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# CORPORATE BIODIVERSITY GOVERNANCE AND FIRM ENVIRONMENTAL PERFORMANCE: THE ROLES OF BIODIVERSITY DISCLOSURE, CSR-LINKED EXECUTIVE COMPENSATION, AND ENVIRONMENTAL INNOVATION

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**Abstract**

*Whether corporate environmental performance reflects what firms disclose, how executives are rewarded or the capabilities firms build remains an open empirical question. Drawing on stakeholder theory, this study examines the joint association of biodiversity disclosure (an information mechanism), CSR-linked executive compensation (an incentive mechanism) and environmental innovation (a capability mechanism) with the environmental pillar score of 664 firms from 20 countries and economies over 2015–2025. Pooled, random-effects and firm fixed-effects estimates show positive associations for all three variables. Within firms, biodiversity disclosure is associated with a 5.743-point higher score and CSR-linked compensation with a 2.781-point higher score, while a one-standard-deviation increase in environmental innovation corresponds to a 14.0-point higher score (0.60 standard deviations). Innovation is the most robust association, remaining stable when year effects are introduced, whereas the disclosure and compensation associations are sensitive to common time trends. All estimates are conditional associations. The findings imply that boards and investors should give weight to innovation capability and complement disclosure and pay-linkage practices with measurable targets and verification, while regulators should specify the content and quality of biodiversity disclosure.*

**Keywords:** Biodiversity Disclosure, Corporate Environmental Performance, CSR-linked Executive Compensation, Environmental Innovation, Stakeholder Theory, Panel Data

## 1. Introduction

The pressure of human activities on the Earth system has grasped a scale at which the stability of the conditions underpinning economic activity can no longer be assumed. The most recent assessment of planetary boundaries concludes that six of the nine boundaries have been transgressed (Richardson et al., 2023), and the global assessment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services estimates that around one million animal and plant species face extinction, many within decades (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], 2019). Giglio et al. (2023) develop measures of aggregate and firm-level biodiversity risk and relate them to asset prices, and Garel et al. (2024) find that a science-based biodiversity footprint commanded a premium after the Kunming Declaration, consistent with investors anticipating regulatory and litigation risk. Garel et al. (2026) extend this line of work with firm-level measures of nature dependence. Policy is converging on disclosure as the primary instrument: target 15 of the Kunming-Montreal Global Biodiversity Framework asks governments to take measures so that large and transnational companies and financial institutions regularly monitor, assess and transparently disclose their biodiversity risks, dependencies and impacts (Convention on Biological Diversity [CBD], 2022), and the recommendations of the Taskforce on Nature-related Financial Disclosures (TNFD, 2023) provide a reporting architecture. Finance research on nature has nevertheless

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concentrated on exposure and asset pricing. It has been said much less about whether the levers that firms themselves control are associated with better environmental outcomes.

These factors may serve as important determinants of environmental performance. The first is biodiversity disclosure; it may make corporate conduct visible and contestable to investors, regulators, and civil society, and may oblige firms to build the measurement systems on which improvement depends. Yet disclosure can substitute equally for action: better environmental performers disclose more, which implies that causality may run from performance to disclosure (Clarkson et al., 2008), and biodiversity reporting is susceptible to impression management (Boiral, 2016). The second knob is incentives. Linking executive pay to environmental and social benchmarks may redirect managerial attention towards stakeholders in decisions. Flammer et al. (2019) connect the integration of CSR criteria into pay with greater long-term orientation, higher firm value and better social and environmental performance, and Cohen et al. (2023) provide evidence for the rapid international diffusion of ESG metrics in pay, accompanied by improvements in key ESG outcomes but not in financial performance. Bebchuk and Tallarita (2022), however, argue that such metrics are limited, opaque, and potentially self-serving. The third level is capability. Environmental innovation changes products and processes and is the most direct route through which a firm can alter its footprint (Berrone et al., 2013; Porter & van der Linde, 1995).

Existing empirical research has four limitations. First, the three mechanisms are studied in isolation, so their relative association with environmental performance is unknown. Second, the biodiversity-reporting literature has mainly described reporting practice or its determinants within particular jurisdictions (Rimmel & Jonäll, 2013; van Liempd & Busch, 2013; Haque & Jones, 2020; Hambali & Adhariani, 2024; Bernardo & Carnegie, 2024), and the studies that relate biodiversity disclosure or exposure to ESG outcomes draw on Chinese listed firms (Ding et al., 2026; Wang et al., 2026); cross-country evidence on disclosure and environmental performance is thin. Third, studies use heterogeneous outcome measures, such as emissions, carbon performance or composite ratings, and composite ratings differ across providers in scope, weights, and measurement (Berg et al., 2022; Drempetic et al., 2020). Fourth, reverse causality, measurement overlap between a composite score and its components, and common time trends are seldom confronted openly, even though environmental performance may itself shape disclosure (Al-Tuwaijri et al., 2004), executive pay (Berrone & Gomez-Mejia, 2009) and innovation (Lian et al., 2023).

These limitations define the research problem of this paper: it is unclear which corporate levers are consistently associated with environmental performance across countries, and how far apparent associations reflect common time shocks, score construction or selection rather than firm-level relationships. In the literature this study reviewed, this study did not identify a study that examines biodiversity disclosure, CSR-linked executive compensation and environmental innovation jointly in a multi-country panel while reporting how the estimates change once time effects, cross-sectional dependence and measurement overlap are acknowledged. This study presents this as a gap in the literature reviewed and not as a claim that no related study exists. The study addresses four research questions. Is biodiversity disclosure associated with higher firm-level environmental performance (RQ1)? Is CSR-linked executive compensation associated with higher environmental performance (RQ2)? Is environmental innovation associated with higher environmental performance (RQ3)? And how stable are these associations, once common time shocks, cross-sectional dependence, and heterogeneity across firms are considered (RQ4)?

