Effectiveness of emission reduction policies and the role of corporate governance

Author Michael König-Sykorova[1],[2] (ORCID: 0000-0003-3278-2679), PhD Candidate at Technische Universität Ilmenau

Contact details Adickesallee 32-34, 60322 Frankfurt am Main, m.koenig@fs.de, +49 69 154 008 867

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[1] Frankfurt School of Finance and Management, FS-UNEP Collaborating Centre for Climate & Sustainable Energy Finance
[2] Technical University Ilmenau, Faculty of Economics and Media field of Accounting and Controlling

Abstract This study investigates the relationship between emission reduction policies (ERPs), corporate governance (CG), and greenhouse gas (GHG) emissions across firms from developed and emerging economies between 2011 and 2022. Using a dataset of 18,559 firm-year observations from 28 countries, this study provides cross-sectional evidence that robust corporate governance enhances the effectiveness of ERPs in reducing GHG emissions intensity. The findings highlight that higher ERPs are associated with reducing emissions in cross-sectional analysis, whereas firms with stronger governance structures—measured by A-ranked Governance Pillar Ratings—achieve more substantial reductions. The results, confirmed across various robustness tests, including instrumental variable analysis, demonstrate that CG mitigates the risk of symbolic enactment and enhances ERP implementation. The analysis provides sectoral insights regarding sector emission intensities and greenwashing prone sectors and underline the importance of focussing on corporate governance for effective emission reductions. Recommendations for investors, regulators, and policymakers promoting genuine sustainability efforts are provided.

Keywords climate change, energy efficiency, business ethics, strategy, neo-institutional theory

1. Introduction

Following key findings from the Intergovernmental Panel on Climate Change (IPCC, 2022), human-induced climate change is undeniable and rapid and widespread changes have already impacted every inhabited region, leading to severe economic losses for businesses worldwide. In response, the Paris Agreement (PA) – signed by 197 member states in 2015 – requires all members to develop and implement Nationally Determined Contributions (NDC) to achieve the global climate goals (UNCFFF, 2015a) and reduce global warming to well below 2°C. Despite these efforts, current projections indicate that even if all countries fulfil their NDCs, global warming will still exceed pre-industrial levels by at least 2.5°C by the end of the century (IEA, 2021; UNEP; 2023). Given these insufficient national commitments and slow progress in international climate negotiations, policymakers, researchers, and industry leaders advocate for more firm-level driven decarbonization (Blanco et al., 2020), with emission abatement projects that are already financial feasible and more competitive than fossil fuel alternatives (Davis et al., 2022). However, this requires setting up proper emission reduction policies (ERPs), such as science-based transition plans (NGFS, 2023; Tanthanongsakkun, 2022; Krabbe et al., 2015) guiding high to low emission technology pathways. As the private sector plays a pivotal role in addressing climate change (Kreibiehl et al., 2022), their actions substantively contribute to the achievement of the United Nations Sustainable Development Goals (SDGs) and the objectives outlined in the PA (Adu et al., 2021; Choi et al., 2021; Zamarioli et al., 2021).

(Background) The relationship between firm-level ERPs and emission reductions has been a point of emphasis in the academic literature (Klaaßen et al, 2024). While the literature provides ambiguous results depending on the theoretical framework, and the empirical operationalization, there is a broad consensus that firm-level sustainability actions and low emission business models are deeply connected and determinants for future success in many sectors (Adams et al., 2016; Brunner et al., 2024; IPCC, 2022). As switching from high to low emission technologies requires major changes in firms' strategic orientation (Hoang et al., 2023), certain risks and challenges may materialize, such as loosing economic viability, and general market competitiveness (Campiglio et al., 2022). Against these risks, there is growing evidence, that climate action strategies are frequently prone to credibility and reliability issues in line with greenwashing and impression management arguments (Marquis et al., 2016; Van Halderen et al., 2016; Keerthi et al., 2024). Firms provide false claims about an environmental benefits, with the aim to avoid pressure from stakeholders or institutional risks (Becker-Olsen et al., 2013). To diminish the use of such greenwashing tactics, strong corporate governance within a firm is considered as a fruitful element and may help to turn symbolic announcements into substantial climate action depending on the ambitiousness of ERPs, which is key for long-term sustainability (Haque et al., 2017).

