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Corporate Environmental Innovation and Environmental Decoupling: International Evidence

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ABSTRACT

This study investigates whether environmental innovation reduces environmental decoupling, defined as the mismatch between a company's environmental disclosures and its actual environmental performance. Drawing on legitimacy theory, we argue that environmental innovation represents a substantive organizational response that reduces companies' reliance on symbolic environmental communication and promotes alignment between reported claims and actual practices. Using a sample of 10,463 firm-year observations of companies listed in the Bloomberg Global Large and Mid-Cap Index from 2010 to 2020, we find that environmental innovation is negatively and statistically associated with environmental decoupling. This result remains robust across multiple model specifications, including two-stage least squares and propensity score matching approaches. The study offers generalizable insights into the role of environmental innovation in enhancing the credibility of sustainability reporting and provides practical implications for managers, investors, and policymakers seeking to mitigate environmental misinformation and improve the integrity of disclosure.

1 | Introduction

Corporate commitments to environmental sustainability are increasingly communicated through extensive environmental disclosures (Chung et al. 2025; Mallin et al. 2013). However, these commitments do not always align with firms' actual environmental performance. A substantial body of evidence indicates that improvements in environmental disclosure do not necessarily translate into corresponding improvements in environmental outcomes (Gull et al. 2023; Pisano et al. 2025; Tang et al. 2023). This divergence, commonly referred to as environmental decoupling, reflects a gap between what firms claim to achieve and what they actually achieve in practice (Abweny et al. 2025; Gull et al. 2024). As societal, regulatory, and investor expectations regarding environmental responsibility intensify, firms face increasing pressure to signal alignment with sustainability norms, further expanding environmental reporting (Pisano et al. 2025).

Such misalignment raises concerns about the credibility of sustainability reporting and the effectiveness of disclosure-based accountability mechanisms (Velte 2023).

Recent research conceptualizes environmental decoupling as a strategic response to legitimacy pressures rather than a mere reporting inconsistency (García-Sánchez et al. 2022; Tang et al. 2023). As firms face growing expectations to demonstrate environmental responsibility, they may rely on symbolic disclosure to maintain legitimacy when substantive environmental change is costly, uncertain, or difficult to verify (Hyatt and Berente 2017; Meng et al. 2019). While prior studies have examined the role of governance structures, institutional pressures, and executive characteristics in shaping environmental decoupling (e.g., Abweny et al. 2025; Gull et al. 2024; Pisano et al. 2025; Sauerwald and Su 2019; Tashman et al. 2019), there remains a limited understanding of how substantive operational

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strategies, defined as practices embedded in firms' core production and operational processes, constrain firms' ability to decouple environmental disclosure from performance.

Environmental innovation has attracted increasing scholarly attention as a key driver of credible corporate environmental behavior. Prior research consistently links environmental innovation to improved environmental performance, reduced greenwashing risk, and enhanced disclosure credibility (e.g., Amore and Bennedsen 2016; Arena et al. 2018; Hamim and Mollah 2025; Nadeem et al. 2020; Zaman et al. 2021). However, this literature largely examines environmental innovation as an outcome or correlate of sustainability engagement rather than as a mechanism that shapes firms' legitimacy strategies. As a result, it remains unclear whether environmental innovation coexists with more credible reporting or whether it actively strengthens the alignment between environmental disclosure and environmental performance by limiting firms' reliance on symbolic legitimacy responses.

Drawing on legitimacy theory, this study examines whether environmental innovation serves as a substantive mechanism through which firms maintain legitimacy by reducing environmental decoupling and aligning environmental disclosure with verifiable environmental performance. Specifically, environmental innovation represents a costly and operationally embedded practice that integrates environmental responsibility into firms' core activities (Bhatia 2021; Qin et al. 2026). Therefore, we argue that integrating environmental responsibility into firms' core operations ties environmental commitments to actual practices, thereby reducing managerial discretion over sustainability narratives and limiting firms' reliance on symbolic reporting strategies.

Using a multinational panel dataset of 10,463 firm-year observations from firms included in the Bloomberg World Large and Mid-Cap Index over the period 2010–2020, we find that environmental innovation is negatively and significantly associated with the level of environmental decoupling. This finding remains robust across alternative specifications, including a different measure of environmental decoupling, subsample analyses, and endogeneity treatments (i.e., two-stage least squares and propensity score matching).

This study makes several contributions to the literature. First, it advances research on environmental decoupling by reconceptualizing environmental innovation as a substantive mechanism that constrains symbolic legitimacy strategies, rather than treating innovation merely as a correlate or outcome of sustainability engagement. While prior studies largely emphasize governance arrangements, institutional pressures, or managerial characteristics as drivers of decoupling (Gull et al. 2024; Hyatt and Berente 2017; Pisano et al. 2025; Sauerwald and Su 2019; Talpur et al. 2024), we advance legitimacy-based accounts by demonstrating how operationally embedded practices, specifically environmental innovation, discipline firms' ability to manage legitimacy through disclosure alone. In doing so, we respond to recent calls to move beyond disclosure-centric explanations of sustainability misalignment and to better integrate substantive organizational practices into legitimacy-oriented analyses (Talbot and Boiral 2018; Velte 2023).

Second, by explicitly focusing on environmental decoupling, rather than aggregate CSR decoupling, this study contributes to a more nuanced understanding of sustainability misalignment in a domain that is particularly salient for climate policy and stakeholder scrutiny. Prior research has predominantly examined decoupling at the overall CSR level (e.g., Abweny et al. 2025; García-Sánchez et al. 2022; Tashman et al. 2019), potentially obscuring important domain-specific dynamics. Third, this study contributes by using a large, multinational sample, which enhances external validity and addresses the limited comparative evidence between countries on environmental decoupling. While previous studies have relied on single-country contexts, which may limit generalizability (Gull et al. 2023; Morrison et al. 2024; Ye et al. 2024), our results demonstrate that innovation-based legitimacy mechanisms operate across diverse institutional and regulatory contexts, making them relevant to globally integrated capital markets.

Finally, the study offers practical implications for managers, investors, and policymakers. The findings suggest that investments in environmental innovation not only improve environmental performance but also augment the credibility of sustainability reporting, thereby reducing exposure to greenwashing accusations and stakeholder skepticism. For policymakers and standard-setters, the results underline the importance of encouraging innovation-oriented environmental strategies as complements to disclosure requirements, particularly as sustainability regulation increasingly shifts toward performance-based evaluation and verification (Kim and Lyon 2015).

The remainder of the paper is structured as follows. Section 2 presents a literature review and hypothesis development. Section 3 describes the research design, data, and variable measurement. Section 4 reports the empirical results and additional analyses. Section 5 concludes and outlines implications and avenues for future research.

2 | Literature Review and Hypothesis Development

2.1 | Environmental Innovation

Environmental innovation refers to the development and implementation of new or significantly improved products, processes, technologies, or organizational practices that reduce environmental harm or enhance environmental performance (Nadeem et al. 2020; Rennings 2000). Unlike disclosure-based commitments or symbolic sustainability initiatives, environmental innovation is typically embedded in firms' core operational activities and investment decisions, making it more directly linked to observable environmental outcomes (Arena et al. 2018; De Marchi 2012; Doran and Ryan 2016; Phung et al. 2023; Singh et al. 2020).

The literature on environmental innovation has expanded substantially in recent years, reflecting growing recognition of its role in addressing environmental challenges while sustaining firm competitiveness. Prior studies consistently show that firms engaging in environmental innovation achieve superior environmental performance, including reductions in

emissions, improvements in resource efficiency, and lower exposure to environmental risks (Dwekat et al. 2025; Ren et al. 2021; Singh et al. 2020). These outcomes are typically monitored through performance indicators, regulatory disclosures, and third-party assessments, distinguishing environmental innovation from narrative sustainability claims that rely primarily on self-reported information (Chang and Sam 2015; Gull et al. 2023).

