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Articles

Environmental disclosure: Mitigation and adaptation using ESG statistics from Latin American public companies

Divulgación de información ambiental: mitigación e adaptación empregando estatísticas ASG de empresas públicas latinoamericanas

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Abstract

Governments and organizations encourage companies to measure and report their environmental impact. However, in Latin America, a standardized framework for companies to disclose environmental information has yet to be established. This article investigates changes in CO_2 emission intensity and water usage, as well as the effects of corporate actions related to environmental mitigation and adaptation. To this end, we created two indices—one for adaptation and one for mitigation—using data from 672 publicly listed companies across six Latin American countries from 2017 to 2023. We conducted an analysis using a structural equation model to measure the effects on company value, water usage intensity, and CO_2 emissions in relation to sales. The findings suggest that reported mitigation actions effectively reduced companies' CO_2 intensity. However, no evidence was found that adaptation actions reduced water usage. These results are based on data from one-third of the listed companies that disclose environmental information. This group invested the equivalent of 0.70% of their sales in sustainability. Addressing climate change moving forward will require deeper engagement in new environmental actions and the involvement of a broader range of companies.

Keywords: Market value; Climate change; Information disclosure; Simultaneous equations; Emissions intensity.

Resumo

Os gobernos e organizacións incentivan ás empresas para medir e reportar o seu impacto ambiental. En Latinoamérica aínda non se acordou un marco estandarizado para que as empresas divulguen a súa información ambiental. No presente artigo, o obxectivo foi investigar o cambio na intensidade de emisións de CO_2 e uso de auga e o efecto que tiveron as accións empresariais de mitigación e adaptación ambientais. Para iso creamos dous índices, un de adaptación e outro de mitigación, usando datos de 672 empresas públicas de seis países de Latinoamérica de 2017 a 2023. A estimación realizouse cun modelo de ecuacións estruturais para medir os efectos sobre o valor das empresas, a intensidade do uso da auga e a cantidade de emisións de CO_2 nas vendas. Atopouse que as accións de mitigación reportadas foron efectivas para reducir a intensidade de CO_2 das empresas. Con todo, non atopamos que as accións de adaptación reducisen o uso de auga. Os resultados obtivéronse cun terzo das empresas públicas que divulgan a súa información ambiental. Este conxunto de empresas investiu en sustentabilidade o equivalente ao 0.70% das súas vendas. Cara adiante para enfrontar o cambio climático aínda se require profundar en novas accións ambientais e sumar o esforzo da maior parte de empresas.

Palabras chave: Valor de mercado; Cambio climático; Divulgación da información; Ecuacións simultáneas; Intensidade de emisións.

JEL classification: R11; O44; O54; G28; G38.

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If a high-growth economy [more resources] is needed to fight the battle against pollution, which itself appears to be the result of high growth, what hope is there of ever breaking out of this extraordinary circle?

-E. F. Schumacher, 1973

1. INTRODUCTION

Governments and international organizations are addressing the climate crisis by working to mitigate greenhouse gas emissions and curb global warming, while simultaneously adapting to its current and future impacts, such as rising sea levels and extreme weather events. To combat environmental degradation, companies are being urged to adopt sustainable production practices. In response, many now measure and disclose their environmental performance, enhancing transparency for stakeholders in decision-making processes (Freeman et al., 2010). According to signaling theory, such disclosures act as a signal of proactive environmental responsibility, which investors view favorably—potentially increasing company value (Spence, 1973; Arif Khan, 2022; Lee et al., 2022).

In recent years, the proliferation of environmental metrics and standards has led to dissatisfaction, reporting fatigue, and higher costs, as companies navigate diverse—and often contradictory—sustainable accounting frameworks (Bose, 2020). In Latin America, while most regulations mandate environmental risk reporting, the region still lacks a standardized framework (OECD, 2023).

This paper aims to construct two indices: one measuring CO_2 mitigation actions and another assessing environmental adaptation initiatives, evaluating their impact on the CO_2 and water usage embedded in sales. The mitigation index comprises 19 items, while the adaptation index includes six. A secondary objective is to determine how CO_2 emissions and water usage influence company value. The analysis uses data from 672 Latin American publicly listed companies sourced from the LSEG Workspace database, spanning 2017–2023 (N = 4 705 observations).

Using a structural equation model, we analyze (i) the impact of CO_2 emission intensity (per million dollars) and water usage on company value, and (ii) the effectiveness of mitigation and adaptation indicators. Our findings reveal that CO_2 emission intensity significantly affects firm value: a 1% increase in emissions leads to a 0.15% decline in value ($p = 0.000$). In contrast, water usage does not exhibit a negative effect; instead, higher water consumption is weakly but positively associated with company value ($p = 0.000$).

Further analysis of the model shows that mitigation strategies have been effective in reducing emissions per million dollars of sales. However, the evidence on water usage is less encouraging. While companies with high water consumption have adopted most environmental adaptation measures, their overall impact remains limited.

The database allows for estimating the cost of environmental mitigation and adaptation measures, which amounts to approximately 0.70% of sales (or 0.35% of value added). Notably, Latin American companies allocate three times more resources to environmental actions than to technological R&D (OECD, 2024).

Prior research has examined various strategies to reduce corporate CO_2 emissions (see Sections 2.1 and 2.3), often with a regional focus on Europe. Our study contributes to this literature by (1) addressing the understudied context of Latin America, (2) expanding the environmental analysis to include both CO_2 emissions and water usage conservation, and (3) incorporating mitigation and adaptation indices as predictor variables—a novel approach, given the scarcity of business literature discussing adaptation actions specifically. The results confirm that these measures have successfully reduced CO_2 emissions. However, greater efforts are still needed to monitor and curb corporate water usage.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature, Section 3 outlines the methodology—including variable definitions, the construction of the mitigation and adaptation indices, and descriptive statistics. Section 4 presents the empirical results of the structural equation model and discusses the findings. Finally, Section 5 provides the concluding remarks.

2. LITERATURE REVIEW: CORPORATE DECISIONS, CLIMATE ADAPTATION AND MITIGATION

Corporations have frequently been associated with economic, labor, and environmental controversies, often stemming from a narrow focus on profit maximization as their core objective. This traditional shareholder-centric model has faced growing criticism, particularly from stakeholder theory, which argues that neglecting broader societal and environmental concerns is unsustainable in the long term (Freeman et al., 2010). In response to escalating environmental challenges, national governments and international bodies have increasingly advocated for the adoption of the 2030 Sustainable Development Goals (SDGs), which aim to reconcile economic growth with ecological preservation.

This shifting paradigm has elevated the importance of Environmental, Social, and Governance (ESG) criteria over the past four decades, pushing corporations to adopt more sustainable practices and responsible production methods.

2.1. DISCLOSURE OF CORPORATE ENVIRONMENTAL INFORMATION

The growing emphasis on corporate sustainability (Alsayegh et al., 2020; Moliterni, 2018) reflects increasing public awareness, corporate reputation concerns, and the imperative to mitigate environmental and operational risks. Companies now demonstrate their commitment through transparent disclosure practices and the adoption of comprehensive human rights and environmental policies (Brogi & Lagasio, 2018). This shift originated from academic-professional collaborations that recognized the impossibility of implementing effective Corporate Social Responsibility (CSR) without first addressing an organization's fundamental social and ethical dimensions. These efforts ultimately spurred the development of standardized methodologies for assessing corporate performance across social, ethical, and environmental parameters (Freeman et al., 2010).

Corporate reporting has emerged as a critical transparency mechanism for disclosing non-financial performance. This accountability framework helps organizations delineate their social responsibility parameters while communicating relevant information to stakeholders (Freeman et al., 2010). While disclosure practices vary globally, most jurisdictions now either mandate or encourage non-financial reporting (Zeng et al., 2019). Current adoption rates reveal a significant gap - although only 19% of listed companies worldwide publish sustainability reports, these firms account for 84% of global market capitalization (OECD, 2023), highlighting the disproportionate influence of large corporations in sustainability disclosure practices.

Research on corporate governance, ESG disclosure, and stakeholder orientation remains notably underdeveloped in Latin America and Mexico. Deeper examination of these areas could elucidate critical relationships between governance structures and stakeholder rights (Husted et al., 2019). ESG disclosure practices vary considerably across the region: while Brazil and Colombia emphasize climate-related reporting, other countries are increasingly focusing on

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broader sustainability communication. Notably, 330 companies representing 83% of the region's market capitalization now publish sustainability reports (OECD, 2023). Sectoral differences are pronounced - in 2021, 89% of mining and mineral processing firms disclosed sustainability information, compared to 61% of service sector companies and 66% of transportation firms.