(Research gap) While the literature on firm-level policies (ERPs in this study) and their impact on GHG emissions is expanding, significant inconsistencies and gaps remain that warrant further investigation. Previous studies have produced mixed results regarding the effectiveness of ERPs, with some research highlighting substantial GHG reductions (Haque et al., 2022), while others suggest that these policies often fail to produce meaningful environmental outcomes, potentially due to symbolic adoption or greenwashing intentions (Marquis et al., 2016; Coen et al.,2022). The existing literature has largely overlooked the role between corporate governance in determining the effectiveness of ERPs. Thus, while some studies acknowledge the importance of governance in environmental strategy, they have not systematically examined how corporate governance influence the success of ERPs. This gap is particularly substantive given that robust governance is increasingly recognized as a critical factor in ensuring that environmental policies are not merely symbolic but are also effective in achieving their intended outcomes (IPCC, 2022).

(Scientific contribution) This study adds evidence to the limited literature on the relationship between ERPs and GHG emissions by conducting ex-post analysis, advancing the understanding of how institutions and policies interact to reduce emissions. This study uses the largest dataset to date across 28 emerging and developed countries, and provides insights on policy and government factors driving emission reductions. It emphasizes on the reliability of ESG data in guiding both private investment decisions and policymaking, particularly for sustainable disclosure schemes, shareholder activism, and aligning economic activities with

the finance objectives of the Paris Agreements (Zamarioli et al., 2021). In sum, the study expands knowledge on the moderating role of corporate governance, as measured by ESG Governance Ratings, in determining the success of ERPs in reducing emissions.

(Findings) Using three-way-fixed effects with country, sector, and year effects, the positive role of good governance in the ERP-GHG nexus has been largely confirmed. An incremental increase of one ERP point is associated with a marginal reduction of 1 percentage point for good governed (-1.5%) vs. non-good (-0.5%) firms. The results are confirmed by applying a large set of robustness tests. incl. variations in measuring emission reductions, different forms of corporate governance, sectoral granularity, and the application of an instrumental variable (IV) approach to address endogeneity concerns. In the various specifications, the interaction term between ERP and CG remains significant in all specifications, reaffirming that firms with stronger governance frameworks are more successful in translating ERPs into lower GHG emissions.

The study is organized as follows. Section 2 introduces the theoretical background, followed by empirical literature and hypothesis development in section 3. Section 4 and discusses data and results respectively, including robustness tests in section 5.1. Section 6 concludes with a discussion, and recommendations for future research.

2. Theoretical background

This study adopts a multi-theoretical framework to provide a comprehensive understanding of the firm-level ERP-GHG nexus, corresponding to the need for a deeper theoretical integration in better explaining corporate responses to climate change (Shahab et al., 2019). While the NIT serves as the primary lens, the NIT is inherently multi-faceted, incorporating elements from other theories, including principal agent theory and the policy cost theory. The policy cost theory complements the NIT by emphasizing the economic trade-offs firms face, such as transaction and opportunity costs, when responding to institutional pressures to adopt ERPs. This alignment underscores that firms with sound governance may better manage these costs, enhancing their ability to transition ERPs from symbolic commitments to substantive environmental outcomes.

Foundations of the NIT and the link to climate strategies: The NIT is frequently used to analyze organizational behavior, particularly in terms of how firms operate within broader institutional environments (Scott, 2013; Lounsbury et al., 2020). According to the NIT, firm-level actions often result from institutional pressures exerted by governments (e.g., policy-making and standard-setting), societal shifts (e.g., changing consumer preferences, household income, and market demands), and market developments (e.g., competitive advantages through technological innovation) (Haapamäki et al., 2022).