Importantly, environmental innovation is widely characterized as costly, path-dependent, and difficult to reverse, requiring sustained financial commitment, organizational learning, and coordination across functional units (Arena et al. 2018). Because such investments are closely tied to firms' technical and production processes (Arena et al. 2018; Rennings 2000), they are not easily adopted or abandoned for purely symbolic reasons. As a result, environmental innovation reflects a deeper and more durable integration of environmental considerations into core business activities than disclosure-based sustainability initiatives (Horbach et al. 2013).

Beyond its effects on environmental performance, recent evidence indicates that environmental innovation also shapes how firms are perceived by external stakeholders. Firms with stronger environmental innovation are less exposed to greenwashing accusations and are more likely to be viewed as environmentally credible, particularly in contexts characterized by heightened scrutiny and verification (Huang et al. 2024; Ma et al. 2025; Wang 2025). Nevertheless, the existing literature has predominantly examined environmental innovation as a driver of environmental or financial outcomes, such as emissions reduction, resource efficiency, firm value, and risk exposure, while paying comparatively limited attention to its implications for disclosure behavior and the alignment between environmental reporting and actual performance (Albitar et al. 2023; Nadeem et al. 2020; Singh et al. 2020; Zaman et al. 2021).

Taken together, environmental innovation represents a form of environmental engagement that is substantively embedded in firms' operations and more tightly coupled with actual environmental performance than disclosure alone. These characteristics make environmental innovation a particularly relevant mechanism for understanding whether, and how, firms can sustain alignment between what they report and what they achieve environmentally, providing a natural bridge to the discussion of environmental decoupling that follows.

2.2 | Environmental Decoupling

Environmental decoupling refers to a systematic misalignment between firms' environmental disclosures and their actual environmental performance, whereby communicated commitments, policies, or achievements do not accurately reflect substantive environmental outcomes (Gull et al. 2023). Rooted in the broader concept of organizational decoupling (Meyer and Rowan 1977), environmental decoupling captures firms' tendency to symbolically conform to environmental expectations while limiting, delaying, or selectively implementing substantive operational change (Gull et al. 2024; Papa et al. 2024; Pisano

et al. 2025). As such, environmental decoupling has become a central concern in sustainability and environmental accounting research due to its implications for disclosure credibility, stakeholder trust, and the effectiveness of environmental governance mechanisms (Velte 2025).

Recent literature emphasizes that environmental decoupling is analytically distinct from related concepts such as greenwashing and aggregate CSR decoupling. While greenwashing broadly refers to misleading or exaggerated environmental claims intended to enhance corporate image (Delmas and Burbano 2011), environmental decoupling focuses more narrowly on the structural gap between environmental "talk" and environmental "action," irrespective of whether misrepresentation is intentional (Morrison et al. 2024; Papa et al. 2024). Similarly, CSR decoupling captures misalignment across multiple social, environmental, and governance dimensions (Tashman et al. 2019), whereas environmental decoupling isolates the environmental pillar. This distinction is particularly important given the heightened salience of environmental performance in the context of climate change, regulatory intervention, and intensified stakeholder scrutiny (Gull et al. 2023; Morrison et al. 2024).

Environmental decoupling may manifest in different forms. Firms may engage in positive decoupling, whereby environmental disclosures overstate actual environmental performance in order to signal conformity with prevailing societal norms and expectations (Gull et al. 2024; Sauerwald and Su 2019). Conversely, firms may also exhibit negative decoupling, or underreporting, particularly when transparency increases exposure to regulatory enforcement, political costs, or reputational risk (Kim and Lyon 2015; Pisano et al. 2025). Both forms reflect strategic disclosure behavior, underscoring that environmental decoupling is not merely a reporting error, but a deliberate response to competing legitimacy pressures and disclosure incentives operating across diverse institutional contexts (Crilly et al. 2012; Papa et al. 2024; Tashman et al. 2019).

Importantly, the prevalence and consequences of environmental decoupling have evolved alongside changes in the sustainability reporting landscape. The increasing reliance on externally verified performance metrics, ESG ratings, regulatory monitoring, and third-party audits has reduced the effectiveness of purely symbolic disclosure strategies and heightened the risks associated with misalignment between reporting and performance (Michelon and Parbonetti 2012; Papa et al. 2024). As a result, firms face growing pressure to substantiate environmental disclosures with observable and verifiable environmental practices, rendering environmental decoupling more visible and potentially more costly.

Against this backdrop, understanding the mechanisms that constrain environmental decoupling has become a key research priority. While prior studies have predominantly examined governance structures, institutional pressures, and managerial attributes as drivers of environmental decoupling (e.g., Gull et al. 2023; Sauerwald and Su 2019; Talpur et al. 2024), comparatively less attention has been paid to how substantive operational strategies influence the disclosure–performance relationship. This gap motivates closer examination of environmental innovation as an organizational

practice that may anchor environmental legitimacy in observable performance outcomes and limit firms' reliance on symbolic reporting strategies.

2.3 | Theoretical Background and Hypothesis Development

Legitimacy theory provides a robust framework for explaining environmental disclosure and environmental performance, and the variations in this decoupling among firms. This theory posits that organizations strive to ensure their actions align with prevailing social norms, values, and expectations in order to maintain access to vital resources and social acceptance (Deegan et al. 2002; Suchman 1995). As societal expectations regarding environmental responsibility increase, firms may face legitimacy gaps when their actual practices fail to meet these expectations (Lindblom 1994). In response, environmental disclosure can serve as a strategic tool through which firms attempt to manage stakeholder perceptions and maintain or restore legitimacy, sometimes independently of substantive environmental improvements (Bansal and Clelland 2004; Marquis and Qian 2014; Talbot and Boiral 2018).

Within this framework, environmental decoupling reflects a strategic response to legitimacy pressures that arise when substantive environmental improvements are costly, uncertain, or difficult to verify. Consistent with the broader CSR decoupling literature, prior research suggests that firms may overstate their environmental achievements to signal conformity with societal norms, particularly in contexts where external monitoring mechanisms are weak (Kim and Lyon 2015; Lyon and Maxwell 2011; Tashman et al. 2019). Conversely, firms may intentionally underreport environmental performance when disclosure heightens exposure to regulatory scrutiny, political costs, or negative stakeholder reactions (Decker 2003; Kim and Lyon 2015). In both cases, decoupling reflects managerial discretion over environmental narratives as evaluated by external stakeholders, rather than internal reporting error.

The expansion of ESG ratings, performance benchmarks, regulatory oversight, NGO monitoring, and investigative media has significantly increased the visibility of firms' environmental actions and improved stakeholders' ability to verify corporate environmental claims (Eccles et al. 2014; Lyon and Maxwell 2011). As a result, the credibility of environmental disclosure increasingly depends on the presence of observable, costly, and difficult-to-imitate environmental practices rather than on narrative commitments alone (Balluchi et al. 2021; Michelon and Parbonetti 2012). This shift has important implications for understanding how firms manage organizational legitimacy and why environmental decoupling may become more constrained under conditions of greater scrutiny.

Environmental innovation emerges as a critical substantive mechanism through which firms can respond to legitimacy pressures (Berrone et al. 2013; Hawn and Ioannou 2016; Li et al. 2017; Truong and Berrone 2022). It involves the development and implementation of new products, processes, or technologies that reduce environmental harm and improve

environmental performance (Amore and Bennesen 2016; Arena et al. 2018; Dwekat et al. 2025). Unlike symbolic disclosure, environmental innovation is inherently integrated into firms' operational systems, typically requires sustained investment, and generates outcomes that are more readily observable through external performance metrics, regulatory filings, and independent assessments (Cainelli et al. 2015; Demirel and Danisman 2019; Porter and Linde 1995). Consequently, environmental innovation is more likely to reduce managerial discretion over environmental narratives and constrain firms' ability to decouple environmental disclosure from actual performance.

This argument aligns with and extends recent empirical evidence showing that firms engaged in environmental innovation tend to exhibit stronger environmental performance (Carrión-Flores and Innes 2010; Horbach et al. 2013; Xie et al. 2019), lower exposure to greenwashing risk (Ma et al. 2025), and greater disclosure credibility (Radu and Francoeur 2017). Importantly, the legitimacy value of environmental innovation has become more pronounced over time as sustainability expectations have evolved from symbolic compliance toward demonstrable impact (Berrone et al. 2009; Singh et al. 2023; Truong et al. 2021). Moreover, macroeconomic uncertainty and regulatory tightening have heightened scrutiny of corporate environmental claims, further undermining the viability of disclosure-based legitimacy strategies that lack substantive environmental innovation (Yang and Song 2024; Zhou et al. 2024).