To answer these questions, this study analyzes a balanced panel of 664 firms from 20 countries and economies over 2015–2025, comprising 7,304 firm-year observations. The outcome is the environmental pillar score (0–100), and the explanatory variables are a binary indicator of biodiversity disclosure, a binary indicator of CSR-linked executive compensation and an environmental innovation score (0–100). This study estimates pooled ordinary least squares, random-effects and firm fixed-effects models and report diagnostics for cross-sectional dependence and slope heterogeneity. In the baseline fixed-effects model all three variables are positively associated with environmental performance at the 1% level. A sensitivity analysis on originally observed values, however, indicates that the disclosure and compensation coefficients lose statistical

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significance once year effects are added, whereas the innovation coefficient remains stable. The study reports this pattern as it stands and interprets all coefficients as conditional associations.

Studying contributes in three ways. Theoretically, it applies a single stakeholder-based framework to three mechanisms usually treated separately, assigns each a specific supporting theory, and states for each the symbolic interpretation that would predict no positive association. Through empirical observation, it provides joint multi-country evidence on the association of disclosure, incentives and innovation with environmental performance and shows how far implication changes once common time effects and dependence are acknowledged. Practically, it gives boards, investors and regulators a calibrated view of which indicators are most consistently related to environmental scores, and which require verification before they are examined as evidence of environmental action.

The remainder of the paper is structured in following sequences. The 2nd section presents the theoretical framework, literature reviews literature and develops hypotheses. Section 3 describes the data, variables, and estimation strategy. Section 4 reports the empirical results and discusses them; Section 5 concludes and draws theoretical, managerial and policy implications.

## 2. Literature Review and Theoretical Framework

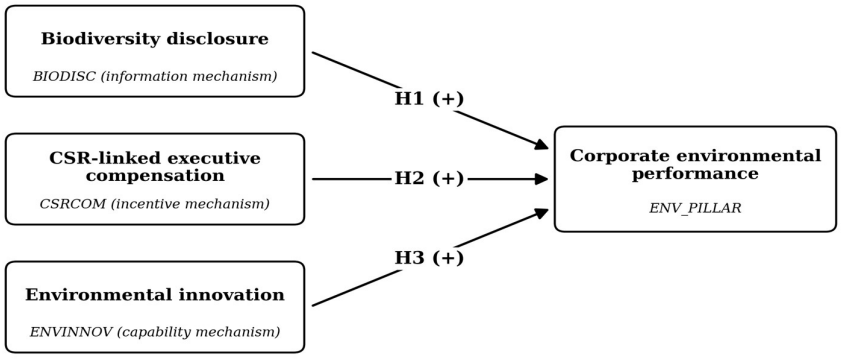
### *2.1 Theoretical Framework*

The study adopt stakeholder theory as the overarching framework because it offers one logic that speaks to all three mechanisms: a firm's outcomes depend on how it manages its relationships with the groups that affect, or are affected by, its operations (Freeman, 1984). Donaldson and Preston (1995) distinguish descriptive, instrumental, and normative strands of the theory. This study draws on the descriptive and instrumental strands, which yield predictions about observable behaviour and outcomes, and take no position on the normative claim. Three concepts organise the arguments that follow. Salience, in the sense of Mitchell et al. (1997), implies that managers deal with claims in proportion to the power, legitimacy and urgency of claimants. The natural environment has legitimacy and urgency but no power of its own, so its claims reach management through intermediaries such as regulators, investors, lenders, and civil society organisations. Accountability and external monitoring describe how these intermediaries obtain the information they need to press such claims. Environmental responsibility describes the capabilities through which responsiveness is converted into action.

The framework is maps on three mechanisms (Figure 1). Biodiversity disclosure is an information mechanism: by making conduct visible, it supports accountability and external monitoring. CSR-linked executive compensation is an incentive mechanism: by embedding environmental criteria in managers' own payoffs, it raises the weight that environmental claims receive in decisions. Environmental innovation is a capability mechanism: it is how the firm can change what it does and so alter its footprint. CSROOM denotes the incorporation of CSR, environmental or sustainability criteria into executive compensation. It does not denote a board-level CSR committee, which is a monitoring structure and not an incentive device; Radu and Smaili (2022) show that the two interact, but only the former is measured here.

**Figure 1**

*Conceptual Framework*



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*Note.* The figure presents the conceptual framework linking biodiversity disclosure, CSR-linked executive compensation, environmental innovation, and corporate environmental performance.

Stakeholder theory is a flexible lens, and its flexibility is also its main weakness. Its core terms are loosely specified, so almost any observed association can be rationalised after the fact, and the theory does not by itself distinguish a substantive response from a symbolic one (Bebchuk & Tallarita, 2022). The study therefore disciplines its use in two ways. First, establishing theories are introduced only where they explain a specific relationship. Agency theory explains why compensation contracts may align managerial payoffs with environmental objectives and why unclear and ambiguous metrics may instead create a new agency problem (Berrone & Gomez-Mejia, 2009; Jensen & Meckling, 1976). The natural-resource-based view explains why capabilities such as pollution prevention and product stewardship should improve environmental performance (Hart, 1995). Legitimacy and institutional arguments explain why disclosure and pay arrangements may be adopted symbolically and why their consequences may differ across regulatory and normative settings (Boiral, 2016; DiMaggio & Powell, 1983; Suchman, 1995).