A striking regional distinction emerges in verification practices: while just 63% of global companies employ third-party validation for their reports, this figure rises to 93% among Latin American disclosers (OECD, 2023). This verification gap underscores that while disclosure itself is important, the credibility of reported metrics remains essential for investor assessment of sustainability progress (Mustafa Khan & Mohd Ali, 2023). However, growing climate policy uncertainty has exacerbated greenwashing risks, particularly in polluting industries within weakly regulated markets. Evidence suggests that enhanced external regulatory pressures may effectively curb such practices (Zhang & Ge, 2024).

2.2. SUSTAINABILITY AND FIRM VALUE

Academic literature demonstrates a consistent negative relationship between carbon emissions and firm valuation across multiple markets. Benkraiem et al. (2022) established this inverse correlation in their analysis of 243 companies (2013-2019), showing that carbon performance improvements positively affect market valuation. This finding aligns with Nurul Houqe et al.'s (2022) study of 2,323 U.S. firms (2007-2016), which confirmed that higher emission levels decrease market value. The pattern persists in European markets, as Perdichizzi et al. (2024) documented using direct emissions data from 1,493 companies. Globally, Choi and Luo (2021) reinforced these conclusions through their examination of 1,748 annual observations, further validating the negative impact of emissions on corporate valuation.

These findings collectively suggest that stakeholders positively value effective carbon management, particularly since emissions' negative impact on firm valuation is more pronounced in countries with weaker environmental regulations (Choi & Luo, 2021). This market preference for substantive action over symbolic gestures is further evidenced by Guastella et al. (2022), whose analysis revealed that environmental disclosure indices lose statistical significance when controlling for actual environmental performance. Their results indicate that financial markets primarily assess corporate environmental behavior through measurable emission outcomes rather than disclosure practices when determining company valuations.

In the Latin American context, González et al. (2021) analyzed 454 companies using environmental initiatives as an emissions proxy, revealing that firms with stronger disclosure practices achieve both higher market valuations and superior accounting performance. The researchers developed a comprehensive disclosure index based on 50 binary indicators derived from environmental reports, where each affirmative response contributed one point to the total score. This methodology generated percentage scores ranging from 0% to 100%—for example, companies with 25 positive responses received a score of 50%, enabling standardized cross-company comparisons of disclosure quality.

While a significant correlation exists between ESG disclosure practices and carbon emissions (Baratta et al., 2023), mere compliance with ESG reporting requirements does not necessarily translate into better emissions performance. Treepongkaruna et al. (2024) demonstrated this disconnect in their analysis of U.S. firms (2005-2018), showing that higher ESG ratings failed to correlate with reduced emissions. This paradox stems from market dynamics where investors disproportionately value sustainability reporting itself—Flammer et al. (2021) found that simply publishing such reports signals corporate sustainability, making firms more attractive to investors regardless of their actual emissions control efforts (Arif Khan, 2022; Lee et al., 2022). This creates a perverse incentive where companies may prioritize disclosure over substantive environmental action.

2.3. RESPONSE TO CLIMATE CHANGE: ADAPTATION AND MITIGATION

Climate change mitigation refers to strategies aimed at counteracting the adverse impacts of climate change, primarily by reducing greenhouse gas emissions (IPCC, 2023) and slowing global warming. However, even full implementation of the Paris Agreement pledges would still lead to a 3.2°C temperature rise by 2100 (Rivera et al., 2022).

Recognizing these limitations, since the 2010 Conference of the Parties (COP), mitigation efforts have been complemented by adaptation strategies. Given that the cumulative effects of climate change will persist for centuries, adaptation is critical for enhancing resilience—developing capacities and reducing vulnerabilities in affected systems (IPCC, 2023; Sharifi, 2021).

Mitigation strategies focus on reducing greenhouse gas (GHG) emissions, encompassing corporate initiatives designed to curb their carbon footprint (Cadež & Czerny, 2015; Cadež et al., 2019). In contrast, adaptation strategies involve reactive or proactive measures taken by firms to minimize climate-related risks and enhance their resilience. To assess these adaptation efforts, Juhola et al. (2024) evaluate both internal and external factors, including economic and environmental performance, as well as regulatory compliance.

Research demonstrates that mitigation strategies effectively reduce emissions, with studies identifying three primary approaches: Scope 1 (direct emissions), Scope 2-3 (indirect emissions from energy/value chains), and offsetting mechanisms (Cadež & Czerny, 2015). While carbon-intensive firms tend to favor low-investment strategies like marginal efficiency gains – which show limited transition potential – broader mitigation efforts positively impact emissions performance. Cadež et al. (2019) confirmed this through a study of 247 European carbon-intensive firms, analyzing strategies including recycled materials, product redesign, energy efficiency, process optimization, and emissions-reduction technologies.

While mitigation strategies have received substantially more attention than adaptation efforts (Sharifi, 2021), research specifically measuring adaptation's impact remains scarce. However, some studies have assessed adaptation through sustainability indices. For instance, Quian and Liu (2024) demonstrate that higher ESG ratings enhance carbon efficiency, particularly in non-state-owned and cleaner firms. Similarly, Haque and Ntim (2022) developed a disclosure index—based on 2 444 firm-year observations—tracking sustainable initiatives like emission reductions, environmental innovations, and resource efficiency. Their findings reveal that higher index scores correlate with lower GHG emission intensity, especially in polluting industries.

2.4. USE OF RESOURCES: CO_2, MATERIALS AND WATER

The literature demonstrates a strong emphasis on carbon emissions as the primary environmental metric, with markets predominantly using this measure to assess firm value. This focus has created a significant research gap regarding the valuation impacts of other

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critical resources. While environmental regulations increasingly align with SDG principles—promoting sustainable production without depleting natural resources—and despite 85% of global investors prioritizing water management and climate action (OECD, 2023), few studies examine non-carbon environmental factors. A notable exception is Simionescu et al. (2020), who identified negative correlations between both water consumption and waste generation with firm value, highlighting the need for broader environmental valuation metrics.

Cohen et al. (2023) analyzed 76 284 observations from the Carbon Disclosure Project (CDP) spanning 2003-2020, finding that carbon disclosure is significantly associated with reduced subsequent emissions. However, Bui et al. (2022) revealed an important nuance: while climate disclosure ratings exert pressure on poorly-rated firms to improve their reporting quality in subsequent years, these companies show little propensity to actually reduce their emissions - particularly among those with the lowest ratings.

Several studies have constructed environmental disclosure indices based on corporate initiatives. Iatridis (2013) developed an index assessing five key areas: (i) environmental management systems, (ii) credibility, (iii) performance indicators, (iv) environmental expenditures, and (v) environmental initiatives. The study found that companies with lower hazardous waste volumes and active reduction programs achieved higher disclosure ratings. Similarly, Giannarakis, Konteos et al. (2017) and Giannarakis, Zafeiriou et al. (2017) created a Climate Performance Leadership Index with five components (management, risks, emissions, opportunities, and approval), requiring a minimum score of 50 for inclusion (n = 102 and n = 119 firms, respectively). Both studies revealed that higher emissions correlated with lower carbon transparency, suggesting that stronger environmental performance (lower emissions) drives greater disclosure.

Research on non-carbon resources remains limited, likely due to weaker compliance requirements. Studies reveal significant gaps across sectors and regions: in France, companies fail to report water extraction data (Gibassier, 2018), while in China only 38% of listed firms disclose water metrics despite guidelines (Zeng et al., 2019). The mining sector lacks consensus on baseline water consumption levels across regions, hindering target-setting (Northey et al., 2019). Even in energy transitions, the water-carbon nexus persists—low-carbon technologies may increase water demand (Macknick et al., 2012).

Research on alternative environmental metrics remains scarce. Alonso Fernández et al. (2024) found that European Union dematerialization efforts have largely failed, with material resource reductions only occurring during the 2008 GDP contraction. In the electronics sector, waste volume studies exist, but implementation gaps persist—López Pérez et al. (2024) show Mexico's environmental policies lack supporting regulatory frameworks, discouraging proper resource management.

This literature review highlights a critical limitation: the overwhelming focus on CO_2 metrics neglects other vital resource measures, ultimately impeding progress toward Environmental Sustainability Goals.

