it should be structured to maximize shareholder wealth (Dell'Erba and Ferrarini 2024). Edmans (2023) opposed this idea because CEOs may then focus on ESG than on the other drivers of value. Scholars have also expressed significant concern about structural inconsistency (Drei et al. 2019; Edmans 2023; Sheehan et al. 2023), which may lead to financial risk, investor exposure, and systematic risk (Dell'Erba and Ferrarini 2024). In a broader context, this may pose a threat to new approaches that drive changes in corporate market prices (Dell'Erba and Ferrarini 2024).

Critiques of ESG have merged at different levels, including corporate governance mechanisms (Tallarita 2022). ESG structural inconsistency and bad governance issues further increase agency issues regarding ESG reporting and ESG-linked pay. The shift in corporate focus from the maximization of shareholder wealth to that of stakeholder value creates doubts regarding ESG-linked pay. According to this line of thought, ESG-linked pay may create additional costs for shareholders. For example, Haskel and Westlake (2017) documented cases where companies invest in employee training but do not reap its benefits because of staff turnover or relocation. ESG investments also differ from other investments because they are used to achieve social goals at the cost of social governance, which may create agency problems for managers and shareholders.

For a better understanding of executive compensation and ESG, our study highlights the role of ESG training in the relation between ESG compensation policies and environmental innovation (Figure 1). It also explores how environmental innovation leads to better firm value.

Evidence regarding ESG-linked pay, financial performance, and environmental performance is mixed. For instance, Cohen et al. (2023) reported a significant positive relation between ESG-linked pay and environmental performance, but an insignificant relation with financial performance in an international context. By contrast, Flammer et al. (2019) reported that CSR criteria in compensation contracts positively influence firm performance. Homroy et al. (2023) studied Swedish firms and concluded that they adopted ESG-linked pay contracts to meet stakeholders' expectations beyond financial performance. From an agency theory perspective, linking executive compensation to ESG objectives can reduce managerial short-termism by aligning managerial incentives with longer term organizational outcomes. At the same time, stakeholder theory suggests that incorporating ESG criteria in executive compensation broadens managerial attention beyond immediate shareholder returns toward the environmental and social expectations of multiple stakeholders. Therefore, ESG-linked pay may influence firm value by encouraging managerial decisions that balance financial objectives with stakeholder-oriented sustainability priorities. However, because ESG targets may be difficult to measure and monitor, the effectiveness of this incentive mechanism remains an empirical question. Based on the aforementioned literature, we hypothesized as follows:

H1. *ESG-linked pay significantly positively influences firm value.*

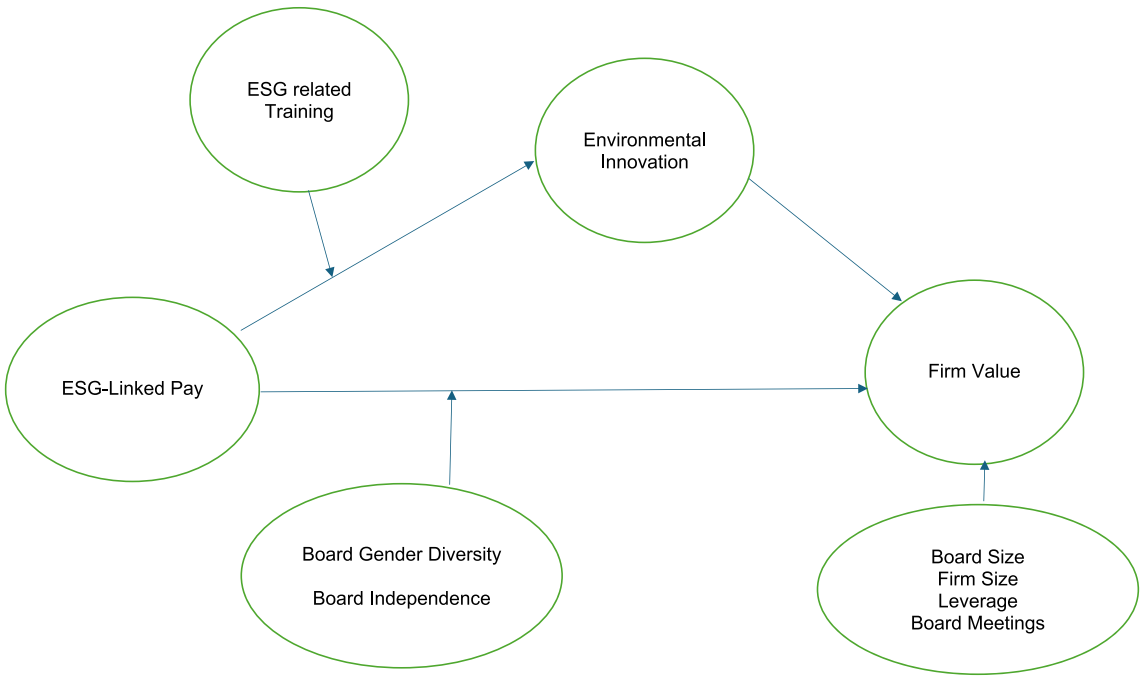


FIGURE 1 | Proposed model.

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Over the past decade, global warming has become a major concern for academics, researchers, and regulators (Afzali et al. 2025; Boiral 2006; Hossain and Masum 2022). Controlling global warming requires curbing greenhouse gas emissions in different sectors. The goal of reducing greenhouse gases has become the agenda of all stakeholders (Doran and Ryan 2016) and firms are taking serious action to achieve this goal by increasing environmental innovations. These environmental innovations reduce environmental pollution and material waste, thus creating additional firm value (Iqbal et al. 2022; Sharma 2017). Using sustainability committees established by European firms, Alodat et al. (2025) examined the role of ESG and environmental innovation, finding a positive association between ESG and environmental performance. Liao (2018) examined the moderating role of environmental attitudes in market orientation and environmental innovation. Using 247 Chinese manufacturing firms, Liao (2018) concluded that environmental attitudes positively moderate the relation between market orientation and firms' environmental innovation. Konadu et al. (2022) reported the moderating role of environmental innovation in the relation between board gender diversity and carbon emissions among US S&P 500 companies. From a stakeholder-theory perspective, ESG-linked compensation can direct managerial attention toward environmental objectives that are valued by stakeholders, thereby encouraging investment in environmental innovation. Environmental innovation, in turn, may improve resource efficiency, reduce environmental costs, strengthen stakeholder legitimacy, and create competitive advantages that can contribute to firm value. Therefore, environmental innovation represents a potential organizational channel through which ESG-linked incentives may be translated into value-relevant outcomes Thus, we hypothesized as follows:

H2. *Environmental innovation mediates the relation between ESG-linked pay and firm value.*

Executives are responsible for implementing corporate strategies, and their perceptions, decisions, attitudes, and capabilities are directly linked to effectiveness and innovation management (Gröschl et al. 2019; Zhao et al. 2025). Edmans (2023), in an article on the evolution of ESG from a niche subfield to a mainstream practice, argued that large shareholders not only consider quarterly earnings but also care for intangible assets, such as customer culture and innovative capabilities. Similarly, Long et al. (2023) documented that ESG is key to global competitiveness and necessitates sustainable development. Green innovation is key to achieving this goal (Klewitz and Hansen 2014; Long et al. 2023). Without environmental innovation, ESG reporting does not significantly improve firm performance. Notably, few studies have explored the link between executive ESG-linked compensation and green innovation (Zhao et al. 2025), despite the importance of environmental innovation outcomes. Many studies have shown that ESG is positively associated with green innovation. Long et al. (2023) documented a positive relation between ESG and green innovation. Zhao et al. (2025) documented that executive salary incentives promote green innovation. A capability-based perspective suggests that incentives alone may be insufficient to generate environmental innovation unless firms possess the necessary human capital. ESG-related training develops employees' environmental knowledge, skills, and problem-solving capabilities, thereby strengthening the organizational capacity to translate managerial ESG incentives into substantive environmental actions. Training can operate as a complementary internal capability that conditions the effectiveness of ESG-linked compensation in promoting environmental innovation. Based on this discussion, we hypothesized as follows:

H3. *ESG-related training moderates the relation between ESG-linked pay and environmental innovation.*