### *2.2 Biodiversity Disclosure and Corporate Environmental Performance*

The theory of stakeholders indicates three pathways through biodiversity disclosure to improve environmental outcomes: External accountability is the first. Disclosure provides investors, regulators and civil society with the information they need to assess and challenge corporate actions, and the policy environment is placing a premium on disclosure: the Kunming-Montreal framework requires disclosure of biodiversity risks, dependencies and impacts (CBD, 2022), and investors have begun to value biodiversity exposure since the Kunming Declaration (Garel et al., 2024). The second path is inwards. But a firm that can't measure its impact and take responsibility for it isn't really disclosing if it isn't also creating an information system that supports improvements. Signaling is the third path; voluntary disclosure by stronger performers can help to separate them from poorer performers (Clarkson et al., 2008; this is also an implicit argument of the observed association, that it might be part of a selection into disclosure).

Disclosure is believed to be an alternative to action in the opposing literature. Boiral (2016) considers biodiversity reporting as impression management, and Berrone et al. (2017) explore the link between environmental actions and environmental legitimacy, which assumes that there is separation between communication and substance. The evidence of motives is the same. Biodiversity reporting in a Finnish sample was found to be positively associated with the legitimation process (interpreted by the authors as weak water and waste performance) and found to be associated with assurance, sector and country factors as well as with greenwashing motives (Hassan et al., 2020; Dutta & Dutta, 2024). From this perspective, disclosure of biodiversity would have nothing to do and perhaps even be inversely related with environmental performance, after controlling for exposure.

The empirical foundation for biodiversity is expanding, and is now largely descriptive and jurisdictional specific. Documentation of reporting practices exists for Sweden and Denmark (Rimmel & Jonäll, 2013; van Liempd & Busch, 2013) and determinants have been examined for European firms, for example through gender diversity in the boards (Haque & Jones, 2020), for companies from 37 countries between 2016 and 2020 through institutional and governance factors (Hambali & Adhariani, 2024) and for firms from Italy through a disclosure-quality index, where about 30% of the sample reported biodiversity practices and disclosure was not optimal (Bernardo & Carnegie, 2024). On the performance side, Ding et al. (2026) report that corporate biodiversity exposure is positively related to ESG performance among Chinese listed firms, and Wang et al. (2026), using Chinese listed firms over 2010–2022, find that biodiversity disclosure enhances ESG performance and that the effect weakens under physical climate risk. Both studies use composite ESG outcomes, and the latter is closest to the present question; neither is cross-country, and neither examines how the estimates behave once common time effects are added. The broader environmental-disclosure literature is also bi-directional; those firms with better environmental performance disclose more (Clarkson et al., 2008) and that disclosure, 2004).

There are four outstanding problems. The first is direction: For instance, the paragraphs above demonstrate that. The second is quality: a binary measure of adoption can't distinguish between detailed and

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verifiable reporting and boilerplate. The third is time. However, disclosure and environmental scores may be increasing in tandem in recent years, without a clear correlation with the firm level as increasing regulatory and investor focus on biodiversity. The fourth is measurement. Many of the parts of any association would be mechanical if the environmental score is constructed from data that is publicly reported, with firms that report more data having more data to score. The stakeholder theory suggests that disclosure would support scrutiny and accountability, and that disclosure firms would be more likely to have the capacity to measure what they disclose that would enable them to improve, while the symbolic view suggests no positive relationship. In this study, the positive prediction is examined and the competing prediction acknowledged.

**H1.** Biodiversity disclosure is positively associated with corporate environmental performance.

### *2.3 CSR-Linked Executive Compensation and Corporate Environmental Performance*

Tying executive pay to environmental, social or sustainability criteria is increasingly proposed as a governance remedy for the under-representation of non-shareholder claims in managerial decisions. Stakeholders and agency arguments identify three channels through which such contracts could raise environmental performance. When part of an executive's reward depends on environmental outcomes, the executive's private payoff becomes sensitive to the interests of stakeholders who would otherwise exert little influence on resource allocation. Flammer et al. (2019) argue that CSR criteria in compensation redirect managerial focus towards stakeholders who are less salient but financially material over the long run, which, in the salience logic of Mitchell et al. (1997), raises the weight that environmental claims receive in decision-making. The third is organisational learning: adopting such contracts commits the firm to measurement and reporting, and may thereby build the routines required to act on environmental targets.

The empirical record offers qualified support for these channels. Flammer et al. (2019), studying US firms and exploiting a legal instrument for adoption, associate the integration of CSR criteria into executive pay with greater long-term orientation, higher firm value and improved social and environmental outcomes. Cohen et al. (2023), using an international sample, document the rapid diffusion of ESG metrics in pay and find that adoption is accompanied by improvements in key ESG results but not in financial performance. Derchi et al. (2021) report that CSR-linked compensation promotes CSR performance as firms accumulate experience with it, and Haque and Ntim (2020) provide related evidence on sustainable compensation policy and carbon performance. Adoption itself is not exogenous; better-governed firms are more likely to link pay to CSR criteria (Hong et al., 2016).