Taken together, legitimacy theory suggests that environmental innovation plays a central role in aligning environmental disclosure with actual performance by reducing firms' ability and incentives to rely on symbolic legitimacy strategies. Firms that invest in environmental innovation are therefore expected to exhibit lower levels of environmental decoupling. Accordingly, we propose the following hypothesis:

H1. *Corporate environmental innovation is negatively associated with environmental decoupling.*

3 | Research Design

3.1 | Sample Selection and Data Sources

The study sample comprises all non-financial companies included in the Bloomberg Large and Mid-Cap World Index from 2010 to 2020. This index is an equity benchmark that uses a market-cap-weighted methodology to assess the performance of large- and mid-cap companies worldwide. It represents around 85% of the total market capitalization, distributed across 33 countries.¹ Data for the study variables are sourced from two main databases: Bloomberg and the LSEG Group (formerly Refinitiv Eikon). More specifically, the environmental disclosure score and data on CEO characteristics were obtained from the Bloomberg database, while data on environmental performance, environmental innovation, and other firm-level variables were collected from the LSEG Group.

Table 1 illustrates the sample selection process, from initial data collection to the selection of the final sample used in the analysis. The initial data set consisted of 40,959 observations

TABLE 1 | Sample selection process.

	Obs.	Percentage
Initial sample	40,959	100
Less:		
Firms in the financial industry	6507	15.89
Firms with missing observations	23,820	58.16
Countries with fewer than 20 observations	169	0.41
Final sample	10,463	25.55

Note: This table presents the process of sample selection.

from Bloomberg (2010–2020). Subsequent exclusions included financial firms (6507 observations) and firms with missing data (23,820 observations), resulting in a final sample of 10,463 observations.

3.2 | Measurement of the Variables

3.2.1 | Dependent Variable

To operationalize the environmental decoupling construct, this study adopts a widely accepted approach based on the divergence between firms' environmental disclosure and their actual environmental performance. Specifically, we calculate environmental decoupling as the difference between Bloomberg's environmental disclosure score and a one-year lag of LSEG's environmental performance score, scaled by the natural logarithm of total assets. Scaling by the natural logarithm measurement of total assets standardizes the disclosure and performance gap across firms of different sizes and helps ensure that the measure reflects environmental decoupling rather than underlying size-related differences in reporting volume or operational complexity (Gull et al. 2023).

This measure captures the extent to which firms overstate or understate their environmental efforts relative to their actual environmental outcomes. A higher score indicates a greater decoupling between what the firm reports and what it substantively achieves. This approach aligns with prior studies in the environmental and CSR decoupling literature that have similarly used variations of disclosure-performance gaps to identify symbolic sustainability practices (Gull et al. 2023; Papa et al. 2024; Velte 2025). The use of lagged performance scores ensures temporal alignment and minimizes simultaneity bias, a concern echoed in previous empirical work (Morrison et al. 2024).

3.2.2 | Independent Variables

Arena et al. (2018), Konadu et al. (2022), and Konadu et al. (2022) argue that the main issue with environmental innovation measures is that firms are not required to disclose environmental innovation and research activities. Consequently, previous studies find some difficulties in

measuring environmental innovation. While some use expenditures on research and development as a proxy for environmental innovation initiatives, others rely on a widely recognized database, "LSEG" that provides an environmental innovation score (Abu Alia et al. 2024; Dwekat et al. 2025; Konadu et al. 2022).

This database provides relevant, reliable, and auditable environmental innovation data that reduces reliance on self-reported information, minimizes replication errors, and improves generalizability (Moreno-Ureba et al. 2022). Our study, therefore, measures environmental innovation as an independent variable using the LSEG's environmental innovation score. More specifically, this score captures a firm's ability to acquire and develop competitive advantages by providing environmentally designed processes and products (Abu Alia et al. 2024). In other words, this scale examines how firms cope with their financial and environmental difficulties by improving their future prospects through innovation and development of environmental products and technologies. It ranges from 0 to 100. A higher score, closer to 100, indicates greater efficiency in environmental innovation, demonstrating a firm's ability to reduce environmental costs and negative impacts on its surrounding environment (Zaman et al. 2024).

3.2.3 | Control Variables

Based on previous studies (Gull et al. 2024; Meqbel et al. 2025; Morrison et al. 2024; Pisano et al. 2025; Saeed et al. 2025; Velte 2025; Ye et al. 2024), we included several control variables that could have an influence on firms' environmental disclosure and performance. Referring to firms' specific factors, we control for firm size, profitability, leverage, firm age, and sales growth. Larger companies claimed to have greater exposure to shareholders, and therefore tended to be less likely to engage in such symbolic behavior (Gull et al. 2023; Velte 2023, 2025). Similarly, profitable firms are more motivated to show their sustainability activities more transparently (Gull et al. 2023; Pisano et al. 2025). It is argued that companies with high debt face greater pressure to meet their obligations, which impacts their ability to invest in substantive environmental initiatives (Velte 2025). As a company ages, older companies may develop more sophisticated reporting practices and stronger concerns about their reputation; however, this does not necessarily translate into a decrease in environmental decoupling, as mature companies may become more adept at managing external impressions through selective disclosure (Ye et al. 2024). Most existing research suggests that companies with rapid sales growth tend to shift their focus to innovative environmental activities and prioritize market expansion. Therefore, this is expected to have a positive impact on environmental decoupling (Hawn and Ioannou 2016).

We further control over governance quality, the CSR committee, and executive compensation. We suggest that higher corporate governance quality and the existence of a CSR committee promote greater transparency, thus narrowing the gap between environmental disclosure and performance (Gull et al. 2023; Morrison et al. 2024). Compensation refers to ESG-aligned compensation, which is a binary variable that

indicates whether executive pay is explicitly linked to ESG objectives. This variable captures the extent to which managerial incentives promote genuine sustainability efforts compared to symbolic disclosure (Flammer et al. 2019; Velte 2025). Previous research shows that incentives linked to ESG criteria reduce environmental disconnection by aligning reporting with performance (Gillan et al. 2021).

Finally, given the pivotal role of the CEO in shaping corporate strategy, allocating resources, and setting disclosure priorities, their personal characteristics can significantly influence the degree of environmental decoupling (Gull et al. 2023; Shahab et al. 2021). Accordingly, we incorporated into the main model the dual role of CEO and chairman, the CEO's gender, tenure, and age. The CEO-Chairman duality is expected to increase the environmental decoupling by weakening board oversight and increasing management discretion, while the CEO's gender may reduce this decoupling if female CEOs are more focused on ethical and environmental considerations (Gull et al. 2023; Pisano et al. 2025; Velte 2025). The CEO's tenure and age may also be important because differences in experience, entrenchment, and openness to change can influence how well environmental disclosures reflect substantive rather than symbolic reporting (Gull et al. 2023; Velte 2025).

3.3 | Empirical Model(s)

To test our hypothesis, we run a regression equation using a two-way cluster approach at both firm and year levels. This approach confirms well-defined parameters and addresses any potential heteroscedasticity in the context of a panel data set, yielding robust standard errors (Bouslah et al. 2018; Petersen 2008). The regression equation is as follows:

$$\text{Env_decoupling}_{it} = \alpha_0 + \beta_1 \text{Env_Innovation}_{it} + \sum \beta_x \text{control}_{it} + \sum \beta_1 \text{YFF}_t + \sum \beta_1 \text{IFF}_i + \sum \beta_1 \text{CFF}_i \varepsilon_{it} + \varepsilon_{it} \quad (\text{Eq 1})$$

In the above equation, the variable $\text{Env_decoupling}_{it}$ represents environmental decoupling, while $\text{Env_Innovation}_{it}$ represents environmental innovation for firm i in year t . control_{it} represents a vector of control variables including firm size, return on assets (ROA), leverage, firm age, sales growth, CSR committee presence (CSR committee), executive compensation (Compensation), governance score (Gov_score), CEO duality, CEO gender, CEO tenure, and CEO age. The inclusion of these variables helps mitigate potential endogeneity arising from omitted variable bias by controlling for firm-level characteristics, governance structures, and managerial attributes that may affect both environmental innovation and environmental decoupling. Furthermore, the model includes year (YFF), industry (IFF), and country (CFF) fixed effects to control for unobserved heterogeneity across time, industries, and countries that may affect firms' environmental innovation activities and environmental disclosure practices. All continuous variables are winsorized at the 1st and 99th percentiles to mitigate the influence of extreme observations.