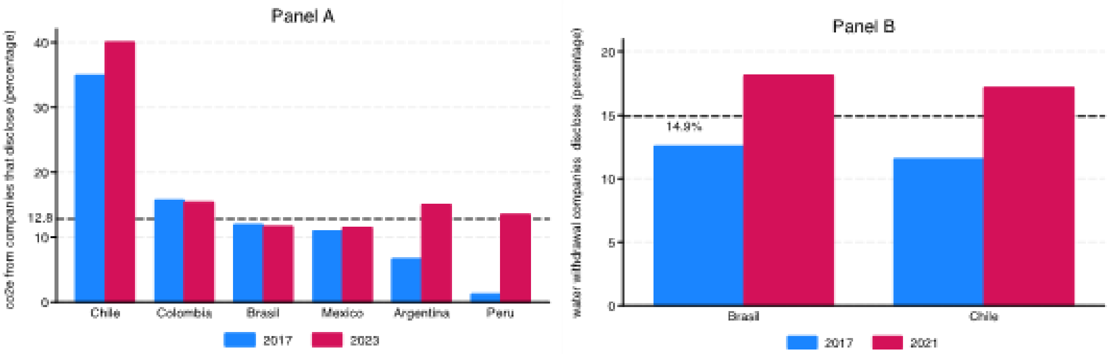
3. MATERIALS AND METHODS

3.1. DATA

This study evaluates the efficacy of environmental mitigation and adaptation initiatives implemented by Latin American publicly traded companies from 2017 to 2023. While disclosure rates have shown gradual improvement, they remain notably low relative to global standards. The sample comprised firms from six countries (Argentina, Brazil, Chile, Colombia, Mexico, and Peru). This group of countries accounts for approximately 480 million inhabitants, representing about 76% of Latin America's population. The contribution percentage is even higher (85%) when considering Gross Domestic Product as the variable (IMF, 2024). Although data were available for more countries, we restricted our sample to these six nations to avoid introducing additional heterogeneity.

As illustrated in Figure 1, sample companies account for an average of 12% of national CO_2 emissions across the six studied countries (Panel A). Chilean listed companies demonstrate disproportionately higher emission contributions compared to regional peers. Regarding water resources (Panel B), Brazil and Chile emerge as the dominant consumers among reporting firms. Data from Argentina, Colombia, Mexico, and Peru were excluded from water usage analysis as listed companies in these nations represent ≤0.5% of national withdrawals.

Figure 1. Share of national CO2 and water withdrawal



Note. a) In 2017 and 2023, 102 and 218 companies reporting CO2, respectively, and b) in 2017 and 2021, 90 and 171 companies reporting water, respectively. Source: Authors' elaboration using data from European Commission Emissions (2024) and Food and Agriculture Organization of the United Nations (2024).

The analysis draws on two primary data sources identified in the literature: Refinitiv (Perdichizzi et al., 2024; Treepongkaruna et al., 2024) and the Carbon Disclosure Project (Bui et al., 2022; Giannarakis, Konteos et al., 2017; Giannarakis, Zafeiriou et al., 2017; Haque & Ntim, 2022; Nurul Houqe et al., 2022). For this study, we utilized the LSEG Workspace database (Refinitiv's successor), which covers global listed companies.

Our sample selection process began with all companies listed on major Latin American stock exchanges (*n* = 725). After excluding 53 firms (23 inactive/incomplete records, 17 with pre-2018 data, and 13 trusts), the final sample comprised 672 companies analyzed over seven years (2017-2023), yielding 4 704 firm-year observations. Country-level distributions are detailed in Appendix 1.

Despite mandatory ESG disclosure requirements for public companies, reporting remains limited. Our sample construction required firms to disclose environmental indicators in at least three reporting years (2018, 2020, 2023), yielding a final sample of 156 listed companies (*n* = 1 106 firm-year observations). Sectoral and geographical distributions are presented in Appendix 1.

The environmental performance of companies signals market actors about sustainability commitments, enhancing corporate reputation and investor appeal through demonstrated reductions in pollution and improvements in resource efficiency (Arif Khan, 2022; Lee et al., 2022; Spence, 1973). This commitment operates through two distinct channels: mitigation actions (addressing climate change causes) and adaptation measures (managing climate impacts across time horizons). Our study focuses on analyzing how these mitigation and adaptation efforts influence environmental outcomes (CO_2 emissions and water use), while

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secondarily examining the relationship between resource efficiency and firm valuation. Accordingly, our dependent variables comprise both environmental metrics (emissions and water withdrawal) and financial performance (firm value).

Research Hypotheses

H1a: Mitigation actions have succeeded in reducing emissions. However, they have become more effective since 2021.

H1b: If adaptation measures are effective, water use metrics should show an inverse relationship.

H2: Investor perceptions respond differently to distinct environmental indicators.

H2a: Firm valuation is negatively associated with CO_2 emissions, as they represent a direct measure of climate change exposure.

H2b: Higher water use leads to higher firm valuation, as lax regulatory scrutiny prevents investors from imposing penalties for environmental externalities.

3.2. VARIABLES

3.2.1. DEPENDENT VARIABLES

This study uses emissions intensity—measured as CO_2 emissions (metric tons) per million USD revenue—as the primary variable, since CO_2 represents the principal climate change driver. This intensity metric standardizes emissions across companies, enabling comparisons independent of firm size or industrial sector.

Alongside CO_2 emissions, three additional variables were initially evaluated: water extraction, waste generation, and energy expenditure. Water extraction (measured in cubic meters per million USD revenue) was ultimately selected as a secondary metric, with lower values indicating greater efficiency. The waste variable was excluded due to inconsistent reporting patterns across years, while energy expenditure was omitted because of its strong correlation with emissions intensity (r = 0.70; Appendix 2), which would yield redundant information.

3.2.2. INDEPENDENT VARIABLES

Two indices were developed to examine corporate environmental impact: one measuring mitigation efforts and another tracking adaptation actions. Data were extracted from company ESG reports, which follow the Environmental, Social, and Governance framework containing over 630 standardized metrics (LSEG, 2023). Each metric was coded as a binary variable (1 = action implemented, 0 = not implemented). The environmental component comprises 437 metrics across three categories: (a) emissions-related actions covering pollution control, waste management, and biodiversity protection; (b) product innovation and green revenue generation; and (c) resource management addressing water use, energy efficiency, sustainable packaging, and supply chain sustainability. To ensure reliable analysis, only metrics reported by at least one-third of the sample companies (n = 672) were included. For context, financial variables showed higher reporting rates, with 520 to 565 companies disclosing such data annually between 2017 and 2023.

Climate change results primarily from greenhouse gas accumulation, with mitigation representing deliberate human efforts to reduce CO_2 emissions (IPCC, 2023). Adaptation comprises behavioral and operational adjustments to address existing and anticipated climate impacts. This cyclical process involves vulnerability assessment, strategy implementation, and capacity building to enhance resilience (IPCC, 2023; Sharifi, 2021).

While the theoretical distinction between mitigation and adaptation is well-established, practical classification of environmental actions proves challenging. To strengthen the classification procedure, we supported our decisions using artificial intelligence (AI). This approach ensured a uniform application of criteria, reducing bias and maximizing consistency. Specifically, to label actions as mitigation or adaptation, we consulted three well-recognized AI platforms—ChatGPT, Perplexity, and Claude.ai—to cross-validate our classifications.

Each platform received standardized definitions and assigned percentage weights (0-100%) indicating alignment with either category. Items receiving >50% mitigation weighting from at least two platforms were classified as mitigation actions, resulting in 19 mitigation and 6 adaptation items (Appendix 3). This outcome reflects the current research emphasis on mitigation over adaptation (Sharifi, 2021) and demonstrates the methodological value of AI-assisted classification in research.

Following the classification of items into mitigation and adaptation categories, both indices were computed as weighted averages using identical methodological procedures (see Equations 1 and 2).

$$Mitig_t = \sum_{i=1}^{n} D_{it}^{x} \times \bar{\bar{w}}_i^{x} \tag{1}$$

where D_{it}^{x} is the value of the mitigation action item per company and per year, taking the value of 1 if the company performed the action and 0 otherwise, and $\bar{\bar{w}}_i^{x}$ is the normalized weight. The construction of the normalized weight can be found in Appendix 4.

$$Adapt_t = \sum_{i=1}^{n} D_{it}^{z} \times \bar{\bar{w}}_i^{z} \tag{2}$$

where D_{it}^{z} is the value of the adaptation action item per company and per year, taking the value of 1 if the company performed the action and 0 otherwise, and $\bar{\bar{w}}_i^{z}$ is the normalized weight (Appendix 4).

The analysis incorporates control variables consistent with established literature (Benkraiem et al., 2022; Choi & Luo, 2021; Nurul Houqe et al., 2022; Perdichizzi et al., 2024; Wu et al., 2022). Complete variable definitions and operationalizations are provided in Table 1, which corresponds to the specifications in Equations 3 through 5.