Derchi et al. (2021) find that the use of CSR-linked pay does not immediately improve CSR performance and that its effect depends on complementary arrangements. Maas (2018) shows that CSR targets in executive pay do not automatically translate into better social performance, and that quantitative targets are the efficient ones. Haque and Ntim (2020) find that executive pay is related to process-oriented but not to actual carbon performance, which suggests that incentive effects may surface in the policies and practices taken by a composite score before, or instead of, physical outcomes. Bebchuk and Tallarita (2022) argue that ESG metrics in pay cover a limited subset of stakeholder concerns, are difficult to evaluate and may exaggerate the agency problem they are meant to solve, while Kolk and Perego (2014) ask whether sustainability bonuses signal responsibility or constitute window dressing. Causality may also run in the opposite direction, because environmental outcomes may itself be rewarded in pay, as Berrone and Gomez-Mejia (2009) report for polluting industries.

First, adoption varies scientifically across countries, industries and firms (Cohen et al., 2023), so adopters may differ in ways that also determine environmental performance. Second, a binary indicator of CSR-linked pay cannot capture the consequence, quantifiability or scope of targets, which the literature identifies as decisive (Maas, 2018). Third, effects may materialise only with a lag (Derchi et al., 2021). Fourth, because adoption has circulated rapidly over the same period in which environmental scores have coasted upward, common time trends may generate an association that is not firm-specific. The compensation mechanism must also be distinguished from board-level CSR committees, which operate through monitoring and not through incentives (Radu & Smaili, 2022). The stakeholder-agency account predicts that embedding

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environmental criteria in pay raises the managerial priority attached to environmental claims, whereas the agency critique predicts no association where metrics are weak or opaque.

### *2.4 Environmental Innovation and Corporate Environmental Performance*

Environmental innovation is the most direct channel through which a firm can alter its footprint because it changes products, processes, and services and not only how these are reported or rewarded. Within stakeholder theory it is the capability through which stakeholder claims are translated into practice. The natural-resource-based view adds that capabilities such as pollution prevention and product stewardship can improve environmental outcomes and competitive position (Hart, 1995). Berrone et al. (2013) show that institutional pressure is associated with greater environmental invention among polluting firms, consistent with innovation as a stakeholder-responsive capability, and Porter and van der Linde (1995) argue that well-designed environmental pressure can trigger innovation offsets that improve environmental and economic outcomes together. Firm-level evidence links green research and development to lower carbon emissions (Lee & Min, 2015).

Because the instrumental prediction is the more specific and refutable of the two, it is stated as the hypothesis:

**H2.** CSR-linked executive compensation is positively associated with corporate environmental performance.

### *2.5 Environmental Innovation and Corporate Environmental Performance*

Environmental innovation is the most direct channel through which a firm can alter its footprint because it changes products, processes, and services and not only how these are reported or rewarded. Within stakeholder theory it is the capability through which stakeholder claims are translated into practice. The natural-resource-based view adds that capabilities such as pollution prevention and product stewardship can improve environmental outcomes and competitive position (Hart, 1995). Berrone et al. (2013) show that institutional pressure is associated with greater environmental invention among polluting firms, consistent with innovation as a stakeholder-responsive capability, and Porter and van der Linde (1995) argue that well-designed environmental pressure can trigger innovation offsets that improve environmental and economic outcomes together. Firm-level evidence links green research and development to lower carbon emissions (Lee & Min, 2015).

Empirical literature has, however, addressed the link between innovation and environmental performance indirectly. Most studies examine the determinants of environmental innovation or its financial consequences, and the closest evidence on environmental outcomes is bidirectional: ESG performance has been associated with subsequent green innovation (Lian et al., 2023), which implies that environmentally performing firms, or those with the financial and organisational slack to fund environmental effort, may innovate more. Two issues therefore deserve attention. The first is reverse causality, as just noted. The second is measurement overlapping. Some ESG databases construct the environmental pillar from category scores that include environmental innovation; where this applies, part of any association is mechanical and not behavioural. Innovation activity is also an input or an intermediate output, and its translation into a lower measured footprint is neither automatic nor immediate.

Stakeholder theory in its instrumental form, together with the capability logic of the natural-resource-based view, predicts that firms with stronger environmental innovation achieve higher environmental performance. This study therefore states:

**H3.** Environmental innovation is positively associated with corporate environmental performance.

### *2.6 Research Gap*

Although previous studies have examined biodiversity disclosure, CSR-linked executive compensation and environmental innovation, their joint relationship with corporate environmental performance remains insufficiently understood. Recent research shows that biodiversity disclosure is associated with ESG performance (Bassen et al., 2025; Wang et al., 2026), while other studies highlight its potential role in reducing greenwashing and shaping corporate sustainability strategies (He et al., 2025). Similarly, international evidence links ESG-related executive compensation with improved sustainability

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outcomes (Cohen et al., 2023), although recent findings suggest that its effectiveness depends on complementary governance mechanisms and the extent to which incentives translate into substantive environmental practices (Eliwa et al., 2025). Research also identifies environmental innovation as an important mechanism for improving environmental outcomes, although the relationship may be bidirectional, as stronger sustainability performance can stimulate green innovation (Zhang et al., 2026). Despite these developments, limited evidence examines disclosure, executive incentives and innovation simultaneously within a multi-country firm-level framework, particularly while accounting for firm-specific heterogeneity, common time effects, cross-sectional dependence and potential measurement overlap in composite environmental scores (Berg et al., 2022; Drempetic et al., 2020). Therefore, this study addresses this gap by jointly examining the associations of biodiversity disclosure, CSR-linked executive compensation and environmental innovation with corporate environmental performance across 664 firms from 20 countries and economies over 2015–2025, while assessing the robustness of these relationships across alternative empirical specifications.