Therefore the NIT provides a theoretical basis for announcing and implementing ERPs given the increasing pressure from policymakers, researchs and industry leaders advocating for more firm-level decarbonization (Blanco et al., 2020; Davis et al., 2022; Kreibiehl et al., 2022) to maintain or enhance firms' legitimacy and economic incentives within their institutional context (Scott, 2013).

Short term costs and long-term benefits: Implementing ERPs involves economic trade-offs, with firms navigating transaction and opportunity costs in their efforts to align with institutional expectations. Transaction cost economics posits that firms seek to minimize the costs of transactions and interactions within their institutional environment (Williamson, 1981). This can explain why firms announce ERPs as a strategy to reduce regulatory or reputational risks, thereby aligning with external expectations. Similarly, the resource-based view emphasizes that firms leverage unique internal capabilities, such as innovative technologies, to create a competitive advantage (Barney, 1991).

Firms navigating their transition towards climate goals pricing in short-term costs for mid-term benefits of adopting and implementing ERPs. de Villiers et al. (2011) highlight that firms pursue ERPs not only for environmental compliance, but also to enhance competitiveness and access financial resources, suggesting that efficiency motives can drive GHG reductions in response to growing global demand for sustainable goods and services (Berrone et al., 2009). However, as the phenomenon of "cheap talk" soared, firms start engaging in impression management through announcing ERPs without implementing them (Talbot et al., 2018). Surroca et al. (2018) highlights, that symbolic actions can temporarily boost legitimacy and stock returns, but can lead to negative long-term consequences if not backed by tangible initiatives. As economic motivations can drive ERP adoption, these initiatives do not always yield positive environmental outcomes, even when presented as such (Durand et al., 2019; Herold et al., 2019). This aligns with a principal-agent model, where managers may engage in greenwashing, obscuring true environmental interests from investors (Smith, 2021).

Greenwashing and symbolic action of ERP adoption: Thus, given the various pressures to establish ERPs that align with both internal and external expectations, firms may be tempted to project an image of climate action that matches these demands. This ‘greenwashing’ may occur either intentionally or unintentionally, as overwhelming pressure from institutional and stakeholder expectations can exceed a firm's capacity to implement meaningful changes quickly. For instance, in 2022 in Canada, the Competition Bureau found Keurig Canada Inc. guilty of greenwashing through claims that their single use coffee pods were recyclable when only 2 provinces had the capacity to recycle them. Similarly, Terra-Choice (2010) identified numerous cases of greenwashing in the consumer goods industry, including products falsely labeled as "eco-friendly" due to vague or misleading environmental claims that lacked substantive evidence.

In cases where firms cannot fully meet these high demands, they may resort to symbolic actions, such as greenwashing, to maintain legitimacy (Bansal et al., 2004; Delmas & Burbano, 2011).

Sector and country differences: Within countries and sectors, the likelihood of engaging in greenwashing may differ substantively, as firms in heavily regulated industries such as energy or manufacturing are subject to more stringent environmental scrutiny compared to other sectors such as the service industry (Delmas et al., 2011). Thus, ERP adoption (but not implementation) may be driven by the need to align with stakeholder expectations, including mandatory regulations in some jurisdictions, which can facilitate easier access to resources, reduce scrutiny, and avoid negative consequences such as consumer boycotts (Bansal et al., 2004; de Quevedo-Puente et al., 2007).