Table 2 presents the definitions of the study variables.

4 | Empirical Results and Discussion

4.1 | Descriptive Statistics and Univariate Analysis

Table 3 presents the descriptive statistics for the main variables. The average environmental decoupling score is -1.098 , indicating that, on average, firms disclose less than their actual environmental performance, pointing to a decoupling between actions and reporting. The mean environmental innovation score is 35.60 ($SD = 33.10$), with 25% of firms showing no reported innovation activity. This suggests that a considerable share of firms may not be actively engaged in environmental innovation or fail to report such efforts.

Table 4 reports the average values of environmental decoupling and environmental innovation across the countries in the sample. While environmental decoupling scores are negative in most countries, indicating a consistent tendency for firms to report less than their actual environmental performance, the degree of decoupling varies notably. For instance, France and Spain show the most negative average decoupling scores (-1.719 and -1.635 , respectively), whereas countries like Russia and Thailand display relatively smaller gaps (-0.112 and -0.440). Environmental innovation scores also differ considerably, with higher averages in countries such as Sweden (54.03), Spain (64.39), and Finland (60.15), and lower scores in markets like Macao (6.17) and Russia (11.97).

Table 5 presents the correlation matrix among the independent variables. All pairwise correlation coefficients are well below the conventional multicollinearity threshold of 0.80 (Gujarati 2009), with the highest observed correlation being 0.354 between firm size and compensation. Additionally, all variance inflation factor (VIF) values are below 2.65, which is far below the commonly accepted threshold of 10, further confirming the absence of multicollinearity (Gujarati 2009). These results indicate that the explanatory variables are sufficiently independent, ensuring the reliability of the regression estimates presented in the subsequent analysis.

4.2 | Multivariate Analysis

Table 6 presents the results of the regression analysis exploring the determinants of environmental decoupling. In *Model 1*, we include only the core control variables related to firm size, profitability, leverage, firm age, growth, governance, compensation, and the presence of a CSR committee. In *Model 2*, we expand the baseline specification by adding CEO-level characteristics, including CEO duality, gender, tenure, and age. These two initial models do not incorporate the main independent variable, environmental innovation, as they are designed to isolate the effects of internal governance structures and executive traits on decoupling practices.

Environmental innovation is incorporated into *Model 3* and *Model 4*, which represent the fully specified models and allow for testing the main hypothesis (H1). The coefficient on environmental innovation is negative and statistically significant at the 1% level in both models (Model 3: $\text{coef} = -0.016$; $p < 0.01$; Model 4: $\text{coef} = -0.017$; $p < 0.01$). In terms of economic magnitude,

TABLE 2 | Definitions of the variables.

Variable	Definition
Environmental decoupling (Env_decoupling)	The difference between Bloomberg's environmental disclosure score and a 1-year lag of LSEG's environmental performance score, divided by the natural logarithm of total assets.
Environmental innovation (Env_innovation)	Environmental innovation score as provided by LSEG.
Firm size	Natural logarithm of total assets.
ROA	Net income is divided by total assets.
Leverage	Long-term debt is divided by total assets.
Firm age	Natural logarithm of the years since the firm was listed.
Sale growth	Change in sales revenue divided by a 1-year lag of sales revenue.
CSR committee	Dummy variable coded 1 if the firm has a CSR committee, and 0 otherwise.
Compensation	Executive compensation is divided by total assets.
Governance score (Gov_score)	Governance score as provided by LESG.
CEO duality	Dummy variable coded 1 if the CEO also serves as the chairman, and 0 otherwise.
CEO gender	Dummy variable coded 1 if the CEO is female, and 0 otherwise.
CEO tenure	Number of years the CEO has held the position.
CEO age	Natural logarithm of the CEO's age in years.
Country-level variables	
CSR sensitive countries	Dummy variable coded 1 if the country follows a common law system, and 0 otherwise.
Gross domestic product (GDP)	Natural logarithm of gross domestic product.

(Continues)

TABLE 2 | (Continued)

Variable	Definition
Gross domestic product growth (GDP growth)	Change in gross domestic product divided by a 1-year lag of gross domestic products.
Power distance index (PDI)	Scores (0–100) reflect acceptance of unequal power distribution; higher scores indicate greater acceptance. (Source: the Hofstede Centre)
Individualism (IDV)	Scores (0–100) measure the degree of individual autonomy; higher scores indicate more individualistic societies. (Source: the Hofstede Centre)
Masculinity (MAS)	Scores (0–100) indicate preference for achievement and competition (masculine) over care and quality of life (feminine). (Source: the Hofstede Centre)
Uncertainty avoidance (UAI)	Scores (0–100) show tolerance for ambiguity; higher scores reflect a stronger need for rules and structure. (Source: the Hofstede Centre)
Long-term vs. short-term orientation (LTOWVS)	Scores (0–100) capture the focus on future rewards and perseverance (long-term) versus tradition and short-term outcomes. (Source: the Hofstede Centre)
Indulgence vs. restraint (IVR)	Scores (0–100) reflect the extent to which societies allow gratification of desires (indulgence) versus suppression through norms (restraint). (Source: the Hofstede Centre)

Note: This table presents the definitions of the variables.

and using Model 4 estimation, a one-standard-deviation increase in environmental innovation is associated with a decrease of approximately 0.563 in environmental segregation (-0.017×33.103), which is economically significant compared to the mean level of the dependent variable. This result supports Hypothesis 1 (H1), which suggests that firms with higher levels of environmental innovation tend to exhibit lower degrees of environmental decoupling.

TABLE 3 | Descriptive statistics.

	Obs.	Mean	SD	Min	P25	P50	P75	Max
Env_decoupling	10,463	-1.098	1.159	-5.008	-1.944	-1.143	-0.265	3.790
Env_innovation	10,463	35.599	33.103	0.000	0.000	31.600	63.850	99.740
Firm size	10,463	16.277	1.240	11.795	15.464	16.213	17.074	20.819
ROA	10,463	0.060	0.076	-0.333	0.025	0.052	0.091	0.388
Leverage	10,463	24.022	15.864	0.000	12.500	23.000	33.605	72.395
Firm age	10,463	3.207	0.933	0.000	2.708	3.178	3.892	5.609
Sale growth	10,463	5.210	21.955	-47.619	-4.494	3.030	11.364	200.000
CSR committee	10,463	0.369	0.483	0.000	0.000	0.000	1.000	1.000
Compensation	10,463	8.124	15.948	0.058	0.774	2.031	5.338	64.398
Gov_score	10,463	58.363	20.776	0.210	43.440	60.840	74.990	99.410
CEO duality	10,463	0.282	0.450	0.000	0.000	0.000	1.000	1.000
CEO gender	10,463	0.043	0.202	0.000	0.000	0.000	0.000	1.000
CEO tenure	10,463	6.564	6.197	0.080	2.000	4.670	9.000	31.080
CEO age	10,463	4.027	0.127	3.367	3.951	4.025	4.111	4.522

Note: This table presents the descriptive statistics of the variables. The definitions of the variables are provided in Table 2.