## 3. Data and Methodology

### *3.1 Data and Sample*

The analysis uses a panel of 664 firms from 20 countries and economies observed annually over 2015–2025: Japan, the United States, Malaysia, India, Thailand, Canada, China, France, the United Kingdom, Indonesia, Brazil, Turkey, Germany, Italy, South Korea, Spain, Hong Kong, Taiwan, Mexico and Norway. The panel is strongly balanced and contains 7,304 firm-year observations (664 firms × 11 years). Firm-level data were obtained from LSEG Refinitiv database.

### *3.2 Variables*

Corporate environmental performance (ENV_PILLAR) is the environmental pillar score, which ranges from 0 to 100. Biodiversity disclosure (BIODISC) is a binary indicator equal to one if the firm reports biodiversity-related information each year. CSR-linked executive compensation (CSRCOM) is a binary indicator equal to one if the firm links executive compensation to CSR, environmental or sustainability criteria; it does not capture the existence of a CSR committee. Environmental innovation (ENVINNOV) is a continuous score from 0 to 100. Table 1 summarizes the variables and the hypothesized relationships.

**Table 1**

*Variable Definitions and Hypothesized Relationships*

| Variable | Definition | Type | Role | Predicted sign |
|---|---|---|---|---|
| ENV_PILLAR | Environmental pillar score | Continuous, 0–100 | Dependent | n/a |
| BIODISC | 1 if the firm discloses biodiversity-related information, 0 otherwise | Binary | Explanatory (H1) | Positive |
| CSRCOM | 1 if executive compensation is linked to CSR, environmental or sustainability criteria, 0 otherwise | Binary | Explanatory (H2) | Positive |
| ENVINNOV | Environmental innovation score | Continuous, 0–100 | Explanatory (H3) | Positive |

### *3.3 Econometric Specification*

This study estimates the relationship between environmental performance and the three explanatory variables using pooled ordinary least squares, random-effects, and firm fixed-effects models. Let $i$index firms and $t$index years. The pooled model is

$$\text{ENV_PILLAR}_{it} = \alpha + \beta_1 \text{BIODISC}_{it} + \beta_2 \text{CSRCOM}_{it} + \beta_3 \text{ENVINNOV}_{it} + \epsilon_{it}, \quad (1)$$

where $\alpha$is a common intercept, $\beta_1$and $\beta_2$are the average differences in the environmental score associated with biodiversity disclosure and CSR-linked compensation, $\beta_3$is the change in the score associated

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with a one-point change in innovation, and $\epsilon_{it}$ is the error term. The random-effects model adds a firm-specific component,

$$\text{ENV_PILLAR}_{it} = \alpha + \beta_1 \text{BIODISC}_{it} + \beta_2 \text{CSRCOM}_{it} + \beta_3 \text{ENVINNOV}_{it} + u_i + \epsilon_{it}, \quad (2)$$

where $u_i$ is a firm effect assumed uncorrelated with the regressors. The firm fixed-effects model replaces the common intercept with a firm-specific intercept,

$$\text{ENV_PILLAR}_{it} = \alpha_i + \beta_1 \text{BIODISC}_{it} + \beta_2 \text{CSRCOM}_{it} + \beta_3 \text{ENVINNOV}_{it} + \epsilon_{it}, \quad (3)$$

where $\alpha_i$ absorbs all time-invariant firm and country characteristics, so that the coefficients are identified from within-firm variation over time. For the binary variables this means that $\beta_1$ and $\beta_2$ are identified only from firms whose status changes during the sample. The baseline models include neither year effects nor additional controls and use conventional standard errors. Because common time developments are a central threat to inference in this setting, this study also estimates a two-way specification,

$$\text{ENV_PILLAR}_{it} = \alpha_i + \lambda_t + \beta_1 \text{BIODISC}_{it} + \beta_2 \text{CSRCOM}_{it} + \beta_3 \text{ENVINNOV}_{it} + \epsilon_{it}, \quad (4)$$

where $\lambda_t$ is a year effect that absorbs shocks and trends common to all firms. Equation (4) is estimated on the subsample of originally observed values, with firm-clustered standard errors (Petersen, 2009). All coefficients are interpreted as conditional associations; no identification strategy that would support causal reading is available in the present data.

### *3.4 Diagnostic and Specification Tests*

Cross-sectional dependence is evaluated with the Pesaran (2004, 2015) CD test, which is based on the average of pairwise correlations across firms. Slope homogeneity is evaluated with the Pesaran and Yamagata (2008) test and the Blomquist and Westerlund (2013) test, the latter robust to serial correlation, whose null hypothesis is that slope coefficients are identical across firms. The choice among pooled, random-effects and fixed-effects models draws on the F test for firm effects and the Breusch-Pagan Lagrange multiplier test. Multicollinearity is assessed with variance inflation factors. The Levin-Lin-Chu (Levin et al., 2002) test rejects the unit-root null for all four variables (adjusted $t^*$ between −4.80 and −40.04; all $p < .001$). This study does not rely on it, because it assumes cross-sectional independence, which is rejected below, was run without a deterministic trend and is designed for continuous series, so its verdict for the two binary variables carries little meaning. For the same reasons, and because the panel has only eleven annual observations per firm, cointegration tests are not pursued.

## 4. Results

### *4.1 Descriptive Statistics and Correlations*

Table 2 summarizes the variables. The environmental pillar score has a mean of 61.218 and a standard deviation of 23.373 and spans the full range of the scale. The innovation score is more dispersed (mean 41.682, standard deviation 33.784), a pattern typical of scores on which many firms record little activity while a minority score very highly. Biodiversity disclosure is present in 42.6% of firm-years and CSR-linked executive compensation in 37.8%.