Ludwig and Sassen (2022) noted that sound intracorporate governance plays an important role in supporting efficient sustainability management. High corporate governance standards should be maintained if firms want to achieve certain goals and prosper (Alahdal et al. 2024; Ludwig and Sassen 2022). Executive compensation demands high security from investors and the media because of high remuneration packages (Sapp 2008). As a key part of corporate governance, it deserves better understanding from all stakeholders. Corporate governance has an important role to play, particularly regarding ESG-based pay. Many studies have demonstrated the positive role of women and independent directors in ESG-based pay (Veltri et al. 2025). Women's participation in corporate boards is considered effective (Cabrera-Fernández et al. 2016; Martinez-Jimenez et al. 2020). Liu et al. (2023) examined the role of women's presence on corporate boards and executive compensation contracts among US listed firms. They found that higher female board representation is associated with an increased tendency to offer more ESG-based pay. As for board independence, it positively improves executive compensation contracts (e.g., Liao et al. 2021). From an agency theory perspective, environmental innovation could negatively influence firm performance because of the potential for misallocation of the firm's resources toward the environmental agenda (Konadu et al. 2022; Pereira-Moliner et al. 2015). Therefore, environmentally innovative firms may require tighter board control to use their expertise to maximize the value of money. Griffiths et al. (2019) documented that women directors help mitigate agency issues by tightly monitoring high risk-taking behavior and firms' short-term focus. Orazalin and Baydauletov (2020) examined the role of corporate social responsibility strategies and environmental and social performance by considering the moderating role of gender diversity. They used European firm data from 2009 to 2016 and concluded that board gender diversity positively moderates the relation between corporate social responsibility strategies and environmental performance. Given the role of governance indicators, we hypothesized as follows:

H4. *Board gender diversity moderates the relation between ESG-based pay and firm value.*

H5. *Board independence in corporate boards moderates the relation between ESG-based pay and firm value.*

3 | Data and Methodology

This study used listed firms in the STOXX Europe 600 Index over a period of 9 years from 2015 to 2023. The sample spanned multiple industries, including financial and utility firms, reflecting the broad sectoral composition of the index (Gonçalves

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et al. 2023). After applying the data-availability requirements for the variables used in the empirical analysis, we ended up with a final sample of 357 firms and 2361 firm-year observations across 17 European countries. Financial and utility firms were retained because of their relevance to ESG-linked compensation and environmental performance.

Given that financial institutions differ from nonfinancial firms in their regulatory environment, capital structure, and economic interpretation of accounting-based measures, such as leverage and Tobin's Q, we conducted an additional sensitivity analysis that excluded financial-sector firms and re-estimated the baseline models on the nonfinancial subsample. We retained utility firms given the salience of environmental innovation and transition-related investment in this sector. The environmental innovation score provided a standardized measure of firms' environmental innovation performance. Further, the time period of the study ensured sufficient temporal variation for robust panel estimation and also captured recent trends in ESG performance, corporate governance, and market dynamics. The data were extracted from the LSEG Refinitiv Eikon database, which provides comprehensive and reliable firm-level panel data, including ESG-related variables, governance metrics, financial performance, and control variables.

We used panel data regression models with both fixed and random effects to test the proposed hypotheses (Ahmed et al. 2024; Bel-Oms et al. 2025). To address endogeneity and dynamic persistence, we used a two-step system-generalized method of moments (GMM) estimation. The lagged dependent variable, ESG-linked pay, environmental innovation (where applicable), and moderator and interaction terms in the moderation models were instrumented using internal GMM-style instruments. The financial control variables were also instrumented using internal GMM-style instruments, whereas year indicators were treated as exogenous IV-style instruments. Instrument proliferation was controlled through collapsed instrument matrices and restricted lag depths, with the exact lag structure reported for each specification in the corresponding table notes (Ahmed et al. 2024; Bun and Windmeijer 2010). Model validity was assessed using the Arellano–Bond AR(1) and AR(2) tests, the Hansen test of overidentifying restrictions, and, where generated by the respective specification, difference-in-Hansen tests for instrument subsets. Given that fixed-effect estimators are biased under dynamic endogeneity, we sought to overcome this limitation using the system-GMM method, which reduces bias and also improves estimation efficiency (Li et al. 2021).

3.1 | Difference-in-Differences (DiD) and Event-Study Analysis

To further strengthen causal identification and address potential endogeneity concerns, we complemented the fixed effects and system-GMM estimations with a DiD design implemented through an event-study framework (Wang et al. 2025). This approach exploited the staggered adoption of ESG-linked executive compensation across firms and over time, allowing us to assess the plausibility of the parallel-trends assumption (Lin and Li 2025). Specifically, we identified the first year in which a firm adopted ESG-linked pay and defined this as the treatment event ($t=0$). We then constructed a series of indicator variables capturing event time relative to the first observed adoption. The year immediately preceding adoption ($t=-1$) serves as the omitted reference category. We estimated event periods from $t=-4$ to $t=+4$ separately. We grouped observations five or more years before adoption into $t\leq -5$ and those five or more years after adoption, into $t\geq +5$. This endpoint binning avoided reliance on sparsely populated event-time cells at the tails of the distribution while retaining the available observations (Callaway and Sant'Anna 2021).

We estimated a conventional two-way fixed-effects event-study specification with firm and year fixed effects, as follows:

$$Y_{it} = \alpha + \sum\nolimits_{k\in K, k\neq -1}^{5} \beta_k D_{it}^{k} + X_{it}'\gamma + \mu_i + \lambda_t + \varepsilon_{it}$$

$$K = \{\leq -5, -4, -3, -2, 0, 1, 2, 3, 4, \geq +5\}$$

where Y_{it} denotes either environmental innovation (EIS) or firm value; D^{k}_{it} represents event-time indicators relative to the first observed adoption of ESG-linked pay, with $t=-1$ serving as the omitted reference period; X_{it} represents the vector of control variables; and μ_i and λ_t denote firm and year fixed effects, respectively. The event year is defined as $t=0$. The endpoint categories $t\leq -5$ and $t\geq +5$ pool observations five or more years before and after adoption, respectively. Standard errors are clustered at the firm level. The pre-treatment coefficients are jointly tested to assess the parallel-trends assumption.

3.2 | Mediation Analysis

We tested the mediating role of environmental innovation in the relation between ESG-linked executive compensation and firm value using a panel-based mediation framework. We computed the indirect effects using bootstrapped standard errors clustered at the firm level to account for within-firm dependence (Kline 2023). Three fixed-effects regressions were estimated. First, we regressed firm value on ESG-linked pay and the control variables to estimate the total effect. Second, we regressed environmental innovation on ESG-linked pay and controls to estimate the effect of ESG-linked pay on the mediator (a-path). Third, firm value was regressed on both ESG-linked pay and environmental innovation to estimate the direct and mediating effects on firm value (b-path). The indirect effect was determined through the joint significance of Paths a and b (Baron and Kenny 1986; Gunzler et al. 2013).

All regressions included firm- and year-fixed effects to control for unobserved time-invariant heterogeneity and common macroeconomic shocks. Standard errors were clustered at the firm level to account for serial correlations within firms over time.

To formally test the statistical significance of the indirect effect, defined as the product of the a- and b-path coefficients, we implemented a nonparametric clustered bootstrap procedure.

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TABLE 1 | Variables and measurement.

Variable name	Nature	Definition	Measurement	Reference
Policy executive compensation ESG performance	Independent	The compensation policy includes remuneration for the CEO, executive directors, nonboard executives, and other management bodies based on ESG or sustainability factors	Binary indicator based on the LSEG (formerly Refinitiv Eikon) field "Policy Executive Compensation ESG Performance" Equals 1 if the company reports an extrafinancial-performance-oriented executive compensation policy linking remuneration of executives/ management to ESG or sustainability performance factors, and 0 otherwise The indicator captures the presence, rather than the weight or intensity, of ESG-linked compensation.	Cohen et al. (2023)
ESG-related Training Index	Moderated	Captures the breadth of a firm's ESG-related training practices across environmental management, employee skills, health and safety, and supplier ESG training	An additive index constructed from four binary LSEG indicators: Environmental Management Training, Policy Skills Training, Health and Safety Training, and Supplier ESG Training Each component equals 1 when the corresponding training practice is reported and 0 otherwise. The four indicators are summed to produce an index ranging from 0 to 4, with higher values indicating broader coverage of ESG-related training practices.	Sult et al. (2024), Xie et al. (2024)

(Continues)

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TABLE 1 | (Continued)

Variable name	Nature	Definition	Measurement	Reference
Environmental Innovation	Mediator	Environmental innovation category score	LSEG Environmental Innovation Score, a 0–100 Environmental category score reflecting a firm's capacity to reduce environmental costs and burdens for its customers and create new market opportunities through environmental technologies and processes or eco-designed products. The measure captures a broad environmental innovation construct encompassing product-, process-, and technology-oriented environmental innovation rather than resource-use innovation alone. Higher scores indicate stronger environmental innovation performance.	Porter and Linde (1995)
Firm value	Dependent	Proxied by Tobin's Q, calculated as the ratio of the market value of equity plus total debt to total assets	Tobin's Q	Lang and Stulz (1994)
board gender diversity	Moderator	Percentage of women members on the board	0% to 100% where 0 shows lowest and 100%, highest	Vafaei et al. (2021)
Board independence	Moderator	Percentage of independent directors on the board	0% to 100% where 0 shows lowest and 100%, highest	Dahya et al. (2008)
Firm size	Control		Log of total assets of the firms	Demsetz and Lehn (1985)
Firm Leverage	Control		Percentage of debt to equity	Rajan and Zingales (1995)
Board meetings	Control		Number of board meetings	Vafeas (1999)

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Specifically, a block bootstrap was applied at the firm level; we resampled with replacement firms while retaining their full time series structure (Alfons et al. 2022; He et al. 2025). This approach preserves within-firm dependence and is appropriate for panel data settings (Wang et al. 2025).