Corporate governance as a moderating factor: Within the NIT framework, corporate governance serves as a critical support factor that can influence how effectively ERPs are implemented. Strong governance may ensure that firms adhere to institutional expectations not just symbolically but through substantive actions. Governance mechanisms, such as board oversight and accountability, compel management to prioritize genuine emissions reductions over superficial compliance, thereby strengthening the relationship between ERPs and GHG outcomes (Wang et al., 2023). Strong corporate governance helps mitigate agency problems by aligning managerial behavior with share- and stakeholder expectations, thus reducing the risk of symbolic actions (Jensen et al., 1976), such as greenwashing. Strong corporate governance acts as a powerful self-regulatory mechanism for improving sustainability practices, as it is closely monitored by stakeholders, including institutional investors and regulatory bodies (Oyewo, 2023). This enhances legitimacy via strengthened relationship between institutional pressures and positive environmental outcomes (Berrone et al., 2009; Aguilera et al., 2006), reducing the likelihood of greenwashing.

3. Empirical literature review and hypothesis development

Multiple studies examined the impacts of firm-level climate strategies on firm GHG performance. In sum, the literature generate mixed findings about the effect of ERPs on GHG reductions and supports both only adoption of symbolic (cheap talk) and implementation of substantive (walk-the-talk) outcomes within the ERP-GHG nexus. These discrepancies can be attributed to several factors. First, methodological differences play a significant role. Studies vary widely in their research designs, from cross-sectional analyses (Luo et al., 2021) to longitudinal studies (Yu et al., 2020), coming in with different interpretations. Some research relies on self-reported ESG scores (Raghunandan et al., 2022), which can be biased and inconsistent, while others use more primary collected information (Coen et al., 2022). Second, data limitations often affect the robustness of findings. The quality and availability of environmental data differs across sectors and regions,

making comparisons difficult and contributing to conflicting results (Hassan et al., 2018). Third, contextual factors, such as regulatory environments and industry-specific pressures further contribute to these varied outcomes. For instance, firms in high-emission sectors face stricter regulatory scrutiny, prompting more substantive ERP adoption, while those in less regulated sectors may prioritize symbolic compliance (Haque et al., 2020). Addressing these methodological and contextual nuances is crucial for a more nuanced understanding of the ERP-GHG relationship (Albitar et al., 2023).

The ERP-GHG nexus From a legitimacy perspective, firms often communicate ERPs without monitoring substantial environmental improvements. Positive impacts are highlighted by Haque et al. (2022), where higher Environmental Pillar ESG scores significantly reduce emissions across various sectors. However, this contrasts with their earlier country study findings in 2017, which showed no substantial reductions in GHG emissions among UK firms, suggesting that ERPs may serve as a tool for enhancing corporate image rather than driving genuine environmental change. Further negative impacts are reported by Coen et al. (2022), who analyzed sustainability reports from large listed firms. The authors find that joining voluntary climate-related initiatives—such as the Carbon Disclosure Project (CDP), Science Based Target initative (SBTi), or applying the Task Force for Climate Risk Financial Disclosure (TCFD) frameworks often resulted in symbolic gestures without substantive emission reductions. External stakeholder pressure influences the existence of GHG emissions disclosure, but not its completeness, suggesting firms use incomplete reporting as a legitimation strategy (Liesen et al., 2015). Thus, firms may adopt ERPs primarily for reputational benefits, using climate policies as a form of "greenwashing" to respond to external stakeholders without making substantive changes to their operations.

Barrymore (2022) showed, that investors preferences only correlated with the existence of emission strategies but not with factual reduced emissions. Thus symbolic adoption is even corresponding to the desire to maintain legitimacy in the eyes of investors and regulators, which certainly results in little to no actual reduction in GHG emissions. Raghunandan et al. (2022) find that ESG labelled funds, on average, exhibit worse emission performance than funds without ESG labels. Yu et al. (2020) developed a greenwashing index, demonstrating that sectors within hard-to-abate industries are more prone to greenwashing activities. Against the findings of Haque et al. (2020; 2022), they show that companies in high emission sectors (Materials, Energy, and Utilities) are more likely to engage in greenwashing. Similarly, Lagasio et al. (2023) found high greenwashing probabilities in the materials, communication services, and health care sectors using a greenwashing severity index based on ESG-related terms in sustainability reports. Gourier et al. (2024) extended this analysis globally by tracking climate-related articles, noting significant attention to greenwashing in financial, energy, and construction industries. They showed, that firms operating in service-oriented economic activities are as likely to engage in symbolic

commitments as firms in emission-intensive sectors. Key factors for symbolic enactment are firm-level governance and country factors, such as national income and country corruption. In addition, Zhang (2022) highlights in a multi-country large-caps analysis, that symbolic enactment are often driven by financial constraints, indicating that the financial environment is a significant factor influencing symbolic behavior.