Table 1. Description of Variables

Variables	Definition	Unit
a) Response variables		
Emissions intensity	Logarithm of total carbon dioxide (CO_2) emissions and CO_2 equivalents relative to revenue generated in millions of dollars.	CO_2 ton/ Revenue in millions of USD
Water intensity	Logarithm of total water extraction (total water extraction in cubic meters divided by net sales or revenue in million US dollars) relative to revenue generated in millions of dollars.	Cubic meters/ Revenue in millions of USD

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Variables	Definition	Unit
b) Explanatory variables		
Mitigation (0-100)	Mitigation index is the sum of the 19 mitigation action items per firm and per year (each dummy variable item equals 1 if the company performs the action and 0 otherwise), multiplied by a normalized weight. The normalized weight is formed by an attenuator that reduces the difference between companies that report extensively and those that do not, without equalizing them.	Percentage
Adaptation (0-100)	Adaptation index is the sum of the 6 adaptation action items per company and per year (each dummy variable item equals 1 if the company performs the action and 0 otherwise), multiplied by a normalized weight. The normalized weight is formed by an attenuator that reduces the difference between companies that report extensively and those that do not, without equalizing them.	Percentage
c) Control variables		
Market value	Market value: Share price multiplied by the number of ordinary shares in issue.	Millions of USD
Cash Flow	Revenue before discontinued operations & extraordinary items and depreciation	Millions of USD
Ebit (*ebit*)	It is the natural logarithm of Earnings before Interest & Taxes	Millions of USD
Return on Assets	Revenue before taxes /Total Assets	Percentage
Leverage	Total debt divided by the value of Shareholders equity	Percentage
Revenue	It is the natural logarithm of Total Revenue	Millions of USD
Post	Post=1 when the years are 2021-2023, Post=0 when the years are 2017-2020	Millions of USD

Source: Authors' elaboration using data from LSEG Workspace (LSEG, 2023 & 2024) and Benkraiem et al. (2022), Choi and Luo (2021), Nurul Houqe et al. (2022), Perdichizzi et al. (2024), and Wu et al. (2022).

3.3. MODEL SPECIFICATION

A structural equation model (SEM) was developed to assess (i) the impact of resource use—specifically emissions intensity and water extraction intensity—on firm value (Equation 3, Hypothesis 2) and (ii) the effect of mitigation and adaptation actions on environmental performance (equations 4 and 5). Equation 3 evaluates how a company's market value responds to changes in emissions and water intensity, while Equations 4 and 5 estimate the influence of mitigation and adaptation measures on emissions intensity and total water extraction intensity, respectively.

$$MV = \beta_0 + \beta_1 co2\_int_{it} + \beta_2 h2o\_int_{it} + \beta_3 x_{it} + \beta_4 Firm + e_{it} \quad (3)$$

$$co2\_int = \beta_0 + \beta_1 mitig_{it} + \beta_2 mitig_{it}^2 + \beta_3 adapt_{it} + \beta_4 post_{it} + \beta_5 x_{it} + \beta_6 (Post_{it} \times mitig_{it}) + \beta_7 (Ind_{it} \times mitig_{it}) + \varepsilon_{it} \quad (4)$$

$$h20\_int = \beta_0 + \beta_1 adapt_{it} + \beta_2 adapt_{it}^2 + \beta_3 mitig_{it} + \beta_4 post_{it} + \beta_5 x_{it} + \beta_6 (Post_{it} \times adapt_{it}) + \beta_7 (Ind_{it} \times adapt_{it}) + u_{it} \quad (5)$$

where the dependent variables are $market\ value\ (MV)$, $emissions\ intensity\ (co2\_int\ )$ and $water\ intensity\ (h2o\_int)$. MV is the market capitalization value, $co2\_int$ refers to total emissions relative to revenue, and $h2o\_int$ refers to water withdrawal relative to revenue. Additionally, $mitig_{it}$ is the mitigation index and $adapt_{it}$ the adaptation index; x_{it} represents a set of control variables including cash flow, ROA, $Leverage$ y $Ebit$. $Post_{it}$ is a dummy variable representing a value of 1 for the years post-2020 and 0 for the preceding years. Ind_{it} is a dummy variable representing each industry.

The structural equation model included mitigation and adaptation actions in both Equations 4 and 5, but with distinct nonlinear specifications reflecting their different climate-related focuses. For Equation 4 (emissions intensity), we incorporated only the quadratic term of mitigation actions to capture their nonlinear effect on CO_2 reduction, as these actions directly target climate change mitigation. Conversely, Equation 5 (water extraction intensity) included the quadratic term of adaptation actions to assess their nonlinear impact on water use, consistent with their focus on addressing climate change consequences. This specification acknowledges that while both strategies were evaluated in each equation, their relative importance differs based on the environmental outcome being measured.

3.4. SUMMARY STATISTICS

The analysis used data from 2017 to 2023 to examine temporal trends. For comparison, the period was divided into two groups: pre-2021 and 2021–2023. This division was based on reporting patterns—only 17% of companies disclosed environmental information in the early years, while reporting rates increased significantly to 25% from 2021 onward. By comparing these periods, the study provides clearer insights into evolving trends and stronger evidence for recent developments.

Appendix 5 provides the descriptive statistics for the study variables. Overall, the mitigation index scores were consistently higher than those of the adaptation index. At the start of the study period (2017), the highest mitigation values were observed in the Mining, Extraction, Public Services, and Construction sectors (37 out of 100) and the Manufacturing sector (51 out of 100). By 2021, these values had risen to 66 and 70, respectively. In contrast, the Commerce and Services sectors (Sectors 4 and 5) showed lower initial scores (32 and 36 in 2017) but demonstrated the most significant growth, nearly doubling their values to 54 and 67 by 2021.

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The increased corporate disclosure coincided with substantial improvements in mitigation efforts, with the most notable progress occurring between 2017 and 2021. By contrast, advances in 2023 were marginal. During this most recent period, all sectors converged around an average mitigation score of 70, with peak sector-specific values reaching as high as 90 out of 100.

In contrast to the mitigation trends, the adaptation index showed more consistent progress across industries in both 2021 and 2023, with smaller inter-sector disparities. The Mining, Utilities, and Construction sector (initial score: 39) and Manufacturing sector (46) demonstrated stronger initial performance compared to the Trade, Transport, and Storage sector (28) and Services sector (31). By 2021-2023, these scores had risen substantially to 65 and 75 for the first group, and to 50 and 60 for the second group (all scores out of 100).

Sectoral analysis revealed distinct environmental efficiency patterns, with Agriculture, Mining, and Manufacturing consistently exhibiting the highest emissions and water intensities. While Agriculture and Mining reduced CO_2 emissions by 2023, these gains failed to offset their 2021 increases, leaving Manufacturing as the only high-emission sector demonstrating sustained improvement. Among low-emission sectors, only Trade achieved measurable progress in emissions reduction. Water intensity patterns diverged, with Agriculture showing increased consumption while the other four sectors reduced their water use. These findings highlight sector-specific challenges in environmental performance, particularly the lagging adaptation of water-intensive sectors compared to emissions reduction efforts.

4. RESULTS AND DISCUSSION

This section presents the Structural Equation Model regression results. Table 2 displays the empirical estimates for Equations 3-5, based on a balanced panel of companies that consistently reported environmental data throughout the study period.

The initial estimation results are presented in Appendix 6. We observe that the model exhibited multicollinearity issues, and a high variance inflation factor due to the interaction between the adaptation index and the sector (Equation 5) and the squared mitigation index (Equation 4). Additionally, during the review process, it was suggested that we incorporate Tobin’s Q to enhance the robustness of the analysis. Consequently, Appendix 7 presents an estimation in which, for Equation 3, market value is replaced by Tobin's Q. Our model comparison supported retaining market value and using the Table 2 estimates.

To address multicollinearity, an instrumental variable (IV) was used for the emissions variable in Equation 3. The instrument consisted of Scope 3 emissions (emissions for which a company is indirectly responsible) relative to total assets. This instrumented variable is highly correlated with total emissions and weakly correlated with market value. Additionally, in Equation 4, the mitigation index was replaced by its first lag to address reverse causality. Table 2 presents the estimation results, where we exclude the squared term of the mitigation index in Equation 4, and omit the interaction between the adaptation index and the sector in Equation 5.

The results from Column 1 (Table 2), examining firm value as the dependent variable, reveal two key findings: First, a 1% increase in emission intensity corresponds to a significant 0.15% decrease in firm value (Panel A, Figure 2). Second, water extraction intensity shows a contrasting positive effect, increasing firm value by 0.02% (Panel B, Figure 2). These results suggest investors pay closer attention to emissions - the climate change-related variable - when valuing firms. The control variables exhibit expected relationships: ROA and leverage show negative associations (Benkraiem et al., 2022; Choi & Luo, 2021; Wu et al., 2022), while cash flow demonstrates a positive effect (Benkraiem et al., 2022).

Column 2 analyzes the impact of mitigation actions on emissions intensity, revealing a significant negative relationship. Each one-unit increase in mitigation actions reduces emissions intensity by up to 2.26% (Table 2), demonstrating their substantial effectiveness.

The curves in Figure 3 (Panel A Emissions) show that from 2017-2020, companies experienced slower CO_2 reductions. From 2021-2023, these companies showed faster reductions, indicating that mitigation actions have become more effective at lowering emissions. The average mitigation index rose from 51.7 (2017-2020) to 69.02 (2021-2023). After 2020, when larger companies began reporting, the effect became 38% stronger.