For each bootstrap replication, we re-estimated both mediation equations using a within-transformation function to account for firm fixed effects. The indirect effect was computed for each replication as the product of the estimated a- and b-path coefficients. In this process, we conducted 1000 bootstrap replications, which obtained normal-based, percentile, and bias-corrected confidence intervals (De Vos et al. 2015). This procedure does not rely on the assumption of normality of the indirect effect and therefore provides a more reliable inference than conventional Sobel-type tests.

We applied the mediation framework through the following baseline model:

$$FV_{it} = \alpha + \beta_1 ESGP_{it} + \beta_2 EVI_{it} + \beta_j ControlVariables_{jit} + \varepsilon_{it}$$

where i indexes firms and t indexes years; FV is firm value; $ESGP$ denotes ESG-linked executive compensation; EVI is the environmental innovation score; the control variables are firm size, firm leverage, number of board meetings, and board size; and ε_{it} is the residual of the model.

We conducted the mediation analysis in three paths:

1. Path a (ESG–EVI): estimating the effect of ESGP on EVI;
2. Path b (EVI–FV): estimating the effect of EVI on FV;
3. Path c (ESGP–EVI–FV): estimating the direct effect of ESGP on FV while including EVI in the model.

3.3 | Moderation Analysis

We tested whether ESG-related training (Trindex), board gender diversity, and board independence moderate the relation between ESGP and EVI. Moderation occurs when the magnitude and direction of the relation between two variables change with the addition of a third variable (Hayes 2018). We employed two moderation models to determine changes in the direct paths of ESGP–EVI and ESGP–FV.

3.3.1 | Moderation of ESG-related Training on ESG to EVI

$$EVI_{it} = \alpha + \beta_1 ESGP_{it} + \beta_2 ERT_{kit} + \beta_k \left(ERT_{kit} X\ ESGP_{it}\right) + \beta_j ControlVariables_{jit} + \varepsilon_{it}$$

where i indexes firms and t indexes years; EVI is environmental innovation; $ESGP$ denotes ESG-linked executive compensation; ERT is ESG-related training (policy and skills, health and safety, and supplier ESG training); the control variables are firm size, firm leverage, number of board meetings, and board size; and ε_{it} *is the residual of the model.*

3.3.2 | *Moderation of Board Structure on ESG to FVI*

$$FV_{it} = \alpha + \beta_1 ESGP_{it} + \beta_2 BGD_{it} + \beta_3 \left(BGD_{it} X\ ESGP_{it}\right) + \beta_j ControlVariables_{jit} + \varepsilon_{it}$$

$$FV_{it} = \alpha + \beta_1 ESGP_{it} + \beta_2 BID_{it} + \beta_3 \left(BID_{it} X\ ESGP_{it}\right) + \beta_j ControlVariables_{jit} + \varepsilon_{it}$$

where i indexes firms and t indexes years; FV is firm value; $ESGP$ denotes ESG-linked executive compensation; BGD is the board gender diversity, BID is board independence; the control variables are firm size, firm leverage, and number of board meetings; and $\varepsilon_{it}$is the residual of the model.

All moderation models employed fixed- and random-effects estimations with system-GMM for robustness and testing potential endogeneity. This process ensured that interaction effects were examined while controlling for firm-specific unobservables and endogeneity in both the independent and moderator variables (Giesselmann and Schmidt-Catran 2022). The variables' descriptions are presented in Table 1.

4 | Results and Discussion

Table 2 presents the composition of the sample by country. Most observations are drawn from the United Kingdom,

TABLE 2 | Sample distribution.

Country	Freq.	Percent	Cum.
Austria	29	1.23	1.23
Belgium	49	2.08	3.30
Denmark	88	3.73	7.03
Finland	109	4.62	11.65
France	379	16.05	27.70
Germany	237	10.04	37.74
Ireland	40	1.69	39.43
Italy	70	2.96	42.40
Luxembourg	16	0.68	43.07
The Netherlands	122	5.17	48.24
Norway	48	2.03	50.28
Poland	7	0.30	50.57
Portugal	18	0.76	51.33
Spain	105	4.45	55.78
Sweden	177	7.50	63.28
Switzerland	243	10.29	73.57
United Kingdom	624	26.43	100.00
Total	2361	100.00	

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TABLE 3 | Descriptive statistics.

Variable	Obs.	Mean	Std. dev.	Min	Max
ESG pay	2361	0.699	0.459	0	1
Environmental innovation	2361	54.388	32.115	0	99.097
Board independence	2356	64.995	22.285	0	100
Board gender diversity	2361	34.78	10.654	0	75
Board meeting	2361	9.745	4.236	4	28
Leverage	2361	0.248	0.148	0.002	0.626
Training Index	2353	3.226	0.809	0	4
Environmental management training	2359	0.79	0.40	0	1
Policy and skills training	2361	0.98	0.11	0	1
Health and safety training	2361	0.95	0.21	0	1
Supplier ESG training	2354	0.49	0.50	0	1
Size	2361	23.964	1.657	18.248	28.742
Firm value	2361	1.489	2.971	0.018	63.244

followed by France, Switzerland, and Germany, indicating that the sample is largely concentrated in the major European economies. The dominance of the United Kingdom in the sample is consistent with existing evidence (Hazarika et al. 2023) that ranks it among the leading countries in the adoption of ESG-linked pay.

Table 3 presents the descriptive statistics for the study's variables. ESG-linked pay is measured as a dummy variable, and its mean value of 0.699 indicates that approximately 69.9% of the observations involve firms that adopted ESG-linked compensation schemes. The corresponding standard deviation of 0.459 is consistent with a proportion-based variable suggesting reasonable variation across the firms. The environmental innovation scores indicate substantial heterogeneity in firms' environmental innovation performances. This variation reflects differences in firms' capabilities, resources, and strategic orientations toward sustainability-related activities.

The values for board independence indicate that, on average, a significant proportion of board members are independent. This finding is relatively high and consistent with prior evidence (Gurol and Lagasio 2023), suggesting that the firms in the sample maintain strong governance structures. Board gender diversity reflects a moderate level of female representation on boards, although there is noticeable variation across firms. The average number of board meetings indicates differences in board activity and monitoring intensity. In terms of firm characteristics, the leverage value suggests moderate reliance on debt financing. The firm size value, measured in logarithmic terms, indicates the presence of relatively large firms in the sample. The training index implies that firms engage in multiple training-related activities, although the variation suggests differing levels of emphasis on capacity building. Finally, the result for firm value indicates considerable dispersion across firms. This suggests that firm value varies substantially, further justifying the need for rigorous empirical analysis.

TABLE 4 | Distribution of the ESG Training Index.

Training Index	Frequency	Percentage (%)
0	9	0.38
1	58	2.46
2	336	14.23
3	940	39.81
4	1010	42.78
Missing	8	0.34
Total	2361	100

Table 4 presents the distribution of the ESG Training Index. The index is concentrated at relatively high levels. This distribution indicates that ESG-related training practices are relatively widespread among the sampled firms, although variation remains sufficient for the moderation analysis.

Table 5 reports the correlation matrix and presents the variance inflation factor (VIF) values on the diagonal. ESG-linked pay shows a positive and significant correlation with environmental innovation and Training Index. It is also positively associated with governance-related variables, including board gender diversity and board independence; its correlation with board meetings remains positive but insignificant. Environmental innovation is positively correlated with Training Index, board gender diversity, board meetings, and firm size, indicating that both firm-level capabilities and governance structures are linked with higher innovation outcomes. In contrast, its relation with leverage and board independence remains weak and statistically insignificant.

Among the governance variables, board gender diversity exhibits a positive and significant association with ESG-linked

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pay, environmental innovation, and board meetings; board independence positively correlates with ESG-linked pay and gender diversity but does not have a significant relation with environmental innovation. Board meetings are also positively associated with several variables, including environmental innovation, size, and leverage. Overall, the correlation coefficients are moderate, suggesting no strong linear dependence between the variables. This is further supported by the VIF values reported on the diagonal, all of which are close to 1 and below the conventional threshold of 10 (the highest value being 1.24). These results confirm that multicollinearity is not a concern and that the variables are suitable for subsequent regression analysis.

TABLE 5 | Pairwise correlations.

Variables	VIF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) ESG pay	1.10	1								
(2) Environmental innovation	1.18	0.092*	1							
(3) Board gender diversity	1.10	0.192*	0.090*	1						
(4) Leverage	1.09	0.092*	−0.045	0.122*	1					
(5) Training Index	1.10	0.158*	0.159*	0.130	0.186*	1				
(6) Size	1.24	0.186*	0.350*	0.118*	−0.103*	0.053	1			
(7) Firm value	—	−0.084*	−0.110*	0.044	−0.018	−0.025	−0.339*	1		
(8) Board independence	1.03	0.091*	0.039	0.077*	0.005	0.045	0.029	−0.007	1	
(9) Board meetings	1.11	0.043	0.146*	0.161*	0.097*	0.008	0.218*	−0.110*	0.120*	1

Abbreviation: VIF, variance inflation factor.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

TABLE 6 | Regression results for ESG pay, environmental innovation, and firm value.