Our findings suggest that environmental innovation serves as a substantive rather than a symbolic response to legitimacy pressures. Environmental decoupling reflects incongruity between companies' environmental disclosures and their actual environmental performance, meaning that companies may seek to maintain their legitimacy through communication that is not fully supported by operational results (Gull et al. 2023; Pisano et al. 2025; Sauerwald and Su 2019). In contrast, environmental innovation is likely to produce tangible improvements in environmental practices and outcomes, making companies' disclosures more credible and reducing the likelihood of a discrepancy between disclosure and performance (Albitar et al. 2023). This interpretation is consistent with previous studies showing that the disconnect between performance and economic results undermines the credibility of reporting and is associated with negative market consequences, including a decrease in company value, a higher cost of capital, and reduced access to financing (García-Sánchez et al. 2020; Hawn and Ioannou 2016). Accordingly, our results indicate that companies that engage intensively in environmental innovation are less dependent on token legitimacy strategies because innovation helps align companies' words with their actions, reducing the disconnect between performance and economic outcomes (Tashman et al. 2019; Velte 2025).

Regarding the control variables, several firm-level variables show significant associations with environmental decoupling. Firm size and firm age are negatively and significantly related to decoupling ($coef = -0.050$; $p < 0.01$, and $coef = -0.072$; $p < 0.01$, respectively). This means that larger and more mature firms are more likely to align their environmental disclosures with actual performance. These results support prior findings that such firms experience greater public scrutiny and are more likely to adopt formalized reporting systems (Cormier

and Magnan 2007; Gull et al. 2023; Rupley et al. 2012), which increases the reputational costs associated with symbolic disclosure strategies. Additionally, sales growth is positively associated with decoupling ($coef = 0.002$; $p < 0.01$), indicating that fast-growing firms may resort to symbolic disclosures to maintain external legitimacy, particularly under pressure to demonstrate sustainability credentials (Chen et al. 2018). Leverage is negatively associated with decoupling ($coef = -0.002$; $p < 0.05$), which may reflect creditor pressure for credible reporting (Velte 2025). Finally, executive compensation exhibits a positive and significant effect ($coef = 0.006$; $p < 0.01$), potentially revealing incentive structures that encourage image management over substantive environmental efforts (Flammer et al. 2019; Jiraporn and Chintrakarn 2013), consistent with symbolic legitimacy motivations.

The findings also highlight the importance of internal sustainability governance mechanisms. The presence of a CSR committee is negatively and significantly associated with environmental decoupling ($coef = -0.065$; $p < 0.01$), reinforcing the argument that formal sustainability oversight promotes more authentic and consistent reporting (Gull et al. 2023). Similarly, a higher governance score is associated with lower decoupling ($coef = -0.001$; $p < 0.01$), suggesting that firms with stronger governance structures are more likely to disclose performance that accurately reflects their actual environmental actions. This finding aligns with the view that effective governance enhances transparency and reduces the risk of symbolic or misleading disclosures (Michelon and Parbonetti 2012; Talpur et al. 2024; Velte 2025).

Regarding CEO characteristics, the results show mixed effects. CEO duality is positively associated with environmental decoupling ($coef = 0.093$; $p < 0.01$), indicating that when the CEO also chairs the board, the lack of oversight may lead to

TABLE 4 | Average values across countries.

Country	Obs.	Env_ decoupling	Env_ innovation
Australia	281	-1.153	22.970
Austria	66	-1.160	51.751
Belgium	70	-1.660	48.450
Brazil	93	-0.869	31.150
Canada	385	-0.724	24.028
Chile	81	-0.558	37.769
China	661	-0.482	22.977
Denmark	104	-1.518	40.093
Finland	135	-1.268	60.154
France	397	-1.719	52.538
Germany	435	-1.350	52.661
Hong Kong	357	-0.920	37.281
India	410	-1.002	31.144
Ireland	105	-1.102	32.318
Japan	544	-1.178	52.402
Macao	22	-1.234	6.174
Malaysia	111	-0.771	15.195
Netherlands	112	-1.404	40.813
New Zealand	35	-0.863	12.484
Norway	87	-1.099	43.581
Philippines	48	-1.143	39.204
Poland	62	-0.545	21.542
Russia	98	-0.112	11.969
Singapore	132	-1.391	38.879
South Africa	254	-1.220	23.044
South Korea	73	-1.401	45.837
Spain	48	-1.635	64.393
Sweden	249	-1.318	54.028
Switzerland	110	-1.369	38.360
Taiwan	69	-0.912	48.002
Thailand	144	-0.440	27.595
United Kingdom	621	-1.578	41.363
United States	4064	-1.084	32.407
Total	10,463	-1.098	35.599

Note: This table presents the average values of Env_decoupling and Env_innovation across the countries included in our sample.

more strategic, symbolic reporting (Gull et al. 2023; Pisano et al. 2025). Conversely, CEO gender has a negative and significant effect ($coef = -0.135$; $p < 0.01$), suggesting that female

CEOs may be more committed to transparent sustainability practices, consistent with the literature on ethical leadership and stakeholder orientation (Velte 2025). CEO tenure is positively associated with decoupling ($coef = 0.004$; $p < 0.05$), possibly due to entrenched managerial behaviors or reduced responsiveness to evolving sustainability expectations (Velte 2025).

4.3 | Sensitivity Analyses

4.3.1 | Environmental Decoupling: Positive vs. Negative

Environmental decoupling refers to the gap between a firm's environmental disclosures and its actual environmental performance (Gull et al. 2023). Environmental decoupling can take two forms. Positive decoupling occurs when environmental disclosures are greater than actual performance (overreporting). In contrast, negative decoupling means that environmental performance is higher than what is disclosed (underreporting) (Abweny et al. 2025; Gull et al. 2023). Previous studies suggest that executives tend to overreport environmental activities when they face pressures from stakeholders or aim to achieve personal objectives, especially when actual environmental performance is weak (García-Sánchez et al. 2022; Sauerwald and Su 2019). On the other hand, underreporting may occur when executives seek to conceal excessive spending on CSR activities or to reduce the risk of external scrutiny of their actions (Abweny et al. 2025; Kim and Lyon 2015).

To provide more insightful results on the relationship between environmental innovation and decoupling, we examine the influence of environmental innovation on each type of environmental decoupling separately. To achieve this, we follow Gull et al. (2023) and Abweny et al. (2025) and employ a Tobit regression model, using "zero" as the cutoff point, where zero acts as an upper limit for negative decoupling and a lower limit for positive decoupling. Table 7 presents the results of the Tobit regression. In Model 1, we examine the effect of environmental innovation on positive environmental decoupling (overreporting), while Model 2 assesses its effect on negative environmental decoupling (underreporting). Both Models 1 ($coef = -0.017$; $p < 0.01$) and 2 ($coef = -0.017$; $p < 0.01$) document a significant negative relationship at the 1% level, indicating that environmental innovation reduces both positive environmental decoupling (overreporting) and negative environmental decoupling (underreporting). These results are consistent with our main findings, which suggest that environmental innovation reduces the tendency for firms to engage in environmental decoupling, regardless of its direction. This supports the predictions of legitimacy theory, indicating that innovative firms are more likely to close the gap between actual environmental performance and reported disclosures, thereby enhancing their legitimacy among stakeholders (Bansal and Clelland 2004; Talbot and Boiral 2018; Velte 2023).

4.3.2 | Different Sample Specification (United States vs. the Rest of the World)

Table 8 provides an additional robustness test, dividing the sample into two subgroups: US-based firms and firms from the rest

TABLE 5 | Correlation matrix.

No.	Variables	VIF	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Env_innovation	1.34	1.000												
2	Firm size	1.70	0.329*	1.000											
3	ROA	1.21	-0.012	-0.165*	1.000										
4	Leverage	1.40	-0.039*	0.159*	-0.190*	1.000									
5	Firm age	1.30	0.228*	0.116*	0.077*	-0.139*	1.000								
6	Sale growth	1.14	-0.132*	-0.118*	0.074*	-0.041*	-0.152*	1.000							
7	CSR committee	1.52	0.078*	0.179*	-0.013	0.042*	0.081*	-0.095*	1.000						
8	Compensation	2.65	-0.069*	-0.354*	0.079*	-0.209*	0.128*	0.039*	0.038*	1.000					
9	Gov_score	1.16	0.208*	0.265*	0.008	0.037*	0.138*	-0.142*	0.193*	-0.064*	1.000				
10	CEO duality	1.37	-0.008	0.060*	0.015	0.020*	0.050*	0.060*	-0.004	-0.010	-0.070*	1.000			
11	CEO gender	1.04	-0.019*	0.001	0.018	0.039*	-0.015	-0.038*	0.027*	-0.018*	0.050*	-0.026*	1.000		
12	CEO tenure	1.32	-0.071*	-0.098*	0.059*	-0.050*	0.054*	0.058*	-0.063*	0.016	-0.077*	0.266*	-0.050*	1.000	
13	CEO age	1.42	0.070*	0.150*	0.004	0.041*	0.171*	-0.084*	0.047*	0.038*	0.075*	0.212*	-0.066*	0.324*	1.000

Note: This table presents the correlation among independent variables. The definitions of the variables are provided in Table 2.