These findings align with recent literature, particularly Bersalli et al. (2023), who document peak emissions attainment across multiple economies. The observed emissions intensity reduction also corresponds with IPCC (2023) projections of global emissions peaking during 2020-2025. Notably, this study demonstrates declining emissions intensity despite concurrent revenue growth, suggesting successful decoupling of economic activity from environmental impact.

Column 3 reveals a counterintuitive positive relationship between adaptation actions and water extraction intensity, with each unit increase in the adaptation index associated with up to a 6.75% rise in water use.

The nonlinear pattern in Figure 3 (Panel B Water) further shows temporal differences in this relationship: during 2017-2021, water intensity grew at slower rates for firms with low adaptation indices compared to the accelerated growth observed during 2021-2023 for comparable firms.

The analysis reveals a plateau effect when the adaptation index approaches 80, where water intensity stabilizes rather than decreases. This stagnation suggests diminishing returns of adaptation measures on water conservation at higher implementation levels. The data show significant temporal progression in adaptation efforts, with average index scores rising from 45.49 during 2017-2020 (dashed reference line) to 65.44 in the 2021-2023 period (scale: 0-100).

Table 2. Estimation of the structural model of emissions and water intensity, company value and mitigation and adaptation actions

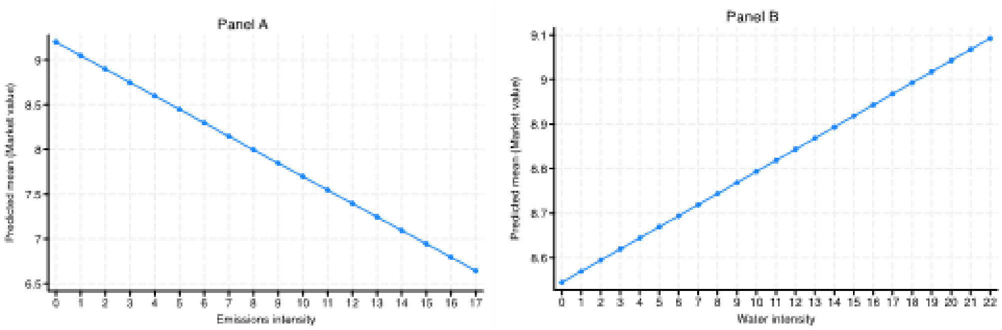
Variables	ESG data		
	Market value	Emissions intensity	Water intensity
	(Eq 3)	(Eq 4)	(Eq 5)
Instrument (Emissions)	-0.1504**		
	(0.0000)		
Water intensity	0.0248**		
	(0.0000)		
L.Mitigation		-0.0226**	-0.0189**
		(0.0000)	(0.0000)
L.Mitigation x Industry	NO	SI	NO

Variables	**ESG data**		
	Market value	Emissions intensity	Water intensity
	(Eq 3)	(Eq 4)	(Eq 5)
Adaptation		0.0034**	0.0675**
		(0.0000)	(0.0000)
Adaptation x Industry	NO	NO	NO
Adaptation squared			-0.0004
			(0.0000) **
Post 2020		0.3849**	-2.7690**
		(0.0003)	(0.0004)
Post 2020 x L.Mitigation		-0.0060**	
		(0.0000)	
Post 2020 x Adaptation			0.0307**
			(0.0000)
ROA	0.0011**	-0.0009**	-0.0055**
	(0.0000)	(0.0000)	(0.0000)
Cashflow	0.0579**	-0.0785**	-0.4193**
	(0.0000)	(0.0000)	(0.0001)
Leverage	-0.0001**	-0.0003**	-0.0015**
	(0.0000)	(0.0000)	(0.0000)
Ebit	0.1686**	-0.1993**	0.5442**
	(0.0000)	(0.0000)	(0.0001)
Intercept	6.2615**	15.9051**	14.4343**
	(0.0004)	(0.0001)	(0.0003)
Firm effects	YES	NO	NO
Industry effects	NO	YES	YES
n	527	852	754
var(e.*Market value*)		0.0629	
		(0.0000)	

Variables	ESG data		
	Market value	Emissions intensity	Water intensity
	(Eq 3)	(Eq 4)	(Eq 5)
var(e.*Emissions intensity*)		0.9675	
		(0.0000)	
var(e.*Water intensity*)		4.0221	
		(0.0001)	

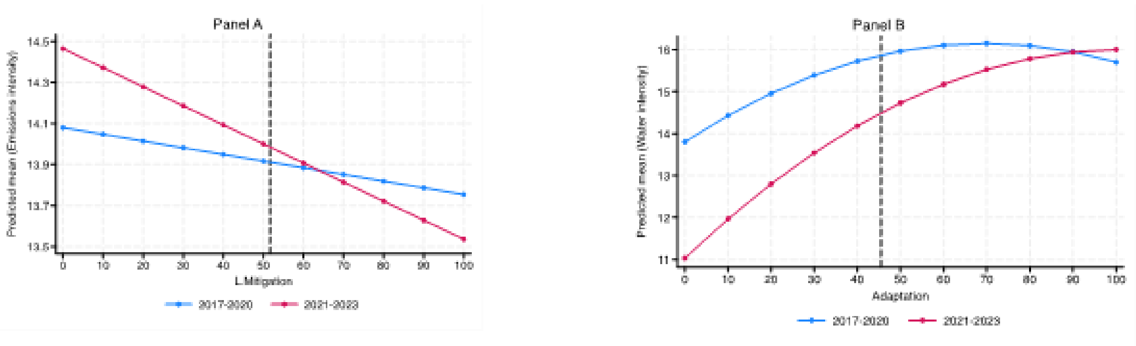
Source: Authors' elaboration. Standard errors in parentheses. Note. ** p<.01, * p<.05.
Weighted using the emissions. The correlation between the instrument and emissions was 0.82, while its correlation with market value was close to zero (-0.009).

Figure 2. Prediction of market value and resource intensity



Source: Authors' elaboration. The predictions are based on the Table 2 estimates.

Figure 3. Prediction of resource intensity and environmental actions



Note. The dashed line shows that companies had a mean mitigation index of 51.7 between 2017 and 2020.

Note. The dashed line shows that companies had a mean adaptation index of 45.49 between 2017 and 2020

Source: Authors' elaboration. The predictions are based on the Table 2 estimates.

The environmental catalog provided to stock exchanges remains incomplete, suggesting additional opportunities exist for water reduction beyond currently reported strategies. While our findings demonstrate measurable progress from unverified approaches, the specific

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methods cannot be precisely identified from available data. Potential undocumented improvements may include infrastructure upgrades, irrigation optimization and soil moisture monitoring, water-efficient process reengineering, conservation awareness programs, dry industrial cleaning methods, and water-minimizing product redesigns in manufacturing processes.

These findings align with Treepongkaruna et al. (2024), Arif Khan (2022), and Lee et al. (2022), confirming that while companies benefit from reputational gains through environmental reporting, substantive ecological commitments remain limited. The evidence reveals a clear prioritization imbalance: stakeholders heavily scrutinize emissions data for valuation purposes, while water intensity metrics—despite their environmental significance—currently fail to meaningfully influence corporate valuation decisions.

The control variables demonstrate the expected significant relationships with environmental performance: ROA exhibits a negative association with emissions intensity (Bui et al., 2022), cash flow is inversely related to CO_2 levels (Haque & Ntim, 2022), and leverage shows a consistent negative effect (Bui et al., 2022; Cohen et al., 2023; Quian & Liu, 2024). These results align with prior findings on the financial determinants of corporate environmental impact.

These findings paint a concerning picture of limited regional progress in curbing CO_2 emissions. The low uptake of recommended mitigation measures appears linked to a persistent tolerance for high carbon intensity in business operations. This trend is particularly notable given the robust 12.8% annual sales growth among large Latin American publicly-traded companies, suggesting that economic expansion has not been accompanied by proportional environmental improvements.

Analysis of water usage patterns reveals two key findings: First, companies with elevated water consumption levels demonstrate more frequent adoption of adaptation measures. Second, and more significantly, the volume of water withdrawal shows no statistically meaningful correlation with corporate market valuation.

Reported environmental expenditures provide a proxy measure for corporate compliance efforts with these indices. This comprehensive variable captures: (i) capital investments and operational costs for environmental protection, and (ii) expenditures related to preventing, mitigating, and controlling environmental impacts and risks. For comparative analysis, the absolute expenditure value was normalized by dividing it by total company revenue.

The analysis included 672 companies, of which only 76 (11.3%) disclosed environmental expenditure data in 2023. After excluding two outliers with environmental expenditures exceeding 20-40% of revenue, the final sample comprised 74 firms. Within this group, 53 companies (representing one-third of the full reporting panel) provided complete mitigation and adaptation data. Results indicate these environmentally transparent firms allocate an average of 0.7% of annual revenue to environmental expenditures.