**Table 2**

*Descriptive Statistics*

| Variable | Obs. | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| ENV_PILLAR | 7,304 | 61.218 | 23.373 | 0.000 | 98.958 |
| BIODISC | 7,304 | 0.426 | 0.494 | 0 | 1 |
| CSRCOM | 7,304 | 0.378 | 0.485 | 0 | 1 |
| ENVINNOV | 7,304 | 41.682 | 33.784 | 0.000 | 99.882 |

Table 3 represents the correlation matrix. All three explanatory variables correlate positively and significantly with environmental performance. The innovation score has by far the strongest correlation (0.617), compared with 0.271 for biodiversity disclosure and 0.217 for CSR-linked compensation. Correlations among the explanatory variables are modest (0.110 to 0.286), and the variance inflation factors

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lie between 1.03 and 1.11, with a mean of 1.08, so multicollinearity does not affect the estimates. A correlation of 0.617 implies that about 38% of the variance of the pillar is shared with the innovation score in a bivariate sense; this is also what mechanical overlap between the two measures would produce, so it should not be read as independent evidence.

**Table 3**

*VIF and Correlation Matrix*

| Variable | (1) | (2) | (3) | (4) | VIF |
|---|---|---|---|---|---|
| (1) ENV_PILLAR | 1 | | | | |
| (2) BIODISC | 0.271*** | 1 | | | 1.11 |
| (3) CSRCOM | 0.217*** | 0.286*** | 1 | | 1.09 |
| (4) ENVINNOV | 0.617*** | 0.150*** | 0.110*** | 1 | 1.03 |
| Mean VIF | | | | | 1.08 |

*Note.* *** $p < .001$.

### *4.2 Cross-Sectional Dependence and Slope Heterogeneity*

Table 4 shows that cross-sectional independence is rejected for every variable. The CD statistics are largest for biodiversity disclosure (1,150.388), implying an average pairwise correlation of about 0.74 across firms; for the environmental pillar, the corresponding average is about 0.22. These values reflect strong common movements in the series, as expected for variables that trend upward across firms over the same period, and they are also influenced by the binary nature of two of the variables and by the completion of missing values.

**Table 4**

*Cross-Sectional Dependence*

| Variable | CD statistic | p-value | Mean pairwise correlation |
|---|---|---|---|
| ENV_PILLAR | 344.472 | 0.000 | 0.22 |
| BIODISC | 1,150.388 | 0.000 | 0.74 |
| CSRCOM | 236.717 | 0.000 | 0.15 |
| ENVINNOV | 137.720 | 0.000 | 0.09 |

*Note.* CD = cross-sectional dependence.

The slope homogeneity tests reject the null of identical slopes at the 1% level (Pesaran-Yamagata adjusted $\Delta = 35.485$ ; Blomquist-Westerlund adjusted $\Delta = 41.226$ ). The relationships between the explanatory variables and environmental performance therefore differ across firms, and pooled coefficients should be read as averages of heterogeneous relationships.

**Table 5**

*Slope Homogeneity*

| Assessment | Δ | Adjusted Δ | p-value |
|---|---|---|---|
| Pesaran–Yamagata (2008) | 26.207 | 35.485 | 0.000 |
| Blomquist–Westerlund (2013), HAC | 30.448 | 41.226 | 0.000 |

### *4.3 Regression Analysis*

Table 6 presents the baseline estimates. In the pooled model all three explanatory variables are positive and significant at the 1% level. Moving to firm fixed effects reduces the coefficient on biodiversity disclosure from 7.220 to 5.743 and the coefficient on CSR-linked compensation from 5.283 to 2.781, whereas the coefficient on innovation is unchanged (0.403 to 0.416). Pooled OLS is rejected in favour of models with firm effects by both the Breusch-Pagan test and the F test. Random-effects and fixed-effects estimates are close (5.793 and 5.743 for disclosure, 2.976 and 2.781 for compensation, 0.414 and 0.416 for innovation), and the correlation between the estimated firm effects and the fitted index is close to zero (0.0088), so the choice between the two estimators does not alter any substantive conclusion; This study report the within estimator as the preferred specification because it makes no assumption about the relation between firm effects and regressors. The share of variance attributable to firm effects is high ($\rho = 0.682$ in the random-effects model

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and 0.704 in the fixed-effects model), so a large part of the variation in environmental scores is persistent across firms.

The fixed-effects coefficients are meaningful in size but differ across variables. Firms with biodiversity disclosure score 5.743 points higher on the environmental pillar, about 0.25 standard deviations of the score and 9.4% of its mean (95% confidence interval 5.199 to 6.287). CSR-linked compensation is associated with a difference of 2.781 points, or about 0.12 standard deviations (2.084 to 3.479). A one-point increase in the innovation score is associated with 0.416 points on the pillar (0.401 to 0.430), so a one-standard-deviation increase in innovation (33.784 points) corresponds to 14.0 pillar points, or about 0.60 standard deviations. The three explanatory variables jointly account for 44.3% of the within-firm variation in the environmental score. The decline of the disclosure and compensation coefficients between pooled and within estimation indicates that part of their pooled association reflects differences between firms, whereas the stability of the innovation coefficient indicates that its association is a within-firm phenomenon.