	(1)	(2)	(3)	(4)
	Firm value (FE)	Environmental innovation (RE)	Firm value (FE)	Firm value (FE)
ESG pay	0.051***	7.603***		0.056***
	(0.015)	(0.925)		(0.015)
Size	−0.268***	6.443***	−0.353***	−0.361***
	(0.024)	(1.52)	(0.016)	(0.016)
Leverage	0.305***	2.947	0.526***	0.486***
	(0.081)	(5.031)	(0.076)	(0.076)
Board meeting	−0.005***	0.006	−0.005***	−0.006***
	(0.002)	(0.107)	(0.002)	(0.002)
Environmental innovation			0.001***	0.000716**
			(0.0002)	(0.0003)
Constant	6.284***	−106.123***	8.232***	8.424***
	(0.576)	(36.007)	(0.373)	(0.375)
Observations	2361	2361	2361	2361
Within R^2	0.06	0.12	0.062	0.066
Hausman-test p	0.00	0.10	0.00	0.000

Note: For fixed-effects (FE) specifications, R^2 refers to the within R^2. For random-effects (RE) specifications, the reported R^2 measure is identified separately. Standard errors are in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

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The results of our panel regression analysis for testing the effect of ESG-linked pay in firm value are presented in Table 6. Model 1 shows that ESG-linked pay has a positive and statistically significant relation with firm value ($\beta = 0.051$, $p < 0.01$). In economic terms, because firm value is measured in logarithmic form, this coefficient corresponds to an approximately 5.2% higher firm value for firms with ESG-linked pay, holding the other covariates constant. This finding suggests that ESG-linked compensation is positively associated with firm value, supporting the view that sustainability-oriented incentives align managerial decisions with long-term objectives. From an agency theory perspective, ESG-linked pay reduces managerial short-termism by incentivizing executives to consider broader long-term outcomes, thereby improving firm valuation (Walker 2022).

However, ESG-linked pay may not be sufficient to fully explain firm value. Bebchuk and Tallarita (2022) argued that ESG-linked contracts may be ineffective or detrimental if poorly designed or lacking measurable targets. Similarly, Hazarika et al. (2023) showed that investor support for ESG-linked pay remains limited, with less than 70% approval among S&P 500 firms. These findings highlight concerns that ESG-linked compensation may often be symbolic rather than substantive, reflecting agency problems related to weak incentive designs and measurement difficulties. Hazarika et al. (2023) cautioned that omitted variables may influence the relation between ESG-linked pay and firm value. To address this issue, we introduced environmental innovation as a potential mediating channel. From a stakeholder-theory perspective, ESG-linked incentives may encourage firms to adopt environmentally responsible practices, thereby enhancing stakeholder trust and long-term firm value (Salvadó 2012; Andries and Stephan 2019).

Consistent with this argument, Model 2 shows that ESG-linked pay has a strong positive association with environmental innovation ($\beta = 7.603$, $p < 0.01$). In substantive terms, the 7.603-point difference corresponds to approximately 14.0% of the sample mean of environmental innovation (54.388) and approximately 0.24 standard deviations (SD = 32.115), indicating a meaningful magnitude of the estimated association. This finding suggests that ESG-linked compensation is associated with greater investment in environmentally innovative activities, consistent with previous studies (Cabaleiro-Cerviño and

TABLE 7 | Mediation (fixed effects): ESG pay → environmental innovation → firm value.

	(1)	(2)	(3)
	Firm value	**Environmental innovation**	**Firm value**
ESG pay	0.0600***	7.9782***	0.0547**
	(0.013)	(0.835)	(0.0140)
Size	−0.2286***	6.1560**	−0.2327***
	(0.0212)	(1.2916)	(0.0213)
Leverage	0.1837**	2.9539	0.1818**
	(0.074)	(4.53)	(0.0743)
Board meeting	−0.0057***	0.0546	−0.0057***
	(0.00165)	(0.1006)	(0.00165)
Environmental innovation			0.0007**
			(0.00033)
Constant	5.3614***	−100.4209***	5.4280***
	(0.500)	(30.563)	(0.5016)
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	2361	2361	2361

Effect	**Estimate**	**Boot SE**	**95% CI (percentile)**	**95% CI (BC)**
a (ESG–EI)	6.901	3.814	[−0.437, 14.497]	[0.923, 16.430]
b (EI–FV)	0.00072	0.00099	[−0.00123,0.00268]	[−0.00146, 0.00245]
Indirect (a × b)	0.0050	0.0077	[−0.0075, 0.0240]	[−0.0045, 0.0301]

Note: Standard errors are in parentheses. Bootstrap mediation (clustered by firm).
Abbreviations: EI–FV, environmental innovation–firm value; ESG–EI, environmental, social, governance–environmental innovation.
Bootstrap mediation (clustered by firm).
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

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Mendi 2024; Gillan et al. 2021). Among the control variables, firm size is positively associated with environmental innovation, indicating that larger firms have a greater capacity to invest in sustainability-related initiatives.

In Model 3, environmental innovation shows a positive and statistically significant relation with firm value ($\beta = 0.001$, $p < 0.01$), supporting the argument that environmentally responsible practices enhance firm value (Hizarci-Payne et al. 2021; Iqbal et al. 2022; Khalil et al. 2024; Yao et al. 2019). In economic terms, a one-standard-deviation increase in environmental innovation (32.115 points) is associated with approximately a 3.3% higher firm value, indicating that the relation is also substantively meaningful.

When both ESG-linked pay and environmental innovation are included in Model 4, both variables remain significant. Although this pattern is consistent with the individual relations underlying the proposed mediation mechanism, the significance of these individual coefficients does not establish a statistically reliable indirect effect. Therefore, we evaluated the proposed indirect effect using clustered bootstrap inference.

For a more rigorous test of the mediation mechanism, we used a bootstrap mediation approach (Table 7). The bootstrap results provide more cautious evidence compared with the stepwise regressions. Although the a-path (ESG-linked pay → environmental innovation) is positive, its statistical inference is not uniform across bootstrap intervals, as the percentile confidence interval includes 0 whereas the bias-corrected interval excludes 0. The estimated indirect effect (a × b) is not statistically significant because its bootstrap confidence intervals include 0. Accordingly, the bootstrap evidence does not support a statistically reliable indirect effect of ESG-linked pay on firm value

TABLE 8 | Results of the dynamic panel system-generalized method of moments (GMM).

	(1)	(2)	(3)	(4)
	Firm value	**Environmental innovation**	**Firm value**	**Firm value**
L. firm value	0.988***		1.229***	1.244***
	(0.17)		(0.143)	(0.127)
ESG pay	0.003	0.445		0.00038
	(0.041)	(1.64)		(0.038)
L. environmental innovation		0.882***		
		(0.047)		
Environmental innovation			0.00038	0.00034
			(0.001)	(0.001)
Size	−0.035	−1.882	0.158	0.186
	(0.178)	(2.12)	(0.167)	(0.121)
Leverage	−0.494	−10.595	−0.949**	−0.903**
	(0.384)	(12.847)	(0.374)	(0.371)
Board meeting	−0.004	−0.28	−0.001	0.001
	(0.013)	(0.548)	(0.011)	(0.011)
Year dummy	Yes	Yes	Yes	Yes
Constant	0.902	56.844	−3.624	−4.325
	(4.151)	(46.851)	(3.892)	(2.797)
Observations	1960	1960	1960	1960
AR(1)	0.00	0.00	0.00	0.00
AR(2)	0.975	0.135	0.851	0.840
Hansen	0.173	0.506	0.407	0.619
Difference-in-Hansen	0.17	0.87	0.12	0.23
Number of instruments	18	25	25	29
Number of firms	357	357	357	357

Note: The table reports two-step system-GMM estimates. The lagged dependent variable, ESG-linked pay, environmental innovation where applicable, and financial controls are instrumented using internal GMM-style instruments; year indicators are treated as exogenous IV-style instruments. Instrument matrices are collapsed to limit instrument proliferation. Model 1 uses Lag 2, whereas Models 2–4 use Lags 2–3. The table reports Arellano–Bond AR(1) and AR(2) tests, Hansen tests, difference-in-Hansen tests for the additional level-equation moment conditions, number of instruments, and number of firms.

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through environmental innovation. Thus, although ESG-linked pay is positively associated with environmental innovation, the proposed mediation effect is not supported.

The inconsistency between the stepwise regression and bootstrap mediation findings can be attributed to methodological differences. As highlighted by Alfons et al. (2022), regression-based mediation approaches rely on normal theory assumptions and may overstate the significance of indirect effects, particularly when the underlying distribution deviates from normality. In contrast, bootstrap methods provide more robust inferences by directly estimating the sampling distribution of the indirect effect, leading to more reliable conclusions. Accordingly, we rely on the bootstrap evidence when drawing conclusions regarding mediation and do not interpret the significance of the individual regression paths as evidence that mediation is established.