*Significant at the 5% level.

TABLE 6 | Environmental innovation and decoupling.

	Env_decoupling			
	Model 1	Model 2	Model 3	Model 4
Env_innovation			−0.016*** (−57.38)	−0.017*** (−50.47)
Firm size	−0.141*** (−15.53)	−0.142*** (−13.20)	−0.053*** (−6.32)	−0.050*** (−5.07)
ROA	−0.306** (−2.32)	−0.466*** (−3.08)	−0.165 (−1.40)	−0.239* (−1.76)
Leverage	0.001 (0.77)	0.001 (0.64)	−0.002*** (−2.68)	−0.002** (−2.43)
Firm age	−0.138*** (−12.64)	−0.142*** (−11.03)	−0.067*** (−6.75)	−0.072*** (−6.21)
Sale growth	0.003*** (6.74)	0.003*** (5.37)	0.002*** (5.86)	0.002*** (4.33)
CSR committee	−0.122*** (−5.30)	−0.089*** (−3.37)	−0.093*** (−4.47)	−0.065*** (−2.77)
Compensation	0.006*** (5.66)	0.007*** (6.04)	0.005*** (5.68)	0.006*** (6.19)
Gov_score	−0.004*** (−8.86)	−0.004*** (−6.75)	−0.002*** (−3.88)	−0.001*** (−2.85)
CEO duality		0.058** (2.08)		0.093*** (3.80)
CEO gender		−0.061 (−1.16)		−0.135*** (−2.63)
CEO tenure		0.008*** (3.80)		0.004** (2.20)
CEO age		−0.060 (−0.61)		−0.079 (−0.89)
Constant	1.892*** (12.71)	2.041*** (5.04)	0.690*** (5.04)	0.910** (2.48)
Year FF	Included	Included	Included	Included
Industry FF	Included	Included	Included	Included
Country FF	Included	Included	Included	Included
Observation	14,917	10,469	14,911	10,463
Adj R-squared	0.163	0.148	0.319	0.318
F-statistic p value	0.000	0.000	0.000	0.000

Note: This table presents the relationship between environmental innovation and decoupling using a two-way clustered regression approach at the firm and year levels. The definitions of the variables are provided in Table 2.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

TABLE 7 | Environmental innovation: positive vs. negative environmental decoupling.

	Env_decoupling	
	Positive decoupling	Negative decoupling
	Model 1	Model 2
Env_innovation	-0.017*** (-50.92)	-0.017*** (-25.41)
Firm size	-0.049*** (-4.89)	-0.142*** (-8.89)
ROA	-0.387*** (-2.68)	-0.204 (-1.21)
Leverage	-0.003*** (-3.47)	0.001 (0.67)
Firm age	-0.063*** (-5.49)	-0.132*** (-7.10)
Sale growth	0.002*** (4.48)	0.002*** (3.51)
CSR committee	-0.081*** (-3.40)	-0.125*** (-3.47)
Compensation	0.006*** (6.19)	0.001 (0.91)
Gov_score	-0.001*** (-2.78)	-0.002*** (-2.81)
CEO duality	0.098*** (3.88)	0.059* (1.75)
CEO gender	-0.140*** (-2.64)	-0.102 (-1.46)
CEO tenure	0.005*** (2.63)	0.006** (2.48)
CEO age	-0.072 (-0.78)	-0.058 (-0.51)
Constant	0.675* (1.72)	2.530*** (4.86)
Year FF	Included	Included
Industry FF	Included	Included
Country FF	Included	Included
Observation	1997	8466
Pseudo R-squared	0.133	0.188
F-statistic <i>p</i> value	0.000	0.000

Note: This table presents the effect of environmental innovation on both types of environmental decoupling (positive and negative) using the Tobit regression approach. The definitions of the variables are provided in Table 2.

****p* < 0.01.

***p* < 0.05.

**p* < 0.1.

TABLE 8 | Environmental innovation and decoupling: United States vs. the rest of the world.

	Env_decoupling	
	United States	Rest of the world
	Model 1	Model 2
Env_innovation	-0.017*** (-32.26)	-0.017*** (-39.01)
Firm size	-0.058*** (-3.39)	-0.035*** (-2.66)
ROA	-0.372* (-1.83)	-0.090 (-0.46)
Leverage	-0.003*** (-3.12)	-0.000 (-0.39)
Firm age	-0.064*** (-3.65)	-0.071*** (-4.51)
Sale growth	0.002** (2.28)	0.002*** (3.75)
CSR committee	0.004 (0.11)	-0.141*** (-4.35)
Compensation	0.007 ^a (1.94)	0.007*** (6.14)
Gov_score	-0.002** (-2.08)	-0.001** (-2.15)
CEO duality	0.089*** (2.59)	0.107*** (2.91)
CEO gender	-0.136 ^a (-1.88)	-0.128 ^a (-1.72)
CEO tenure	0.005 ^a (1.71)	0.003 (1.53)
CEO age	-0.353** (-2.54)	0.049 (0.43)
Constant	2.151*** (3.45)	0.137 (0.30)
Year FF	Included	Included
Industry FF	Included	Included
Country FF	Included	Included
Observation	4064	6399
Adj R-squared	0.275	0.347
F-statistic <i>p</i> value	129.438	161.862

Note: This table presents the relationship between environmental innovation and decoupling in the United States compared to the rest of the world using a two-way clustered regression approach at the firm and year levels. The definitions of the variables are provided in Table 2.

****p* < 0.01.

***p* < 0.05.

**p* < 0.1.

of the world. This statistical division is due to the fact that US firms represent the largest proportion of the sample, disproportionately affecting the overall regression results. By isolating US firms, we test whether the observed association between environmental innovation and environmental decoupling is primarily driven by this subsample, or whether it remains consistent across different institutional contexts.

The results confirm that the negative and statistically significant association between environmental innovation and environmental decoupling persists in both groups. However, the effect is stronger among US firms ($coef = -0.019$; $p < 0.01$) than among non-US firms ($coef = -0.013$; $p < 0.05$). This suggests that while environmental innovation narrows the reporting-performance gap globally, this relationship is more pronounced in the United States, perhaps thanks to stronger regulatory frameworks, higher transparency expectations, and more active stakeholder environments. These results strengthen the robustness and external validity of our main findings and highlight the importance of institutional context in moderating the effect of environmental innovation on decoupling.

4.3.3 | Control for Country- and Industry-Level ESG Sensitivity

Table 9 provides an additional robustness check by incorporating controls for ESG sensitivity at the country and industry levels, reflecting the idea that firms' sustainability behaviors are embedded in broader institutional and sectoral contexts. ESG sensitivity, at both the national and sector levels, captures differences in stakeholder pressures, regulatory expectations, and cultural norms that may shape firms' disclosure strategies and sustainability commitments (Al-Shaer and Zaman 2018; Dwekat et al. 2022; La Porta et al. 2006; Meqbel et al. 2024). For CSR-sensitive industries, we classified companies operating in the utilities, mining, and production sectors as being sensitive to corporate social responsibility. These sectors are believed to be better able to convey a positive social image due to the significant environmental impact of their operations (Dwekat et al. 2022).