When sustainability investment is estimated at 0.7% of revenue (equivalent to ≈0.35% of corporate GDP), it represents a substantial commitment—approximately triple the level of business expenditure on R&D (BERD) in Latin America (averaging 0.10% of GDP). Notably, Brazil's BERD slightly exceeds this regional benchmark (OECD, 2024). This comparative analysis suggests that Latin American firms prioritize sustainability investments over innovation spending at a ratio of 3:1.

This study highlights critical gaps in corporate environmental engagement across Latin America. While 25% of large companies consistently reported environmental actions in 2023, the majority lacked transparent commitments or measurable goals. The data reveal a clear divergence in effectiveness: mitigation efforts successfully reduced CO_2 intensity (per $1M sales) between 2017–2023, whereas adaptation actions failed to curb either water usage or emissions. Despite the existence of ESG guidelines for nearly a decade, regional progress lags behind global self-regulation trends in financial markets. More ambitious short-term sustainability targets—particularly for CO_2 and water reduction—could be achieved through coordinated government policies to steer the private sector toward meaningful environmental accountability.

5. CONCLUSIONS

This study analyzes environmental disclosures from Latin American publicly traded companies to develop mitigation and adaptation indices, evaluating how enhanced environmental compliance affects CO_2 emissions and water extraction intensity. Against the backdrop of global climate action initiatives, corporate environmental practices exhibit substantial variation - a feature we leverage to empirically assess effectiveness, communicate performance outcomes, and identify transferable best practices for sustainable operations.

The analysis reveals a predominant focus on mitigation over adaptation, with most environmental actions targeting emissions reduction and only limited measures addressing water conservation. Our estimates demonstrate a significant inverse relationship between mitigation implementation and CO_2 emissions, particularly when normalized by sales to enable cross-sectoral comparison. The results highlight: (1) prior mitigation efforts yield emissions reductions, (2) this lagged effect has become more pronounced since 2021, (3) if this linear effect continues and more companies start disclosing their environmental impact, significant progress could be made towards decarbonization (H1a).

The second analytical strand examined the efficacy of adaptation measures, revealing no significant reduction in water usage despite increased implementation of such actions (H1b). Further investigation identified industry-specific water demand as a critical factor - water-intensive industries reported more adaptation activities, while less water-dependent sectors implemented fewer measures. Consequently, meaningful progress in water conservation would require expanded adaptation initiatives among traditionally low-water-use industries to complement existing practices in water-intensive sectors.

Reducing CO_2 emissions is both environmentally essential and a driver of corporate market value (H2a). In contrast, water stewardship appears to lack financial rewards. Surprisingly, our statistical evidence reveals a positive association between water usage and market valuation among firms—indicating no signs of environmental adaptation nor market penalties for high water use (H2b).

While corporate environmental disclosures offer valuable insights into resource use patterns and climate response measures, data availability remains limited. Only approximately one-third of publicly traded companies currently provide detailed environmental information, constraining comprehensive assessment of sector-wide performance.

The low proportion of companies sharing environmental data limits robust regional analysis of resource use and emissions. For context, we hypothesize that non-disclosing firms likely exhibit weaker climate commitments and fewer decarbonization efforts than their reporting counterparts. Without mandatory disclosure, their mitigation activities are probably minimal compared to systematic reporters.

Effective climate action requires collaborative governance, yet Latin America faces significant challenges in forging productive public-private environmental partnerships. While corporate disclosures primarily serve investor needs, they also represent a critical policy resource - particularly given that major corporations generate 67% of global emissions

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(Ortega-Ruiz et al., 2022). This dual utility underscores the urgent need to transform voluntary reporting into a foundation for coordinated climate strategy.

The results derive from a comprehensive database of self-reported information provided by companies. To ensure reliability of the estimates, researchers prepared a balanced panel that included the same companies each year. Many questions remain for investigation. For example, estimates could compare companies that present environmental reports with those that do not. Additionally, the self-reported figures from companies could be verified against official statistics for each country. Furthermore, analysis could explore intertemporal relationships in the estimated equations. Examining these aspects would generate stronger evidence regarding progress and effectiveness of the business sector in environmental matters.

Future research in Latin America should prioritize the metrics most frequently reported by companies, as outlined in the adaptation and mitigation indices. By aligning these metrics with existing regulatory frameworks, scholars could develop simplified, standardized reporting systems. Such frameworks would likely increase participation among companies that currently do not disclose environmental data.

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Author contributions

Conceptualization, B.R. and E.K.; Data curation, B.R.; Formal analysis, B.R.; Funding acquisition, B.R.; Investigation, B.R. and E.K.; Methodology, B.R. and E.K.; Writing-original draft, B.R. and E.K.; Writing-review editing, E.K. All authors read and agree with the published version of the manuscript.

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Appendices

Appendix 1. Total and sample firms by sector and country

Sector	Argentina	Brazil	Chile	Colombia	Mexico	Peru
672 firms						
Agriculture	3	3	6	2	0	1
Mining	20	68	34	10	20	26
Manufacture	25	91	37	13	33	29
Trade	5	51	21	1	21	6
Services	6	78	25	3	31	5
Total	59	289	123	29	105	67
165 firms (sample)						
Agriculture	1	1	0	0	0	0
Mining	7	16	8	5	2	7
Manufacture	5	22	7	4	12	3
Trade	1	16	6	1	10	3
Services	2	9	3	1	4	0
Total	16	64	24	11	28	13

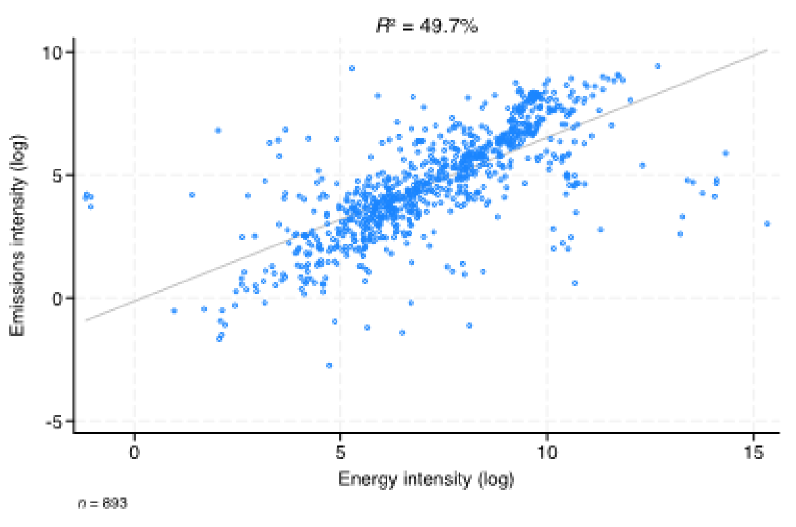
Source: Authors' elaboration using data from LSEG Workspace (LSEG, 2024).

Appendix 2.A Correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)Emissions intensity	1										
(2) Energy intensity	0.705***	1									
(3) Water intensity	0.505***	0.450***	1								
(4) Mitigation	0.084***	0.093***	0.0280	1.							
(5) Adaptation	0.284***	0.220***	0.263***	0.900***	1						
(6) Market value	0.052*	0.0110	0.0300	0.529***	0.533***	1					
(7) ROA	0.0330	-0.062*	0.0330	0.0150	0.0210	0.098***	1				
(8) Cash Flow	0.185***	0.128***	0.123***	0.591***	0.573***	0.811***	0.047***	1			
(9) Leverage	-0.0010	-0.0160	-0.0450	0.027*	0.037**	0.0060	-0.066***	0.052***	1		
(10) Ebit	0.200***	0.146***	0.142***	0.575***	0.563***	0.812***	0.085***	0.926***	0.0260	1	
(11) Revenue	0.0200	0.0050	0.0350	0.427***	0.421***	0.410***	0.0210	0.490***	0.0140	0.484***	1

Source: Authors' elaboration using data from LSEG Workspace (LSEG, 2024).
Note. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix 2.B Correlation between emissions intensity and energy intensity



Source: Authors' elaboration using data from LSEG Workspace (LSEG, 2024).