To address potential endogeneity, reverse causality, and dynamic persistence, we used a system-GMM estimator, following Arellano and Bond (1991) and Blundell and Bond (2000). This approach combines moment conditions from both levels and first differences, improving efficiency and mitigating the weak-instrument problems commonly associated with difference GMM (Ullah et al. 2020). The GMM results differ substantially from the FE/RE estimates (Table 8). Specifically, ESG-linked pay is no longer statistically significant in explaining firm value or environmental innovation, and environmental innovation itself does not significantly affect firm value. By contrast, the lagged dependent variable remains strongly significant, indicating substantial persistence in firm value over time. Notably, the coefficient on lagged firm value is 0.988 in Model 1 and exceeds unity in Models 3 and 4 (1.229 and 1.244, respectively). The latter estimates indicate very high and potentially unstable persistence and, therefore, warrant caution in interpreting dynamic firm-value specifications.

Thus, the positive association observed in the baseline regression models may be driven by reverse causality, omitted variables, or dynamic effects rather than a true causal relation (Montalvo 1997). The inconsistency between the FE/RE and GMM results reflects differences in estimator efficiency and robustness against data limitations. Conventional estimators may yield inefficient or biased results in settings with incomplete or unbalanced data, whereas GMM estimators improve efficiency by using all available moment conditions (Muris 2020). Consistent with this argument, the loss of significance in the GMM results indicates that the baseline associations are not robust in terms of explicitly modelling dynamic persistence and potential endogeneity, rather than establishing that the baseline estimates are necessarily biased or noncausal. The diagnostic tests support the validity of the GMM specification, including the absence of second-order serial correlation and acceptable Hansen's test statistics, indicating that the instruments are appropriate. Notably, these diagnostic tests assess serial correlation and instrument validity rather than dynamic stability. Accordingly, despite satisfactory specification diagnostics, the lagged firm-value coefficients exceeding unity in Models 3 and 4 require these GMM estimates to be interpreted cautiously.

The results of our event-study DiD approach are reported in Table 9 and Figures 2 and 3. For environmental innovation, the

TABLE 9 | Difference-in-difference (DiD) results for ESG pay.

	(1)	(2)
	Environmental innovation	**Firm value**
($t \leq -5$)	1.446	−0.062
	(4.730)	(0.062)
($t-4$)	1.851	−0.036
	(3.498)	(0.049)
($t-3$)	2.168	−0.048
	(2.315)	(0.036)
($t-2$)	1.514	−0.046**
	(1.386)	(0.022)
($t-1$) (Reference period)	–	–
($t=0$) (adoption year)	2.088	0.013
	(1.815)	(0.022)
($t+1$)	1.837	0.031
	(2.479)	(0.030)
($t+2$)	1.776	0.052
	(3.166)	(0.040)
($t+3$)	0.277	0.042
	(3.904)	(0.048)
($t+4$)	−2.082	0.043
	(4.617)	(0.060)
($t \geq +5$)	−5.731	0.041
	(5.819)	(0.072)
Size	0.262	−0.322***
	(3.908)	(0.070)
Leverage	−2.593	0.247
	(9.727)	(0.169)
Board meeting	−0.115	−0.006***
	(0.111)	(0.002)
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Pretrend test	0.839	0.308
Observations	2361	2361
Number of firms	357	357

Note: This table reports conventional two-way fixed-effects event-study estimates around the first observed adoption of ESG-linked pay. The dependent variables are environmental innovation in Model (1) and firm value in Model (2). The omitted reference period is $t=-1$, 1 year before first adoption, and $t=0$ denotes the adoption year. The endpoints are binned such that $t \leq -5$ includes observations five or more years before adoption and $t \geq +5$ includes observations five or more years after adoption. All models include firm and year fixed effects. The reported standard errors, in parentheses, are clustered at the firm level. The pretrend p-value is obtained from a joint test that the reported pre-treatment event-time coefficients are equal to 0.

***$p < 0.01$.

**$p < 0.05$.

*$p < 0.10$.

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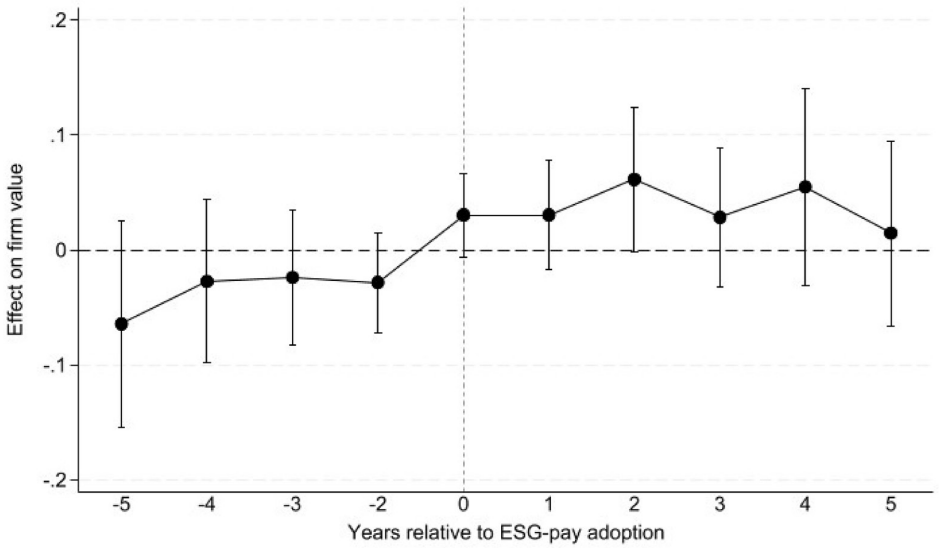


FIGURE 2 | ESG-pay adoption and effect on firm value.

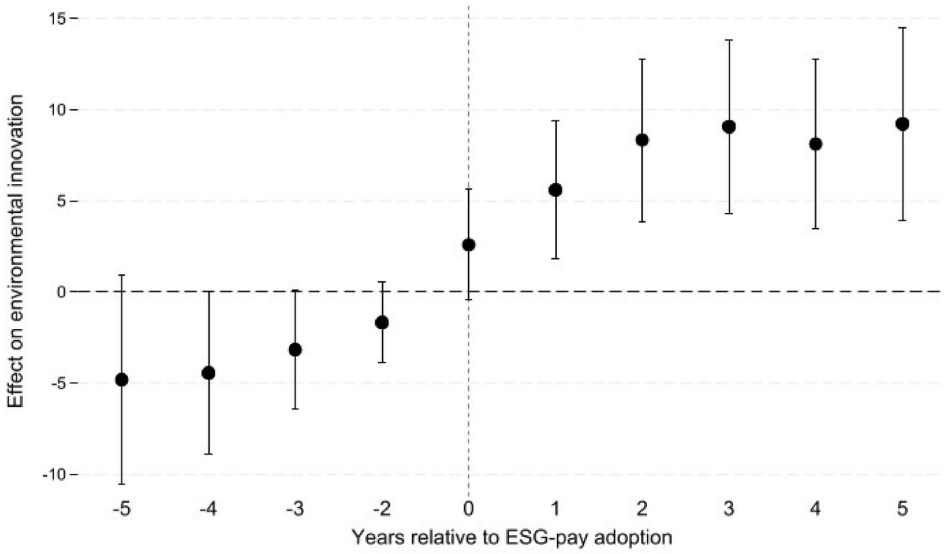


FIGURE 3 | ESG-pay adoption and effect on environmental innovation.

postadoption coefficients are generally positive in the initial periods following adoption, but they are not statistically significant after accounting for firm and year fixed effects and clustering standard errors at the firm level. The estimated coefficients do not provide statistically robust evidence of a postadoption increase in environmental innovation. The literature shows that policy and sustainability-related interventions may influence innovation and environmental outcomes, although such effects can vary across institutional and organizational settings (Andrea and Del Bo 2018; Jiang et al. 2021; Qiong et al. 2023; Wang and Deng 2022).

Similarly, the postadoption coefficients for firm value are not statistically significant, indicating no consistent evidence of an immediate or sustained change in firm value following ESG-linked pay adoption. This pattern is consistent with the possibility that improvements in sustainability-related practices do not necessarily translate immediately into market valuation because their economic consequences may depend on implementation quality, organizational conditions, and the broader institutional environment (Anthopoulos 2017; Mora et al. 2019; Yigitcanlar and Kamruzzaman 2018).

The pre-treatment estimates provide additional information regarding the parallel-trends assumption. For environmental innovation, the pre-treatment coefficients are individually and are jointly insignificant ($p = 0.839$). For firm value, although the coefficient at $t = -2$ is individually significant, the pre-treatment coefficients are jointly insignificant ($p = 0.308$). Thus, the joint pretrend tests do not provide evidence of systematic differential pre-treatment trends. Nevertheless, the event-study estimates are interpreted cautiously and as complementary evidence rather than definitive causal identification. Overall, the results do not provide statistically robust

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evidence of postadoption changes in either environmental innovation or firm value once firm and year fixed effects are incorporated.