From the efficiency perspective within the NIT framework, firms can leverage technological advancements to adopt low-emission business practices, such as utilizing renewable energy sources and enhancing operational efficiency, ultimately leading to reduced emissions (Haque et al., 2022). Qian et al. (2017) suggest that even the disclosure of carbon initiatives can act as a catalyst for improving actual carbon performance. They argue that ERPs are increasingly being integrated into firms' strategic priorities, evolving from a mere focus on legitimacy to achieving genuine carbon emission reductions, thereby contributing meaningfully to society and ecosystems.

Across sectors the effectiveness of ERPs are significantly shaped by industry-specific factors. Source (2023) suggest that firms in heavily regulated sectors, such as utilities and energy, are more likely to implement substantive ERPs due to stricter compliance requirements and heightened public scrutiny. In contrast, firms in less regulated sectors tend to exhibit minimal genuine adoption of such policies, underscoring the crucial role of external regulatory environments in shaping ERP effectiveness. Haque et al. (2020; 2022) confirm that the association between ERPs and reduced emissions are stronger in high-emitting compared to low emission firms. Torpey (2022) found that firms in heavily regulated sectors, such as utilities, demonstrate significantly higher environmental ratings compared to less regulated sectors like IT and consumer discretionary.

The role of corporate governance in the ERP-GHG nexus. Generally, there is a large strand of literature showing that good governance as such reduces emissions. For instane, independent boards and board size (Ghitti et al., 2024; Gold et al., 2022), sustainability-focused committees (Elsayih et al., 2021; Gold et al., 2022), board female share (Peng et al., 2022; Ghitti et al., 2020), stronger governance frameworks (Haque et al., 2018), and performance-linked compensation (Moussa et al., 2020), are drivers for substantive emission reductions per se.

Yu et al. (2020) identifies factors that act as a safeguard against greenwashing, ensuring that environmental claims are backed by real climate actions. They find in their longitudinal set up between 20112 and 2016 that firms are less prone to greenwashing with higher independent directors, higher institutional investors, more operating within less corrupt country systems with strong public interest influence, and are cross-listed on multiple exchanges.

Martínez-Ferrero et al., (2020) show the positive role of internal governance factors, such as CEO independence and board composition on firm's adoption of SDG implementation. Their findings suggest that while many firms symbolically conform to environmental policies through carbon reporting, it is the governance structures that determine whether these policies result in substantial GHG reductions. Firms with poor governance are more likely to use ERPs as a tool for impression management, rather than achieving real environmental performance improvements. On the relationship between ERPs and governance, Tanthanongsakkun et al. (2022) tests if staggered boards are influencing the level of ERP and find, that staggered boards reduce ERP scores by around 10 percent. Analyzing data from U.S. companies, the authors find that firms with staggered boards are less likely to disclose carbon emissions, suggesting that this governance structure may hinder transparency in environmental reporting. The study highlights the importance of board composition in promoting environmental accountability and suggests that more flexible board structures could enhance transparency in carbon emission disclosures and foster ultimately emission reductions.

Hyatt & Berente (2017) differentiate between internal and external stakeholder pressures, and found that internal pressures drive substantive environmental commitments, while external pressures lead to more symbolic responses.

Albitar et al. (2022) demonstrate that innovation contributes to emission reductions, with governance acting as a key moderating factor in this relationship. The authors emphasize that board independence and sustainability-linked executive compensation significantly enhance the implementation of ERPs, leading to more effective emission reductions.