Appendix 3. Items description for Mitigation and Adaptation indexes (Dummies)

Mitigation items	Description
Resource Reduction Policy	1 if the company has a policy for reducing the use of natural resources or to lessen the environmental impact of its supply chain, 0 otherwise.
Policy Energy Efficiency	1 if the company has a policy to improve its energy efficiency, 0 otherwise.
Policy Sustainable Packaging	1 if the company has a policy to improve its use of sustainable packaging, 0 otherwise.
Policy Environmental Supply Chain	1 if the company has a policy to include its supply chain in the company's efforts to lessen its overall environmental impact, 0 otherwise.
Resource Reduction Targets	1 if the company set specific objectives to be achieved on resource efficiency, 0 otherwise.
Targets Energy Efficiency	1 if the company set targets or objectives to be achieved on energy efficiency, 0 otherwise.
Environment Management Team	1 if the company has an environmental management team, 0 otherwise.
Environmental Materials Sourcing	1 if the company claims to use environmental criteria (e.g., life cycle assessment) to source or eliminate materials, 0 otherwise.
Renewable Energy Use Ratio	1 if the company makes use of renewable energy, 0 otherwise.
Green Buildings	1 if the company reports about environmentally friendly or green sites or offices, 0 otherwise.

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Mitigation items	Description
Environmental Supply Chain Management	1 if the company uses environmental criteria (ISO 14000, energy consumption, etc.) in the selection process of its suppliers or sourcing partners, 0 otherwise.
Env Supply Chain Partnership Termination	1 if the company reports or shows to be ready to end a partnership with a sourcing partner, if environmental criteria are not met, 0 otherwise.
Policy Emissions	1 if the company has a policy to improve emission reduction, 0 otherwise.
Targets Emissions	1 if the company set targets or objectives to be achieved on emission reduction?; 0 otherwise.
Waste Reduction Initiatives	1 if the company reports on initiatives to recycle, reduce, reuse, substitute, treat or phase out total waste, 0 otherwise.
e-Waste Reduction	1 if the company reports on initiatives to recycle, reduce, reuse, substitute, treat or phase out e-waste, 0 otherwise.
Staff Transportation Impact Reduction	1 if the company reports on initiatives to reduce the environmental impact of transportation used for its staff, 0 otherwise.
Environmental Investments Initiatives	1 if the company reports on making proactive environmental investments or expenditures to reduce future risks or increase future opportunities, 0 otherwise.
Environmental Partnerships	1 if the company reports on partnerships or initiatives with specialized NGOs, industry organizations, governmental or supra-governmental organizations, which are focused on improving environmental issues, 0 otherwise.
Adaptation	
Policy Water Efficiency	1 if the company has a policy to improve its water efficiency, 0 otherwise.
Targets Water Efficiency	1 if the company set targets or objectives to be achieved on water efficiency, 0 otherwise.
Land Environmental Impact Reduction	1 if the company reports on initiatives to reduce the environmental impact on land owned, leased or managed for production activities or extractive use, 0 otherwise.
Biodiversity Impact Reduction	1 if the company report on its impact on biodiversity or on activities to reduce its impact on the native ecosystems and species, as well as the biodiversity of protected and sensitive areas, 0 otherwise.
Climate Change Commercial Risks Opportunities	1 if the company is aware that climate change can represent commercial risks and/or opportunities, 0 otherwise.
Environmental Restoration Initiatives	1 if the company reports or provides information on company-generated initiatives to restore the environment, 0 otherwise.

Source: Authors' analysis of LSEG Workspace data (LSEG, 2023).
Note. Section 3.2.2 details our methodology for categorizing items as either mitigation or adaptation. While mitigation items were relatively straightforward to classify (showing a clear 60/40 distribution favoring mitigation with high inter-rater agreement), adaptation items proved more challenging. Adaptation items exhibited a narrower 52/48 distribution favoring adaptation, accompanied by greater score dispersion.

Appendix 4. Calculation of the normalized weight of the mitigation index and the adaptation index

Calculation of the normalized weight of the mitigation index

Total sum of yes responses to the item by year= $= \sum_{i=1}^{n} D_{it}^{x}$

Total sum of yes responses for all items = $= \sum_t \sum_i^n (D_{it}^{x})$

Weighted calculation $w_i^x = \frac{\sum_{i=1}^{n} D_{it}^{x}}{\sum_t \sum_i^n (D_{it}^{x})}$

Dampened weighting calculation $\bar{w}_i^x = \sqrt[2]{\frac{\sum_{i=1}^{n} D_{it}^{x}}{\sum_t \sum_i^n (D_{it}^{x})}}$

Normalized weighting calculation $\bar{\bar{w}}_i^x = \frac{\bar{w}_i^x}{\sum \bar{w}_i^x}$

Calculation of the normalized weight of the adaptation index

Total sum of yes responses to the item by year $= \sum_{i=1}^{n} D_{it}^{z}$

Total sum of yes responses for all items $= \sum_t \sum_i^n (D_{it}^{z})$

Weighted calculation $w_i^x = \frac{\sum_{i=1}^{n} D_{it}^{z}}{\sum_t \sum_i^n (D_{it}^{z})}$

Dampened weighting calculation $\bar{w}_i^z = \sqrt[2]{\frac{\sum_{i=1}^{n} D_{it}^{z}}{\sum_t \sum_i^n (D_{it}^{z})}}$

Normalized weighting calculation $\bar{\bar{w}}_i^z = \frac{\bar{w}_i^z}{\sum \bar{w}_i^z}$

Appendix 5. Summary statistics by sector, weighted by income of the selected variables 2017, 2021, 2023

Variable	n	Mean	S. D.	Min	Max	n	Mean	S. D.	Min	Max	n	Mean	S. D.	Min	Max
	2017					2021					2023				
1 Agriculture															
Emissions int	0					2	13.5	0.0	13.5	13.5	2	13.0	0.4	12.7	13.3
Water int	0					1	17.3	.	17.3	17.3	1	17.2	.	17.2	17.2
Emissions	0					2	13.0	0.0	13.0	13.0	2	13.3	0.5	13.0	13.6
Revenue	2	750.7	275.1	487.1	894.3	2	1021.3	313.7	739.1	1195.7	2	1045.6	124.2	950.0	1126.3
Mitigation	2	0.0	0.0	0.0	0.0	2	59.8	9.7	51.1	65.1	2	63.3	7.4	57.5	68.1
Adaptation	2	0.0	0.0	0.0	0.0	2	71.6	6.8	67.8	77.7	2	71.5	7.9	66.4	77.5
Market value	2	6.1	1.0	5.6	7.1	2	6.3	1.8	5.3	7.9	2	6.6	1.0	6.0	7.4
Cash Flow	1	4.8	.	4.8	4.8	2	5.0	0.3	4.9	5.3	2	4.6	1.1	3.9	5.4
Ebit	2	4.0	1.1	3.4	5.1	2	5.1	0.7	4.7	5.7	2	5.2	0.3	5.0	5.4
Return on Assets	2	-5.9	15.9	-14.2	9.3	2	19.4	5.4	14.5	22.4	2	21.5	17.6	8.0	32.9
Leverage	2	109.7	47.8	63.9	134.6	2	89.4	90.4	39.1	170.7	2	78.8	101.2	13.1	156.8
2 Mining															
Emissions int	26	13.0	1.3	7.7	16.0	45	12.8	1.2	7.3	15.8	43	12.6	1.2	8.4	16.2
Water int	24	15.5	2.9	9.3	21.0	39	15.4	2.9	8.8	20.6	39	15.0	2.7	8.6	20.5
Emissions	26	15.1	1.8	7.0	16.4	45	14.9	1.7	6.3	16.5	43	14.8	1.7	8.0	16.4
Revenue	45	11340.4	10702.0	99.6	30261.7	45	17308.7	17051.5	53.9	43834.2	45	12442.6	11230.9	55.3	29845.4
Mitigation	45	57.7	26.9	0.0	93.6	45	75.9	12.3	34.7	93.4	45	75.5	13.4	36.7	90.5
Adaptation	45	58.2	27.1	0.0	91.4	45	81.9	20.0	19.3	100.0	45	85.7	18.3	20.3	100.0
Market value	45	9.0	1.3	5.3	10.5	45	9.3	1.5	3.7	10.9	45	9.4	1.4	2.9	11.1
Cash Flow	44	7.3	1.3	3.1	9.1	41	7.8	1.7	1.3	10.0	42	7.4	1.4	0.4	9.0
Ebit	45	7.3	1.3	2.6	9.2	42	7.9	1.7	-0.8	10.1	41	7.5	1.5	1.9	9.3
Return on Assets	44	8.3	4.2	-8.2	23.6	42	16.6	11.5	-29.2	32.6	45	9.1	6.0	-67.3	22.9
Leverage	44	88.5	54.8	7.1	231.3	44	86.3	70.6	0.0	331.9	44	98.9	80.8	0.1	351.3
3 Manufacture															
Emissions int	40	12.6	1.4	8.0	15.2	53	12.6	1.5	7.2	15.3	51	12.1	1.4	9.0	15.6
Water int	38	15.1	1.4	11.6	21.7	52	15.7	1.9	9.5	22.1	53	15.3	1.5	12.0	22.3
Emissions	40	15.5	2.2	7.4	18.0	53	15.2	2.1	6.8	17.8	51	15.1	1.9	7.2	17.7
Revenue	53	30365.7	30639.6	85.8	79102.0	53	26769.2	26065.3	101.3	67600.3	53	28401.8	27799.3	79.9	73441.4
Mitigation	53	68.4	19.8	0.0	86.3	53	77.1	11.8	33.6	90.2	53	79.3	8.9	44.4	89.7
Adaptation	53	62.9	22.7	0.0	100.0	53	80.0	17.9	23.1	100.0	53	86.5	14.6	0.0	100.0
Market value	52	9.0	1.0	3.2	11.3	53	9.0	1.2	3.4	10.6	53	9.3	1.5	3.8	11.4
Cash Flow	47	7.3	1.4	1.6	9.4	52	7.7	1.6	2.7	10.2	46	7.4	1.9	3.7	10.3
Ebit	51	7.3	1.5	2.4	9.3	52	7.8	1.6	3.6	10.1	50	7.1	1.8	2.7	10.3