Overall, the findings provide a more nuanced understanding of the relation between ESG-linked pay, environmental innovation, and firm value. ESG-linked compensation is positively associated with firm value and environmental innovation in the baseline fixed-effects models, but these relations are not consistently supported by the more rigorous empirical analyses. The bootstrap mediation analysis does not provide evidence of a statistically reliable indirect effect through environmental innovation. The system-GMM results do not provide robust evidence that ESG-linked pay affects either firm value or environmental innovation after accounting for dynamic persistence and potential endogeneity. Similarly, the event-study analysis does not identify statistically robust postadoption changes in environmental innovation or firm value after controlling for firm and year fixed effects.

From a theoretical perspective, these findings suggest that the positive associations observed in the baseline models should be interpreted cautiously. ESG-linked pay may be associated with broader firm characteristics, such as governance quality or strategic orientation, rather than independently generating changes in environmental innovation or firm value. Overall, the evidence suggests that although ESG-linked compensation is associated with environmental and financial outcomes in the baseline specifications, its independent contribution becomes less evident under alternative approaches designed to address mediation, dynamic endogeneity, and treatment timing. Consequently, the findings support an associative rather than a strong causal interpretation of the relation between ESG-linked pay and firm outcomes.

TABLE 10 | Moderating effect of board independence and board gender diversity on ESG and environmental innovation, and firm value.

	(1)	(2)	(3)
	Firm value	**Firm value**	**Environmental innovation**
ESG Pay	0.103***	0.052***	12.449***
	(0.04)	(0.015)	(3.095)
Board independence	0.001		
	(0.001)		
Board gender diversity		−0.0004	
		(0.001)	
Training Index			3.596***
			(0.926)
ESG pay × board independence	−0.001		
	(0.001)		
ESG pay × board gender diversity		0.001	
		(0.001)	
ESG pay × Training Index			−1.749*
			(0.961)
Size	−0.271***	−0.269***	5.831***
	(0.024)	(0.025)	(1.539)
Leverage	0.305***	0.306***	3.103
	(0.081)	(0.081)	(5.037)
Board meeting	−0.005***	−0.005***	−0.028
	(0.002)	(0.002)	(0.107)
Constant	6.311***	6.299***	−102.061***
	(0.579)	(0.588)	(36.229)
Observations	2356	2361	2353
Within R^2	0.066	0.065	0.064

Note: Standard errors are in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

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The inconsistency in the firm-value results across empirical specifications has important theoretical and practical implications. The positive association observed in the baseline fixed-effects models, together with its lack of robustness under dynamic GMM and event-study specifications, suggests that ESG-linked compensation should not be viewed as a direct or automatic mechanism for firm-value creation. Theoretically, this qualifies a simple agency-theoretic prediction that aligning executive incentives with ESG objectives necessarily translates to higher market valuation; any valuation consequences may depend on implementation quality, organizational capabilities, time horizons, and other firm-specific conditions. Practically, the findings suggest that firms and policymakers should focus on the design, measurability, and implementation of ESG-linked incentives rather than the expectation of increasing firm value.

Human capital development, particularly through environmental training, is widely regarded as a key enabler of sustainability-oriented practices, enhancing firms' abilities to implement complex environmental strategies (Daily et al. 2012; Jabbour 2015). Building on this perspective, our study examines whether training strengthens the relation between ESG-linked pay and environmental innovation. The results reveal a nuanced and dynamic pattern. In the fixed-effects estimates (Table 10), training has a positive and significant direct effect on environmental innovation, suggesting that firms investing in employee capabilities are better positioned to generate sustainability-oriented innovation. However, the interaction between ESG-linked pay and training is negative and weakly significant, indicating a short-term substitution effect (Figure 4). This finding suggests that firms with more developed training systems may rely less on incentive-based mechanisms because their internal capabilities already support environmental innovation.

By contrast, the GMM results (Table 11), which account for endogeneity and persistence in innovation, show that training has a negative direct effect but positive and strongly significant interaction with ESG-linked pay. More specifically, the conditional marginal effect of ESG-linked pay on environmental innovation is given by $-10.843 + 4.741 \times$ Training Index. Setting this expression equal to 0 indicates that the point estimate changes from negative to positive at a Training Index value of approximately 2.29. Below this threshold, the estimated marginal effect is negative, whereas above 2.29, it is positive and increases with the level of ESG-related training. Importantly, the threshold of 2.29 represents the point at which the estimated marginal effect crosses 0 and should not itself be interpreted as the point at which the effect necessarily becomes statistically significant. Figure 4 presents the conditional marginal effects together with their 95% confidence intervals, allowing the statistical precision of the effect across the observed range of the Training Index to be assessed. This reversal highlights the importance of dynamic considerations. Although training alone may not immediately yield innovation outcomes, it enhances firms' absorptive capacity and enables them to respond more effectively to ESG-linked incentives. Altogether, these findings suggest that training operates as a complementary capability in the long term, strengthening the effectiveness of ESG-linked compensation in driving environmental innovation. This interpretation is consistent with theoretical arguments that the impact of extrinsic incentives depends on underlying organizational capabilities (Bénabou and Tirole 2010), and on empirical evidence linking ESG-contingent compensation to innovation outcomes (Tsang et al. 2021). Accordingly, ESG-linked pay appears to be most effective in firms that possess the human capital necessary to translate incentives into substantive environmental innovations.

Regarding governance mechanisms, the results indicate that board independence does not significantly moderate the relation between ESG-linked pay and firm value in either the FE or the GMM specifications (Figure 5). This finding suggests that

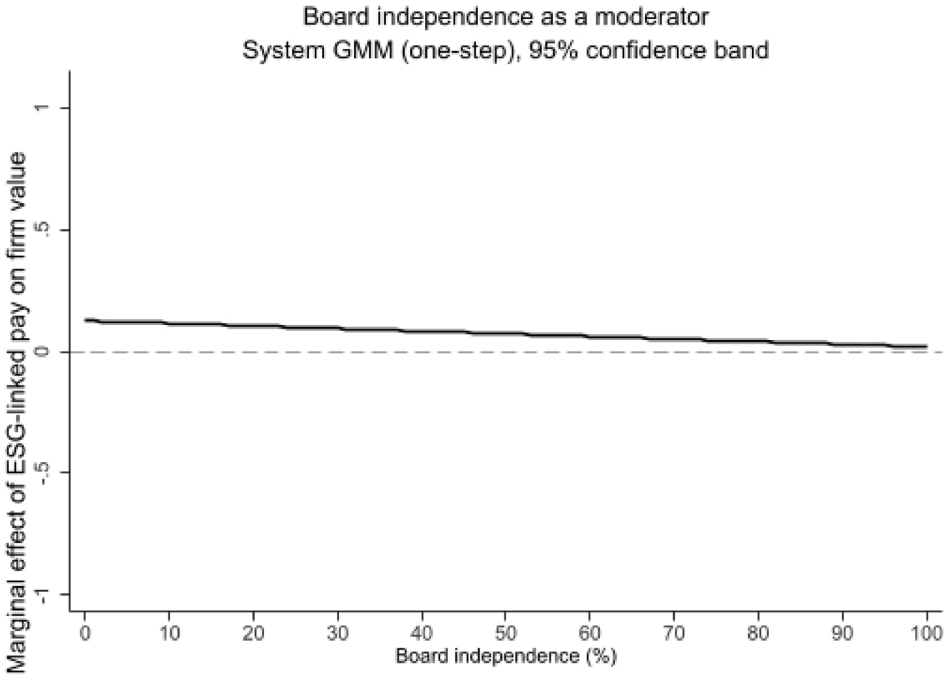


FIGURE 4 | Moderation Effect of ESG-Related Training on the ESG-linked pay–environmental innovation relationship.

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TABLE 11 | Dynamic panel system-generalized method of moments (GMM) results on the moderation of ESG training, board diversity, and board independence for ESG pay, environmental innovations, and firm value.