While firms may adopt ERPs to project legitimacy and meet stakeholder expectations, the effectiveness of these initiatives may largely depending on internal governance structures to translate symbolic actions into tangible environmental outcomes. Thus, this study focuses on the internal governance responses that mediate external institutional pressures, offering a comprehensive analysis of how corporate governance shapes the ERP-GHG emissions nexus.

In sum, the literature reveals a complex interplay between symbolic and substantive outcomes of ERP adoption. While some studies emphasize the legitimacy-driven motives behind climate strategies, others highlight efficiency gains and genuine emission reductions. The role of corporate governance emerges as a crucial factor in determining the effectiveness of these policies. Strong corporate governance appear to mitigate the risk of symbolic compliance and ensure that environmental initiatives translate into measurable performance improvements. In this regard, the following hypothesis will be tested.

Firms with sound corporate governance are more likely to translate emission reduction policies (ERPs) into substantive GHG emission reductions, thereby minimizing the risk of symbolic enactment.

4. Data and empirical model

4.1. Data

This study utilizes a multi-country sample from 2011 to 2022. The sampling frame was constructed using primarily the Refinitiv database[3], utilizing comprehensive financial and Environmental, Social, and Governance (ESG) data on the firm-level. Emissions data drawn from Institutional Shareholder Services (ISS).

Table 1: Sample selection

Stage	Sample	Observations	Delta	Countries	Sectors (NAICS)
1	Initial sample	25,984		72	18
2	Drop countries with low number of observations (less than 5-% percentile)	24,745	-1,239	29	18
3	Drop sectors with low number of observations (less than 5-% percentile)	23,851	-894	29	14
4	Drop missing information for key variables of interest (see table with descriptive statistics)	18,559	-5,292	28	14

Note: Robustness tests with the samples in Stage 1, 2, and 3 are conducted.

The initial sample consisted of 25,984 observations across 72 countries (see table 1). By making use of a percentile-based filtering technique countries and sectors with low observations are removed. The final sample includes 18,559 observations from 28 countries[4] across 14 NAICS sectors[5]. In terms of country coverage, the USA (21%), GBR (12%), and JPN (9%) account for the largest shares of observations (see table x in Annex). To the best of the author's knowledge, this is the most comprehensive data sample used for analysing the relationship between firm level policies' and GHG performance. The study acknowledges the potential for sample selection bias, particularly due to the exclusion of certain countries and industries

[3] Refinitiv gathers information from annual reports, company and non-governmental organizations (NGO) websites, stock exchange filings, Corporate Social and Responsibility (CSR) websites, and news sources. For more details see LSEG (2023).
[4] Countries: Australia, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, Hong Kong, India, Ireland, Italy, Japan, South Korea, Malaysia, Mexico, Netherlands, New Zealand, Norway, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, United Kingdom, United States of America.
[5] Sectors: Manufacturing; Transportation and Warehousing; Retail Trade; Utilities; Construction; Mining, Quarrying, and Oil and Gas Extraction; Information; Finance and Insurance; Real Estate and Rental and Leasing; Wholesale Trade; Professional, Scientific, and Technical Services; Accommodation and Food Services.

where data is incomplete or unavailable. To address this, multiple robustness checks and a sensitivity analyses have been employed to assess the impact of these exclusions on the study's results.

The sample is largely aligned with the overall country GHG emission intensity footprint metric[6] drawn from country level data except for some outliers, such as India and Thailand (See figure 3 in the Annex). Generally, the mean GHG emission intensity used in the sample is higher than the country emissions footprint. Explanations for the difference are two-folded. First, the used data report GHG emissions as CO2 equivalent emissions in the sample, include most relevant reported GHG emissions, while the reference country data reports only CO2 emissions.[7] Second, the study sample may be weighted to industrial sectors with more emission-intensive industries, such as energy, manufacturing, or heavy industrial sectors. This may lead to higher emissions relative to revenue as these firms are often large, publicly listed entities subject to stringent environmental reporting standards. The country data based on national-level GDP, includes a wider range of economic activities, such as lower-emission sectors like services and technology, and may not fully reflect firm-specific emissions variations. This divergence in industry focus and reporting comprehensiveness contributes to the observed differences in emission intensity. Notably, the US and UK, covering one third of the sample are showing very similar emission intensities between the sample and the national carbon footprint.