**Table 6**

*Regression Results (Dependent Variable: ENV_PILLAR)*

| Variable | (1) Pooled OLS | (2) Random effects | (3) Fixed effects |
|---|---|---|---|
| BIODISC | 7.220*** (0.441) | 5.793*** (0.275) | 5.743*** (0.277) |
| CSRCOM | 5.283*** (0.448) | 2.976*** (0.349) | 2.781*** (0.356) |
| ENVINNOV | 0.403*** (0.006) | 0.414*** (0.007) | 0.416*** (0.007) |
| Constant | 39.359*** (0.372) | 40.380*** (0.639) | 40.396*** (0.323) |
| Observations | 7,304 | 7,304 | 7,304 |
| Firms | 664 | 664 | 664 |
| $R^2$(overall) | 0.4244 | 0.4205 | 0.4199 |
| $R^2$(within) | | 0.4429 | 0.4429 |
| $\sigma_u$ | | 14.384 | 15.155 |
| $\sigma_e$ | | 9.817 | 9.817 |
| $\rho$ | | 0.682 | 0.704 |

*Note.* Standard errors are in parentheses. *** $p < .001$.

### *4.4 Sensitivity to Year Effects*

Because the diagnostics point to strong common movements across firms, this study examines how the estimates change when year effects are added (Equation 4). The estimates in Table 7 are computed on originally observed values only (6,585 firm-years) and use firm-clustered standard errors; column (1) repeats the no-year-effects regime and is close to the baseline fixed-effects estimates in Table 6 (BIODISC 5.276 against 5.743; CSRCOM 3.007 against 2.781; ENVINNOV 0.418 against 0.416), which supports comparison across the two samples. Clustering by firm raises the standard errors of BIODISC from 0.29 to 0.45, of CSRCOM from 0.36 to 0.57 and of ENVINNOV from 0.007 to 0.017 relative to conventional errors, a factor of 1.6 to 2.4.

The pattern then differs sharply across variables. With year effects, the coefficient on biodiversity disclosure falls to −0.291 and the coefficient on CSR-linked compensation to 0.531, and neither is statistically distinguishable from zero. The coefficient on environmental innovation declines only from 0.418 to 0.382 and remains significant at the 1% level. In the 2017–2022 window, in which disclosure varies most, neither the disclosure nor the compensation coefficient is significantly positive, and the innovation coefficient remains at 0.370. Most of the baseline association of disclosure and compensation with environmental performance therefore reflects variation common to all firms over time, such as the shared upward drift in scores and the simultaneous spread of both practices and not differences between firms that adopt and firms that do not. The innovation association is not subject to the same concern, although, as discussed in Section 4.5, its stability does not by itself establish an independent effect.

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**Table 7**

*Sensitivity of the Fixed-Effects Estimates to Year Effects*

| Variable | (1) No year effects | (2) Year effects | (3) Year effects, 2017–2022 |
|---|---|---|---|
| BIODISC | 5.276 (0.453) | −0.291 (0.529) | −0.917 (0.552) |
| CSRCOM | 3.007 (0.567) | 0.531 (0.587) | 0.836 (0.561) |
| ENVINNOV | 0.418 (0.017) | 0.382 (0.017) | 0.370 (0.017) |
| Firm fixed effects | Yes | Yes | Yes |
| Year effects | No | Yes | Yes |
| Observations | 6,585 | 6,585 | 3,810 |
| Firms | 664 | 664 | 664 |

*Note.* Firm-clustered standard errors are in parentheses.

### *4.5 Discussion*

The results present a pattern that is more informative than any single coefficient. In the baseline models all three mechanisms are positively and significantly associated with environmental performance, but once common time movements are considered only the innovation association remains stable. This study discusses each hypothesis in turn.

The baseline association between disclosure and environmental performance is the larger of the two binary effects, equal to about a quarter of a standard deviation, and it is reduced by only about 20% when moving from pooled to fixed-effects estimation. Read at face value, this supports the stakeholder argument that transparency raises accountability and builds measurement capacity, and it is consistent with the positive disclosure-ESG association reported for Chinese listed firms (Wang et al., 2026). Three considerations, however, prevent us from reading the baseline as support for H1. First, the very high cross-sectional dependence in BIODISC (CD = 1,150.388) shows that disclosure rises largely in unison across firms, so a regression of a trending score on a variable that moves with the calendar will return a positive coefficient even when disclosure has no firm-level effect. Second, the coefficient is indistinguishable from zero when year effects are included (Table 7). Third, the literature gives reasons for expecting such a result: disclosure may follow performance (Al-Tuwaijri et al., 2004; Clarkson et al., 2008) and may be used for legitimation by weaker performers (Boiral, 2016; Dutta & Dutta, 2024). An alternative reading is that regulatory and investor attention to biodiversity, which intensified after the Kunming Declaration (Garel et al., 2024), is too recent for disclosure to have changed a slow-moving score, in which case effects might emerge later. The data cannot discriminate between these accounts, so H1 is supported as a baseline association but not robustly once time effects are considered. Differences from Wang et al. (2026) may reflect their single-country setting, their longer window, or the absence of an equivalent common-trend test in our baseline models; This study cannot attribute the divergence to any single cause.

The within-firm association is the smallest of the three, at about 0.12 standard deviations, and it falls by half between the pooled and fixed-effects models. The pooled estimate therefore largely reflects differences between firms, which is consistent with selective adoption of the practice (Cohen et al., 2023; Hong et al., 2016): firms that adopt CSR-linked pay may already be stronger environmental performers or share characteristics that make them so. The disappearance of the association once year effects are added is in line with the rapid spread of the practice documented in international evidence (Cohen et al., 2023), which would produce a positive correlation with a rising score even in the absence of a firm-level link. Two features of the measurement weaken the test further. A binary indicator cannot distinguish quantified environmental targets from vague references to sustainability, although the literature suggests that the former matter most (Derchi et al., 2021; Maas, 2018), and incentive effects may appear in process-oriented measures more than in outcomes (Haque & Ntim, 2020). The result accords with the sceptical view that ESG-linked pay is not a reliable lever when metrics are coarse (Bebchuk & Tallarita, 2022) and contrasts with the more favourable findings of studies that rely on a legal instrument or on richer outcome measures (Flammer et al., 2019). H2 is therefore supported only as a fragile baseline association.