	(1)	(2)	(3)
	Firm value	**Firm value**	**Environmental innovation**
Lag firm value	0.43***	0.54***	
	(0.12)	(0.10)	
Lag environmental innovation			0.858***
			(0.041)
ESG pay	0.12	0.05	−10.843*
	(0.49)	(0.10)	(5.672)
Board independence	0.004		
	(0.009)		
Board gender		−0.02	
		(0.013)	
Training Index			−4.983**
			(1.994)
ESG pay×board independence	−0.001		
	(0.007)		
ESG pay×board gender		0.01	
		(0.014)	
ESG pay×Training Index			4.741***
			(1.725)
Size	−0.46**	−0.16*	−1.594
	(0.18)	(0.08)	(1.452)
Leverage	0.96**	1.24***	9.376
	(0.39)	(0.43)	(7.801)
Board meeting	−0.008*	−0.002	0.061
	(0.003)	(0.003)	(0.114)
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Constant	10.84**	3.65***	57.919
	(4.17)	(2.08)	(37.6)
Observations	1956	1960	1995
Number of firm	352	352	357
Number of instrument	20	17	32
AR(1)	0.000	0.000	0.000
AR(2)	0.109	0.2778	0.297
Hansen test	0.06	0.236	0.197
Lag depth	1–2	1	1–2
Difference-in-Hansen	0.15	N.A	0.327

Note: The table reports dynamic panel GMM estimates. The lagged dependent variable, ESG-linked pay, respective moderator, and ESG-linked pay×moderator interaction are instrumented using internal GMM-style instruments. Financial controls are entered using internal GMM-style instruments. Year indicators are treated as exogenous IV-style instruments. Restricted lag windows are employed and instrument matrices are collapsed to limit instrument proliferation. The exact lag depth is reported for each model. Instrument validity is assessed using the Hansen test and, where generated by the corresponding specification, difference-in-Hansen tests for instrument subsets. For the board gender diversity model, which uses Lags 1 only and 17 collapsed instruments, a separate difference-in-Hansen statistic is not generated and is therefore reported as N.A. The table also reports Arellano–Bond AR(1) and AR(2) tests, number of instruments, and number of firms. For Model 3, the conditional effect of ESG-linked pay on environmental innovation is −10.843 + 4.741×Training Index; the point estimate crosses 0 at a Training Index value of approximately 2.29.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

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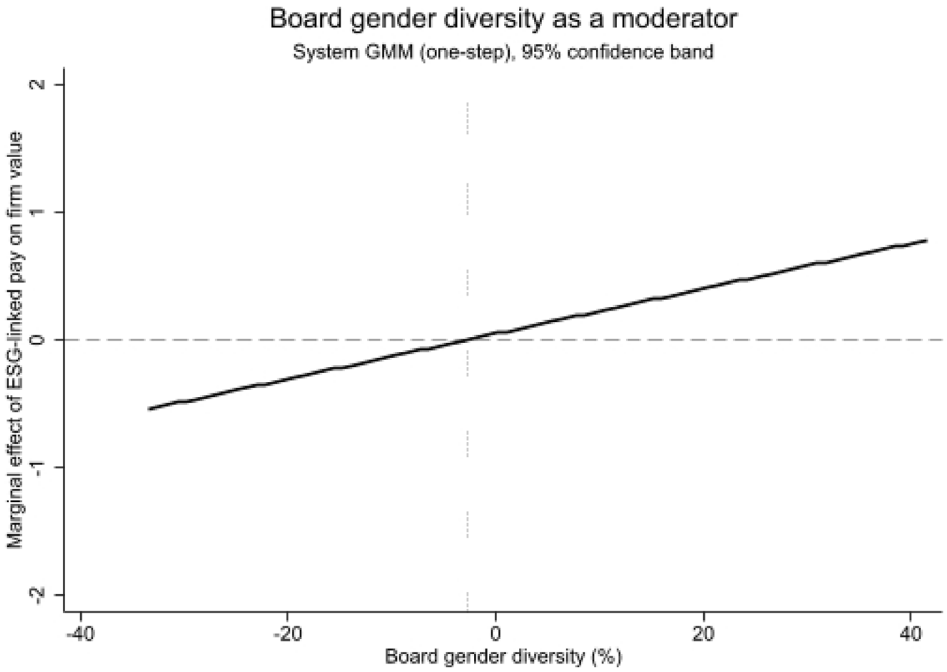


FIGURE 5 | Moderation effect of board independence on the ESG-linked pay–firm value relationship.

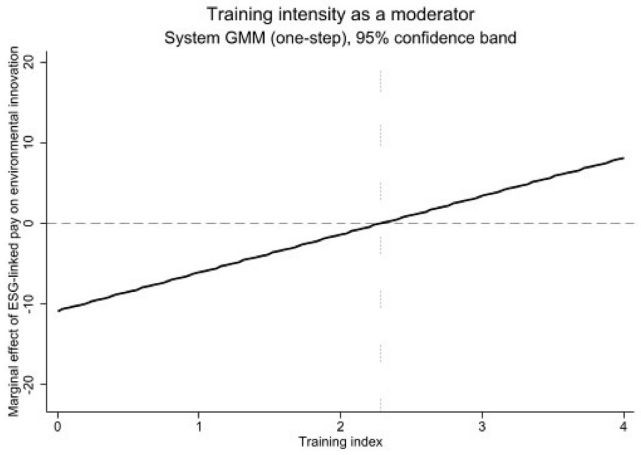


FIGURE 6 | Moderation effect of board gender diversity on the ESG-linked pay–firm value relationship.

independent boards do not materially influence the extent to which ESG-linked compensation translates into firm value. One explanation is that ESG-linked pay functions as a direct alignment mechanism, reducing agency conflicts and limiting the incremental role of independent directors' monitoring. In such settings, formal governance structures may become less relevant as incentive contracts already internalize ESG objectives within managerial decision-making. This finding aligns with the growing body of literature that suggests that the effectiveness of ESG-based compensation is not always reinforced by additional governance mechanisms and may, in cases without clear performance benefits, introduce complexity (Bebchuk and Tallarita 2022).

Similarly, the moderating role of board gender diversity is unsupported by the empirical evidence (Figure 6). The interaction between ESG-linked pay and board gender diversity is statistically insignificant for both estimation approaches, indicating that gender-diverse boards do not significantly alter the effectiveness of ESG-linked compensation in enhancing firm value. As argued in previous studies, gender-diverse boards are more attentive to ESG issues and stakeholder interests. However, this study's findings suggest that such governance attributes do not necessarily strengthen the incentive–performance relation in the context of ESG-linked pay. One explanation is that ESG-linked compensation embeds sustainability considerations in managerial incentives, thereby reducing the marginal influence of board composition. More broadly, these results reinforce the view that governance mechanisms exert context-dependent effects and do not uniformly enhance firm outcomes (Afrifa et al. 2020; Albitar et al. 2023; Jamil et al. 2021). Thus, internal organizational capabilities, such as human capital, appear to play a more decisive role than formal board structures in shaping the effectiveness of ESG-linked incentives.

5 | Robustness

To examine whether the baseline findings are sensitive to the measurement of firm value, we replaced Tobin's Q with the price-to-book value (PBV). PBV is a widely used market-based valuation metric that reflects how equity markets price firms relative to the book value of their equity; it is commonly used in empirical research as a proxy for firm value (Fama and French 1992; La Porta et al. 2002; Ohlson 1995).

The results obtained using PBV provide more qualified support for the baseline findings. ESG-linked compensation retains a positive association with firm value, but the evidence is not consistent across the PBV specifications. In the GMM estimates, ESG-linked pay is only weakly significant in one specification

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TABLE 12 | Robustness test results: generalized method of moments (GMM) results for ESG pay, environmental innovation, and firm value.

	(1)	(2)	(3)
	PBV	**PBV**	**PBV**
L.PBV	0.591***	0.654***	0.717***
	(0.154)	(0.14)	(0.105)
ESG Pay	0.424*		0.162
	(0.218)		(0.12)
Size	−0.296*	−0.238	−0.144
	(0.168)	(0.15)	(0.107)
Leverage	1.066***	0.988***	1.055***
	(0.399)	(0.357)	(0.341)
Board meeting	−0.005	−0.003	−0.0004
	(0.006)	(0.005)	(0.005)
Environmental innovation		0.006**	0.005**
		(0.003)	(0.002)
Constant	6.951*	5.486	3.069
	(4.145)	(3.731)	(2.694)
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Observations	1936	1936	1936
Number of instruments	15	15	19
Number of firms	349	349	349
AR(1)	0.000	0.000	0.000
AR(2)	0.429	0.193	0.373
Hansen	0.10	0.025	0.10

Note: Robust standard errors are in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

and becomes statistically insignificant when environmental innovation is included. This suggests that the relation between ESG-linked pay and firm value is sensitive to both the valuation measure and model specification.

Environmental innovation remains positively and significantly associated with PBV in some specifications, providing partial support for the relation between environmental innovation and firm valuation. However, this evidence is also not uniform across all models. Recent empirical studies have documented that environmental innovation and ESG-related activities are positively associated with firm valuation when market-based measures are used (Macchioni et al. 2024; Munir and Pratama 2025). In addition, the Hansen test for Model 2 yields a *p*-value of 0.025, indicating rejection of the joint validity of the instrument set at conventional significance levels and raising concerns regarding instrument validity in that specification. Therefore, Model 2 should be interpreted with particular caution.

TABLE 13 | Robustness test results: exclusion of financial-sector firms.

	(1)	(2)
	Firm value	**Environmental innovation**
ESG pay	0.034**	6.553***
	(0.016)	(1.78)
Controls	Yes	Yes
Firm fixed effects	Yes	Yes
Observations	1960	1960
Number of firms	293	293

Note: This table re-estimates the baseline fixed-effects specifications after excluding financial-sector firms. The exclusion removes 64 firms (401 firm-year observations). The specifications and control variables correspond to the baseline fixed-effects models reported in Table 5. Standard errors are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Overall, the PBV analysis provides partial rather than comprehensive robustness support for the main findings (Table 12). Some relations remain qualitatively consistent when PBV is used as an alternative measure of firm value. However, the weaker significance of ESG-linked pay and the instrument-validity concern in Model 2 prevent the PBV results from being interpreted as fully confirming the baseline estimates. Accordingly, these findings are best viewed as complementary sensitivity evidence rather than definitive validation of the baseline results.