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Return on Assets	53	2.8	5.1	-22.7	20.6	53	12.6	7.4	-7.8	35.5	53	6.1	8.8	-14.2	26.0
Leverage	53	297.4	1362.1	3.8	13516.3	53	208.2	281.4	3.8	2055.3	53	332.0	1293.9	3.2	12378.1
4 Trade															
Emissions int	20	10.7	1.2	8.3	14.0	37	10.6	1.2	7.2	14.3	37	10.0	1.7	7.2	14.0
Water int	13	13.1	1.7	10.4	20.8	33	12.5	1.9	9.3	19.3	35	11.9	2.4	5.6	19.3
Emissions	20	13.3	1.3	8.2	16.2	37	13.0	1.5	6.5	15.7	37	12.8	1.8	7.3	16.3
Revenue	36	15783.8	8390.1	229.8	27064.1	37	14637.4	9181.6	229.1	29233.2	37	17249.8	11639.5	306.2	35857.3
Mitigation	36	49.4	30.1	0.0	85.0	37	70.8	15.1	18.3	90.5	37	78.3	9.9	53.6	93.4
Adaptation	36	40.6	36.7	0.0	91.4	37	61.6	24.8	0.0	90.5	37	68.1	15.4	0.0	100.0
Market value	35	8.9	1.7	3.8	10.7	37	8.7	1.6	4.5	11.1	37	9.0	1.6	3.4	11.2
Cash Flow	34	6.5	0.9	3.5	7.7	32	6.7	1.0	3.8	7.9	36	6.7	1.1	3.7	8.1
Ebit	35	6.6	0.9	1.1	7.6	34	6.5	1.2	3.9	7.8	35	6.6	1.1	1.7	8.0
Return on Assets	36	6.6	4.6	-5.4	21.3	35	6.7	9.2	-54.2	18.7	37	7.7	7.8	-23.8	35.8
Leverage	35	96.2	132.6	0.7	1204.0	34	127.2	140.5	34.8	977.7	35	199.7	356.3	27.2	1540.3
5 Services															
Emissions int	12	10.5	0.8	5.8	13.6	18	10.5	0.7	5.5	11.8	18	10.35	0.88	7.87	11.13
Water int	11	11.8	1.1	9.8	15.6	15	11.1	1.2	4.9	15.8	16	11.37	1.10	5.39	15.62
Emissions	12	13.4	1.5	5.0	14.6	18	13.2	2.0	4.4	14.8	18	12.78	2.02	7.21	14.61
Revenue	18	27891.0	21801.4	97.3	48222.8	19	18940.9	14957.9	129.4	32992.1	19	18005.20	14936.07	153.48	33005.40
Mitigation	18	62.9	21.3	0.0	80.7	19	71.5	9.5	40.7	89.0	19	69.19	12.41	42.34	90.16
Adaptation	18	47.8	22.2	0.0	74.6	19	52.9	16.6	19.3	90.5	19	57.10	12.45	20.34	90.81
Market value	18	8.7	4.1	-4.8	10.9	19	9.2	2.9	-4.7	11.1	19	9.35	2.20	-0.10	10.97
Cash Flow	17	8.1	1.5	1.9	9.1	18	8.0	1.5	3.4	9.1	17	7.85	1.57	3.44	9.19
Ebit	16	7.6	1.2	4.2	8.5	18	7.3	1.8	2.4	8.8	18	7.42	1.73	1.32	8.82
Return on Assets	18	6.0	11.2	-8.3	54.4	18	5.2	4.5	-15.3	28.4	19	2.96	8.34	-25.14	35.89
Leverage	16	230.0	157.0	2.0	359.4	18	152.0	125.8	4.9	687.4	18	156.74	121.84	2.62	606.61

Source: Authors' elaboration using data from LSEG Workspace (LSEG, 2024).

Appendix 6. Estimation of the structural model of emissions and water intensity, company value and mitigation and adaptation actions

Variables	ESG data		
	Market value	Emissions intensity	Water intensity
	(3)	(4)	(5)
Emissions intensity	-0.3746**		
	(0.0000)		
Water intensity	0.0247**		
	(0.0000)		
Mitigation		-0.0519**	-0.0123**
		(0.0000)	(0.0000)
Mitigation x Sector	NO	SI	NO
Adaptation		0.0039**	0.0749**
		(0.0000)	(0.0000)
Adaptation x Sector	NO	NO	SI
Mitigation squared		0.0002**	
		(0.0000)	
Adaptation squared			-0.0004**
			(0.0000)
Post 2020		0.5141**	-1.9184**
		(0.0003)	(0.0004)
Post 2020 x Mitigation		-0.0079**	
		(0.0000)	
Post 2020 x Adaptation			0.0233**
			(0.0000)
ROA	0.0096**	-0.0006**	-0.0188**
	(0.0000)	(0.0000)	(0.0000)
Cashflow	0.0960**	-0.0594**	0.1711**
	(0.0000)	(0.0000)	(0.0000)
Leverage	-0.00005**	-0.0003**	-0.0005**

	(0.0000)	(0.0000)	(0.0000)
Ebit	0.0790**	-0.2237**	0.0189**
	(0.0000)	(0.0000)	(0.0001)
Intercept	11.9323**	16.8887**	13.9599**
	(0.0004)	(0.0003)	(0.0003)
Firm effects	YES	NO	NO
Sector effects	NO	YES	YES
n	751	852	754
var(e.*Market value*)		0.0928	
		(0.0000)	
var(e.*Emissions intensity*)		0.9452	
		(0.0000)	
var(e.*Water intensity*)		2.9839	
		(0.0001)	

Source: Authors' elaboration. Standard errors in parentheses.
Note. ** p<.01, * p<.05. Weighted by emissions. Due to multicollinearity concerns and elevated variance inflation factors, we favor the model presented in Table 2.

Appendix 7. Estimation of the structural model of emissions and water intensity, Tobin's Q and mitigation and adaptation actions

Variables	ESG data		
	Qtobin	*Emissions intensity*	*Water intensity*
	(3)	(4)	(5)
Emisions intensity	-0.0654**		
	(0.0000)		
Water intensity	-0.0011**		
	(0.0000)		
Mitigation		-0.0519**	-0.0129**
		(0.0000)	(0.0000)
Mitigation x Sector	NO	SI	NO
Adaptation		0.0039**	0.0749**
		(0.0000)	(0.0000)
Adaptation x Sector	NO	NO	SI
Mitigation x Mitigation		0.0002**	
		(0.0000)	
Adaptation x Adaptation			-0.0005**
			(0.0000)
Post2020		0.5141**	-1.9184**
		(0.0003)	(0.0004)
Post x Mitigation		-0.0079**	
		(0.0000)	
Post x Adaptation			0.0233**
			(0.0000)
ROA	0.0072**	-0.0006**	-0.0188**
	(0.0000)	(0.0000)	(0.0000)
Cashflow	-0.0362**	-0.0595**	0.1712**
	(0.0000)	(0.0000)	(0.0001)
Leverage	0.0000**	-0.0003**	-0.0005**
	(0.0000)	(0.0000)	(0.0000)
Ebit	0.0039**	-0.2237**	0.0190**

	(0.0000)	(0.0000)	(0.0001)
Intercept	1.6515**	16.8887**	13.9599**
	(0.0002)	(0.0004)	(0.0003)
Firm effects	SI	NO	NO
Industry effects	NO	SI	SI
n	751	852	754
var(e.*Market value*)	0.0199		
	(0.0000)		
var(e.*Emissions intensity*)	0.9453		
	(0.0000)		
var(e.Water intensity)	2.9839		
	(0.0001)		
	852.0000		

Source: Authors' elaboration. Standard errors in parentheses.
Note. ** p<.01, * p<.05. Weighted by emissions. As a robustness check, we substituted the market value variable with Tobin's Q (column 1). The results, though differing in magnitude, align with those in Table 2.