Regarding the ESG-sensitive countries, and according to Kolk and Perego (2010), the legal environment in which a firm operates determines its CSR expectations and, consequently, its adoption of a sustainability assurance statement. Companies in common law countries tend to follow a shareholder-oriented corporate governance model, while firms in statutory law countries tend to follow a stakeholder-oriented corporate governance model (Ball et al. 2000; Dwekat et al. 2022; Ioannou and Serafeim 2012; La Porta et al. 2006; Meqbel et al. 2024). The shareholder/stakeholder orientation classification is used in this study to identify low and high CSR sensitivity, respectively, and a country's CSR sensitivity is included as a control variable in the model.

By including these controls, we aim to ensure that the observed relationship between environmental innovation and environmental decoupling does not overlap with systemic ESG criteria that vary across jurisdictions and sectors. The results remain consistent with our main findings: Environmental innovation continues to exhibit a negative, statistically significant association with environmental decoupling, even after accounting for

TABLE 9 | Environmental innovation and decoupling (country- and industry-level ESG sensitivity).

	Env_decoupling		
	Model 1	Model 2	Model 3
Env_innovation	-0.016*** (-49.56)	-0.017*** (-53.72)	-0.016*** (-52.82)
Firm size	-0.046*** (-4.72)	-0.034*** (-3.67)	-0.026*** (-2.78)
ROA	-0.271** (-2.00)	-0.200 (-1.47)	-0.292** (-2.15)
Leverage	-0.001** (-2.09)	-0.002*** (-3.40)	-0.002*** (-2.68)
Firm age	-0.072*** (-6.18)	-0.081*** (-7.35)	-0.083*** (-7.49)
Sale growth	0.002*** (4.16)	0.002*** (4.76)	0.002*** (4.64)
CSR committee	-0.059** (-2.50)	-0.160*** (-7.67)	-0.147*** (-7.09)
Compensation	0.007*** (6.39)	0.006*** (9.39)	0.007*** (9.80)
Gov_score	-0.001*** (-2.90)	-0.002*** (-3.28)	-0.002*** (-3.34)
CEO duality	0.083*** (3.41)	0.097*** (4.32)	0.085*** (3.80)
CEO gender	-0.108** (-2.10)	-0.128** (-2.46)	-0.097* (-1.86)
CEO tenure	0.004** (2.11)	0.004** (2.19)	0.004** (2.12)
CEO age	-0.126 (-1.43)	-0.109 (-1.25)	-0.165* (-1.90)
Industry ESG sensitivity	0.238*** (12.12)		0.271*** (13.94)
Country ESG sensitivity		0.073*** (3.29)	0.065*** (2.98)
Constant	0.907** (2.49)	0.852** (2.42)	0.797** (2.26)
Year FF	Included	Included	Included
Industry FF	Excluded	Included	Excluded
Country FF	Included	Excluded	Excluded
Observation	10,463	10,463	10,463
Adj R-squared	0.310	0.298	0.287
F-statistic p value	0.000	0.000	0.000

Note: This table presents the relationship between environmental innovation and decoupling, incorporating country- and industry-level ESG sensitivity variables, using a two-way clustered regression approach at the firm and year levels. The definitions of the variables are provided in Table 2.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

TABLE 10 | Environmental innovation and decoupling (country-level variables).

	Env_decoupling		
	Model 1	Model 1	Model 1
Env_innovation	-0.017*** (-52.36)	-0.017*** (-45.73)	-0.017*** (-45.79)
Firm size	-0.033*** (-3.58)	-0.043*** (-3.70)	-0.051*** (-4.26)
ROA	-0.236* (-1.74)	-0.308** (-1.99)	-0.307** (-1.98)
Leverage	-0.003*** (-3.84)	-0.002** (-2.09)	-0.002** (-2.28)
Firm age	-0.076*** (-6.84)	-0.073*** (-5.48)	-0.074*** (-5.56)
Sale growth	0.002*** (4.12)	0.002*** (3.68)	0.002*** (3.57)
CSR committee	-0.170*** (-8.17)	-0.033 (-1.28)	-0.023 (-0.88)
Compensation	0.006*** (9.30)	0.009*** (8.08)	0.008*** (6.57)
Gov_score	-0.002*** (-3.85)	-0.002*** (-2.67)	-0.002*** (-2.81)
CEO duality	0.062*** (2.66)	0.063** (2.43)	0.047* (1.77)
CEO gender	-0.136*** (-2.60)	-0.188*** (-3.20)	-0.186*** (-3.17)
CEO tenure	0.005*** (2.65)	0.006*** (3.14)	0.007*** (3.39)
CEO age	-0.121 (-1.37)	-0.129 (-1.27)	-0.163 (-1.59)
GDP	0.017** (2.40)		0.054*** (2.70)
GDP growth	0.025*** (4.79)		0.015 (1.44)
PDI		-0.007*** (-3.91)	-0.009*** (-4.62)
IDV		-0.007*** (-5.35)	-0.009*** (-5.90)
MAS		-0.001 (-0.79)	-0.002** (-2.32)

(Continues)

TABLE 10 | (Continued)

	Env_decoupling		
	Model 1	Model 1	Model 1
UAI		0.005*** (4.87)	0.005*** (4.93)
LTOWVS		-0.007*** (-6.95)	-0.005*** (-4.28)
IVR		0.002 (0.86)	0.002 (0.98)
Constant	0.371 (0.94)	1.748*** (3.80)	0.668 (1.16)
Year FF	Included	Included	Included
Industry FF	Included	Included	Included
Country FF	Excluded	Excluded	Excluded
Observation	10,463	10,463	10,463
Adj R-squared	0.299	0.316	0.317
F-statistic <i>p</i> value	0.000	0.000	0.000

Note: This table presents the relationship between environmental innovation and decoupling, incorporating country-level variables using a two-way clustered regression approach at the firm and year levels. The definitions of the variables are provided in Table 2.

****p* < 0.01.

***p* < 0.05.

**p* < 0.1.

country- and sector-specific ESG environments. This strengthens our hypothesis, suggesting that the impact of environmental innovation transcends institutional isomorphism or sectoral norms and reflects embedded strategic capability (Aragón-Correa and Sharma 2003; Hart and Dowell 2011).

Importantly, controls for ESG sensitivity themselves are also significant in several model specifications, suggesting that firms operating in ESG-intensive environments tend to engage in more authentic sustainability practices, consistent with previous findings in institutional and stakeholder theory (Abu Alia et al. 2024; Dwekat et al. 2025; Matten and Moon 2008).

4.3.4 | Control for Country-Level Variables

To further ensure that our main findings reported in Table 6 are robust, we replaced country-fixed effects with several country-level factors that may affect environmental decoupling. We namely included gross domestic product (GDP), gross domestic product growth (GDP growth), and the six Hofstede's cultural dimensions (i.e., power distance index [PDI], individualism [IDV], masculinity [MAS], uncertainty avoidance [UAI], long-term vs. short-term orientation [LTOWVS], and indulgence vs. restraint [IVR]).

In doing so, the outcomes presented in Table 10 show that the association between environmental innovation and environmental

TABLE 11 | Environmental innovation and decoupling (2SLS and PSM approaches).

	2SLS approach		PSM approach	
	Stage 1 Env_innovation	Stage 2 Env_decoupling	Dummy Env_innovation	Env_decoupling
	Model 1	Model 2	Model 3	Model 4
Instrumental variable	0.886*** (37.75)			
FittedEnv_innovation		-0.016*** (-13.37)		
Env_innovation				-0.018*** (-25.82)
Firm size	5.350*** (21.33)	-0.047*** (-3.63)	0.254*** (18.80)	0.039*** (3.05)
ROA	6.001** (2.13)	-0.320** (-2.13)	0.647*** (3.53)	-0.098 (-0.47)
Leverage	-0.116*** (-7.05)	-0.002** (-2.09)	-0.007*** (-7.46)	0.002 ^a (1.84)
Firm age	3.698*** (12.25)	-0.072*** (-5.21)	0.184*** (12.18)	-0.090*** (-6.34)
Sale growth	-0.043*** (-4.23)	0.002*** (3.79)	-0.003*** (-4.56)	0.001 (1.27)
CSR committee	2.007*** (2.99)	-0.062** (-2.39)	0.005 (0.16)	0.011 (0.36)
Compensation	-0.011 (-0.47)	0.007*** (5.80)	-0.002* (-1.73)	0.006*** (4.36)
Gov_score	0.135*** (10.81)	-0.001** (-2.10)	0.007*** (11.01)	0.000 (0.69)
CEO duality	1.283** (1.98)	0.085*** (3.08)	0.004 (0.11)	0.062* (1.84)
CEO gender	-5.148*** (-4.39)	-0.133** (-2.55)	-0.153** (-2.38)	0.007 (0.12)
CEO tenure	-0.145*** (-3.24)	0.004* (1.93)	-0.008*** (-3.67)	-0.001 (-0.39)
CEO age	2.023 (0.91)	-0.056 (-0.58)	-0.062 (-0.53)	0.319** (2.41)
Constant	-104.635*** (-11.54)	0.724* (1.75)	-4.722*** (-9.56)	-2.215*** (-4.17)
Year FF	Included	Included	Included	Included
Industry FF	Included	Included	Included	Included
Country FF	Included	Included	Included	Included