To further confirm the results, we excluded the financial-sector firms from the sample, given that financial institutions operate under distinct regulatory and capital-structure regimes that may affect the interpretation of leverage and valuation measures relative to nonfinancial firms. To assess whether their inclusion drives the baseline findings, we re-estimated the main fixed-effects specifications after excluding financial-sector firms. The coefficient on ESG-linked pay in the firm-value model remains positive and statistically significant ($\beta = 0.034$), compared with $\beta = 0.051$ in the full sample. The environmental–innovation association also remains positive and statistically significant after financial firms are excluded. Overall, the sensitivity analysis indicates that the principal baseline relations are not solely attributable to the inclusion of financial-sector firms.

6 | Conclusion and Policy Implications

This study examines whether ESG-linked executive compensation contributes to firm value, whether this relationship operates through environmental innovation, and how it is conditioned by corporate governance structures and ESG-related training. Using a panel of STOXX Europe 600 firms over 2015–2023, the analysis offers a more nuanced picture of the link between ESG-linked pay and firm value than has typically been reported.

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The findings indicate that ESG-linked compensation is positively associated with firm value in conventional panel estimations, thus supporting H1. However, this relation does not remain robust when dynamic endogeneity and persistence are explicitly addressed through system-GMM and event-study approaches. In these specifications, ESG-linked pay does not exhibit a statistically significant effect on firm value, suggesting that the baseline association may reflect underlying firm characteristics, such as strategic orientation or governance quality, rather than a direct causal effect. Therefore, the evidence points to a distinction between observed correlations and causal influences, which remains insufficiently addressed in much of the literature (Bebchuk and Tallarita 2022; Hazarika et al. 2023).

With respect to the proposed mechanism, ESG-linked compensation has a strong and consistently positive effect on environmental innovation. This partially supports H2, indicating that the incentive structures tied to ESG objectives effectively shape firm behavior, consistent with the evidence on sustainability-oriented incentives (Cabaleiro-Cerviño and Mendi 2024; Gillan et al. 2021). Environmental innovation shows a positive association with firm value in the baseline models. However, mediation analysis based on bootstrapped inferences does not confirm a statistically significant indirect effect. Thus, H2 is not fully supported, and the results suggest that although ESG-linked pay promotes environmentally oriented activities, it does not translate into measurable firm value gains within the observed time horizon.

The moderating role of ESG-related training yielded nuanced insights. Training enhances the effectiveness of ESG-linked incentives in dynamic settings, supporting the view that organizational capabilities are essential for implementing sustainability strategies (Bénabou and Tirole 2010; Jabbour 2015). This provides partial support for H3, indicating that human capital and organizational capabilities play important enabling roles. In contrast, the moderating effects of board gender diversity and board independence are not statistically significant across specifications. Consequently, H4 and H5 are not supported, indicating that governance structures do not uniformly strengthen the incentive–performance relation, consistent with the evidence that highlights the context-dependent nature of governance mechanisms (Afrifa et al. 2020; Albitar et al. 2023).

A robustness analysis using PBV as an alternative proxy for firm value yielded qualitatively similar results. The positive association between ESG-linked compensation and firm value persisted, albeit with weaker statistical significance. In this alternative specification, environmental innovation is positively related to firm value. These findings reinforce the view that the results are not driven by a specific valuation metric but also highlight the sensitivity of market-based measures to expectations and valuation dynamics. Additional sensitivity analysis excluding financial-sector firms yields a positive and statistically significant association between ESG-linked pay and both firm value and environmental innovation under the baseline fixed-effects specifications, indicating that the baseline findings are not solely driven by financial institutions (Table 12).

This study contributes to the literature in several ways. First, it extends research on ESG-linked compensation by moving beyond a linear performance framework and explicitly incorporating behavioral and organizational channels. These findings suggest that ESG-linked pay primarily influences firm behavior rather than immediate financial outcomes, which refines the agency-theoretic argument that incentive alignment directly translates to improved performance.

Second, our results contribute to the growing debate on the effectiveness of ESG mechanisms by highlighting the importance of internal capabilities. The evidence indicates that incentives alone are insufficient, and their effectiveness depends on the firm's ability to absorb and operationalize ESG objectives. This aligns with capability-based perspectives, suggesting that ESG-related investments in human capital and training are critical for translating incentives to tangible outcomes (Table 13).

Third, the absence of significant moderating effects of board characteristics provides a more cautious interpretation of governance-based explanations. Specifically, board independence and board gender diversity do not significantly condition the relation between ESG-linked pay and firm value in the reported models. Accordingly, the findings identify a boundary to governance-based explanations by showing that the effectiveness of ESG-linked incentives does not systematically depend on these board characteristics.

These findings have several implications for corporate practice. First, ESG-linked compensation should not be viewed as a stand-alone mechanism for enhancing firm value. Although these incentives are effective in promoting environmental innovation, their financial benefits are neither immediate nor guaranteed. Therefore, firms should adopt a more integrated approach that combines incentive design with broader strategic and operational alignment. Second, ESG-related training highlights the importance of capability development. Investments in employee skills, organizational learning, and implementation capacity appear to strengthen the effectiveness of ESG-linked incentives over time. Firms seeking to translate ESG commitments to substantive outcomes should prioritize internal capacity building alongside compensation reforms. Third, the limited role of board structure suggests that simply adjusting the board composition may not be sufficient to enhance the effectiveness of ESG-linked pay. Greater attention should be paid to the quality of incentive design, clarity of ESG targets, and integration of sustainability objectives in core business strategies.

From a policy perspective, these findings suggest that promoting ESG-linked compensation alone is unlikely to yield consistent improvements in firm-level financial outcomes. The evidence does not support strong claims that ESG-linked pay directly improves firm value. Accordingly, policy initiatives should focus on the design and implementation of ESG-linked incentive systems rather than treating such compensation as a direct mechanism for firm-value creation.

The evidence on environmental innovation supports continued efforts to encourage sustainability-oriented incentives. In particular, policymakers and standard setters should encourage firms to link executive compensation to clearly defined,

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measurable, and verifiable ESG targets. The effectiveness of these incentives is also likely to depend on firms' implementation capacity. Complementary support mechanisms, such as technical guidance, knowledge-sharing initiatives, and appropriate sustainability-related investment support, may enhance the effectiveness of ESG-linked incentive arrangements.

More broadly, the findings suggest that ESG-linked compensation should be evaluated primarily in terms of its ability to influence sustainability-related corporate behavior rather than presumed improvements in market valuation. The absence of significant moderating effects from board gender diversity does not diminish its broader governance relevance but indicates that board diversity does not appear to condition the firm-value implications of ESG-linked pay in this setting. Regulatory initiatives concerning board composition should be considered within their broader governance objectives rather than justified specifically as mechanisms for strengthening the valuation effects of ESG-linked compensation.

This study has several limitations. First, the analysis focuses on selected governance characteristics; future research could examine broader dimensions of board diversity and governance quality. Second, despite using multiple approaches to address endogeneity, causal interpretation remains challenging because of potential dynamic and unobserved factors. The absence of a statistically reliable indirect effect through environmental innovation further suggests that environmental innovation may not be the primary mechanism connecting ESG-linked compensation to firm-level outcomes. Future research should examine alternative mediating channels, such as broader ESG performance, strategic investment, stakeholder engagement, managerial decision-making, or other organizational capabilities, to better elucidate the pathways through which ESG-linked incentives may influence corporate outcomes. Third, the European setting may limit the generalizability of the findings, warranting research across different institutional contexts and longer time horizons. Fourth, ESG-linked compensation is measured using LSEG's binary indicator of whether a firm reports an executive compensation policy linked to ESG or sustainability performance. The measure does not identify the specific ESG metrics employed, their weight in total compensation, whether targets are quantitative or qualitative, or the amount of compensation contingent on their achievement. Therefore, it captures the presence rather than the intensity of ESG-linked incentives, and firms with the same classification may differ in the substantive strength of their incentive arrangements. Future research using granular compensation contract data could distinguish symbolic policy adoption from economically meaningful incentive design. Finally, although the ESG pay–environmental innovation association remains robust after excluding financial firms, cross-industry differences in valuation, leverage, and environmental innovation may still affect the estimated relations.

Author Contributions

Jinfeng Wu: data curation, formal analysis, software, visualization. **Ramiz Ur Rehman:** writing – original draft, writing – review and editing, investigation, visualization. **Muhammad Ishfaq Ahmad:** writing – original draft, methodology, writing – review and editing, conceptualization. **Riccardo Torelli:** funding acquisition, validation, project administration, supervision and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

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