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The innovation association is the strongest in standardised terms, with a one-standard-deviation difference corresponding to about 0.60 standard deviations of the environmental score, and it is the only one that is stable across estimators and across the inclusion of year effects. This is consistent with the capability logic of the natural-resource-based view (Hart, 1995) and with firm-level evidence on green research and development (Lee & Min, 2015). Two qualifications prevent stronger reading. If the environmental pillar includes an innovation component, part of the coefficient is definitional, and a technical link would also remain stable across specifications because it does not depend on common trends. Moreover, performance may drive innovation, since firms with stronger ESG performance have been found to innovate more (Lian et al., 2023). This study therefore treats H3 as supported for the full environmental score, subject to confirmation that the result survives when the innovation component is excluded from the outcome.

Three questions should be kept distinct. Statistically, all baseline coefficients are significant, but conventional standard errors in a trending, serially correlated panel are likely to be too small, and significance disappears for two of the three variables once year effects are included. Economically, the baseline magnitudes are non-trivial (about 0.25, 0.12 and 0.60 standard deviations), although they describe conditional differences and not the consequences of interventions. Causally, the study cannot support effect claims: the associations are exposed to reverse causality, selection and omitted variables, and no instrument, natural experiment or credible adoption-timing design is used.

## 5. Conclusion and Implications

This study investigates whether three corporate mechanisms, namely information (biodiversity disclosure), incentives (CSR-linked executive compensation), and capability (environmental innovation), are associated with corporate environmental performance, and how stable those associations are. Using a balanced panel of 664 firms from 20 countries and economies over 2015–2025, the study find that all three variables are positively and significantly associated with the environmental pillar score in baseline pooled, random-effects and firm fixed-effects estimates. Within firms, biodiversity disclosure is associated with a 5.743-point higher score, CSR-linked compensation with a 2.781-point higher score, and a one-point increase in the innovation score with a 0.416-point higher score.

The stability of these associations differs sharply. Diagnostics show strong cross-sectional dependence and heterogeneous slopes, and in a sensitivity analysis on originally observed values the disclosure and compensation associations are no longer statistically distinguishable from zero once year effects are added, whereas the innovation association remains stable. This study therefore concludes that the evidence for H1 and H2 is limited to a baseline association that cannot be separated from common time developments, and that the evidence for H3 is stronger but conditional on the environmental pillar not mechanically embedding the innovation score. The findings suggest that adopting transparency and pay-linkage practices is, on their own, not a reliable marker of environmental performance, while capability-based indicators are more consistently related to it. Because the baseline panel was balanced with completion rules, the specifications omit controls and no identification strategy is applied, all estimates are conditional associations, and none supports a causal claim. The contribution of the study lies in an integrated framework for three mechanisms and in a transparent account of how inference changes once common time movements and measurement construction are acknowledged.

The study carries four theoretical implications. First, stakeholder theory gains explanatory power when paired with an explicit symbolic rival for each mechanism, because the rival makes the prediction falsifiable and clarifies what a null result means. The pattern found here, fragile information and incentive associations alongside a stable capability association, is what a symbolic-versus-substantive reading would predict: mechanisms that can be adopted at low cost, namely reporting and pay clauses, show little association with performance once common movements are removed, whereas the mechanism that requires real resources shows a persistent one. This study offers this as an interpretation consistent with the evidence and not as a test of it. Second, agency arguments about compensation require attention to contract design: an indicator that a firm links pay to CSR criteria says little about the intensity, quantifiability, or horizon of the incentive, so tests based on adoption alone may understate or misstate incentive effects. Third, the natural-resource-based

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prediction about innovation can be assessed only with outcome measures that are not constructed from innovation itself. Fourth, institutional and legitimacy arguments imply that associations differ across regulatory settings; the rejection of slope homogeneity in our data is consistent with this, although institutional moderation is not modelled directly.

Regulators moving towards mandatory biodiversity disclosure (CBD, 2022; TNFD, 2023) should consider specifying content and quality, not merely adoption, because adoption on its own show's little robust association with measured performance in our data. Data providers and standard setters should publish score decompositions so that researchers and investors can separate overlapping components and assess how far composite ratings reflect disclosure and innovation inputs, a concern consistent with the divergence across rating providers documented by Berg et al. (2022). Investors who screen disclosure or pay-linkage indicators should complement them with outcome data. Policy that raises disclosure should be evaluated with designs able to separate its effects from common trends. These implications follow from the pattern of association and fragility and not from estimated causal effects, and they should be revisited if analyses on observed data and with credible identification change the picture.

**Ethical Approval**

This study is based entirely on secondary data obtained from published sources, including peer-reviewed journals, industry reports, and regulatory documents. No human participants were involved in the research. Therefore, formal Institutional Review Board (IRB) approval was not required. However, all ethical considerations were strictly followed, including proper citation of sources and adherence to academic integrity.

**Authors' Contributions**

All the authors have read and approved the final manuscript.

**Conflict of Interest Statement**

The author/s declare that there is no conflict of interest regarding the publication of this article.

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**Data Availability**

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request. The authors are committed to transparency and will provide detailed methodological information and analysis protocols upon request.

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