(Continues)

TABLE 11 | (Continued)

	2SLS approach		PSM approach	
	Stage 1 Env_innovation	Stage 2 Env_decoupling	Dummy Env_innovation	Env_decoupling
	Model 1	Model 2	Model 3	Model 4
Observation	10,463	10,463	10,463	5300
Adj <i>R</i> -squared	0.342	0.161		0.201
F-statistic <i>p</i> value	0.000	0.000		0.000
Pseudo <i>R</i> -squared			0.183	
Wald chi2 <i>p</i> value			0.000	

Note: This table presents the relationship between environmental innovation and decoupling using the two-stage least squares (2SLS) and propensity score matching (PSM) approaches. The definitions of the variables are provided in Table 2.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

decoupling across the three models remains consistent after controlling for the aforementioned country-level factors. Among these variables, several factors show a significant impact on environmental decoupling. The economic indicators exhibit mixed effects: while higher GDP is positively associated with decoupling ($coef = 0.054$; p value < 0.01), GDP growth is not consistently statistically significant, suggesting that institutional maturity, rather than expansion dynamics, plays a more important role (Luo et al. 2017; Marquis and Qian 2014).

The cultural dimensions yield insightful results. The PDI and UAI are positively and statistically significantly related to withdrawal ($coef = 0.005$ – 0.009 ; $p < 0.01$), suggesting that hierarchical, risk-averse societies may promote symbolic compliance. In contrast, IDV and LTOWVS exhibit negative correlations ($coef = -0.009$ and -0.005 ; $p < 0.01$), suggesting that cultures that encourage independence and forward-thinking are more likely to implement authentic environmental practices.

4.3.5 | Different Model Specifications

As is common in governance and ESG research, the relationship between environmental innovation and decoupling may be influenced by endogeneity issues arising from omitted variables, reverse causality, and sample selection bias. In line with previous studies (Ahmed et al. 2024; Gull et al. 2024; Meqbel et al. 2025), we address these potential endogeneity concerns by employing two alternative regression approaches: the two-stage least squares (2SLS) model and the propensity score matching (PSM) model.

First, in line with previous studies (Ahmed et al. 2024; Dwekat et al. 2025), we employed the 2SLS model to address potential endogeneity issues related to omitted variables and reverse causality. Applying the 2SLS model requires selecting an instrumental variable that influences the independent (endogenous) variable but does not directly affect the dependent variable. Using the average value at the level of country and industry as an instrumental variable is common in literature (Boubakri et al. 2018; Meqbel et al. 2025). The reasoning is that the governance practices of a firm are highly influenced by other firms

operating in the same country and industry, but the average value does not directly affect the firm's performance. In line with this assumption, we use the country-industry average of environmental innovation as an instrumental variable to estimate the fitted value of environmental innovation (as shown in Table 11, Model 1). In the second step, we examine the effect of the fitted value of environmental innovation on environmental decoupling. The results of this step, reported in Table 11, Model 2, indicate a negative effect ($coef = -0.016$; $p < 0.01$), consistent with our main results. These findings confirm that our results are robust and free from endogeneity concerns.

Second, we employed the PSM model to address potential sample selection bias that may exist in our study. This model is widely used in the literature to mitigate such issues in empirical analyses (Abweny et al. 2026; Gull et al. 2024; Li et al. 2023). In the first step of applying the PSM model, we performed a probit regression with the dependent variable, environmental innovation, coded as 1 if above the overall mean and 0 otherwise. This approach allowed us to create a matched sample that is identical within a 1% difference in propensity scores for our control variables (as shown in Table 11, Model 3), while differing with respect to environmental decoupling. In the second step, we re-estimated the relationship between environmental innovation and decoupling using a matched sample of 5300 firm-year observations (as reported in Table 11, Model 4). The results of the PSM, as reported in Model 4, show a negative relationship between environmental innovation and decoupling ($coef = -0.018$; $p < 0.01$), which is consistent with our main results reported in Table 6, Models 3 and 4. These findings confirm that our results are free from endogeneity concerns, particularly those arising from sample selection bias due to the non-random distribution of firms engaging in environmental innovation.

5 | Conclusion

Despite increasing pressure on firms to adopt sustainability practices, evidence shows that environmental disclosures often deviate from firms' actual performance, leading to what is known as environmental decoupling. This misalignment poses

serious concerns for investors, policymakers, and broader stakeholders, as it undermines their trust, exposes firms to legitimacy risks, and promotes strategic reporting over substantive transformation. Such gaps between disclosure and performance reflect symbolic responses to corporate pressures, as companies seek to maintain their external legitimacy without fully aligning their internal practices.

Against this backdrop, this study aims to examine the relationship between environmental innovation and environmental decoupling. Using a multinational panel dataset for the period 2010–2020, the analysis revealed a strongly significant negative relationship between environmental innovation and decoupling. Specifically, the coefficient on environmental innovation was found to be both stable and significant, supporting Hypothesis 1. This finding suggests that companies that engage in substantive environmental innovation are less likely to rely on symbolic disclosure practices, thus reducing the gap between reported and actual environmental performance.

These findings are consistent with legitimacy theory, which posits that companies respond to increasing societal and regulatory expectations by aligning their activities with external norms and values. In this context, environmental innovation is a reliable and observable mechanism that enables companies to demonstrate a genuine commitment to environmental responsibility and bridge legitimacy gaps. Rather than relying on tokenistic reporting, companies that implement innovation-driven environmental improvements are better positioned to back up their disclosures with tangible results, thereby enhancing their perceived credibility.

This study offers several crucial implications. Theoretically, it contributes to the environmental decoupling literature by providing empirical evidence that core strategic actions, such as environmental innovation, play a crucial role in reducing the discrepancy between reporting and actual performance. By focusing on legitimacy theory, the study deepens the understanding of how companies can move from symbolic compliance to more effective engagement. In practice, the findings highlight the importance of companies integrating environmental innovation into their core operations to enhance credibility and maintain stakeholder trust. Therefore, corporate boards and corporate social responsibility committees should prioritize innovation-led environmental strategies that support both transparent performance and reporting. From a regulatory perspective, policymakers and standard-setting bodies could benefit from strengthening frameworks that emphasize verifiable environmental actions alongside disclosure requirements. At the societal level, the findings support efforts to encourage genuine corporate engagement in addressing environmental challenges, thereby boosting public trust and contributing to broader sustainability goals.

Finally, we acknowledge that our study has some limitations that could be addressed in future research. First, while the focus is on environmental responsibility, future research could broaden the analysis to include the social dimension, thereby allowing a more comprehensive understanding of the disconnect between environmental performance and the ESG (environmental, social, and governance) domains. Second, measurement challenges remain, as differences in ESG classification

methodologies may affect the accuracy of disconnection indicators. Future studies could therefore benefit from incorporating more detailed or qualitative measures of environmental performance and disclosure. Additionally, longitudinal case studies, qualitative interviews, or mixed-methods research could help uncover the organizational processes by which environmental innovation initiatives translate into lower levels of decoupling over time. Third, matching corporate data from multiple sources resulted in missing data, which may affect the generalizability of the findings.

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Conflicts of Interest

The authors declare no conflicts of interest.

Endnotes

¹ Refer to Table 4 for further details.

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