4.2. Empirical model specification

To test the hypothesis, a cross-sectional approach is applied. This method provides a snapshot at a particular point in time across sectors, countries. In the presented pooled OLS (POLS) model (equation 1), firms are compared within sectors, countries and the year based on the ambitiousness of emission reduction policies, focusing on cross-firm comparisons at a single point. For the baseline empirical framework a three-way fixed effects model is formulated:

$$GHG\ Intensity_{\ i,t} = \beta_0 + \beta_1 ERP_{i,t} + \beta_2 CG_{i,t} + \beta_3 (ERP_{i,t} x\ CG_{i,t}) + X'_{i,t}\alpha + Y'_{i,t}\beta + \gamma_{Country_i} + \delta_{Industry_i} + \xi_{Year_t} + \varepsilon_{i,t} \quad (1)$$

[6] Data provided by the Global Carbon Budget (2023)

[7] Beyond carbon dioxide (CO2), it is also considering methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexaluioride (SF6) in case this is reported by the firm, while the used Global Carbon Budget reference data reports only CO2 emissions.

GHG Intensity$_{i,t}$ is firm i's annual GHG emission intensity, calculated as the sum of absolute Scope 1 (direct) and Scope 2 (indirect) tons of CO2 equivalent emissions[8] expressed in logarithmic form divided by net revenues in 1,000 USD. *ERP*$_{i,t}$ is a normalized score ranging from 0 to 100 capturing a firm's ERPs compared to other firms in the same industry and year t, covering processes, mechanisms, or programs. Corporate governance $(CG_{i,t})$ represents a dummy for firms with "Corporate Governance Rating A" counted as 1, and 0 if non-A ranked year t. $ERP_{i,t}x\ CG_{i,t}$ represents the interaction term that assesses whether the effect of ERPs on GHG emissions is influenced by the CG dummy. $X'_{i,t}\alpha$ represents the vector of fundamental firm-level controls following previous literature including firm size, cash, and tangible assets, and market-to-book value. $Y'_{c,t}\beta$ covers time-varying country-level effects – Gross Domestic Product, *GDP*) in current USD, and the countries' governance regime (*Governance*) of the country *c* where firm *i* is located at time *t* which explains further variance beyond the country fixed effects. *Country*$_{_i}$, *Industry*$_{_i}$ and *Year* capture country, industry and time fixed effects.

To mitigate endogeneity concerns, an instrumental variable (IV) approach has been employed in the robustness section. Further robustness tests include use of lagged variables to partially address potential reverse causality and further modifications in the empirical set up are tested.

4.2.1. Dependent variable

The dependent variable is GHG performance, measured at the firm level as total GHG emission intensity (Scope 1 and Scope 2 emissions), which is defined as firm-year emissions in tons of CO2 equivalent (CO2e) divided by net revenue in million USD. Scope 1 emissions cover direct emissions linked to production processes such as combustion. Scope 2 emissions cover indirect emissions of energy usage, such as electricity, heat, cold, and steam. The empirical identification follows Lewandowski (2017), Nuber et al. (2021), and Haque et al. (2022) by using GHG intensity, which is represented in logarithmic (ln) values to improve the normal distribution of the dataset. As a robustness check, Scope 1 and Scope 2 emissions are used separately to account for different characteristics of emission types, as well as in absolute (total in metric tons) and relative terms (non-logarithmic). In addition, to address potential bias due to reverse causality in the GHG-ERP nexus, where companies with greater GHG emission intensity may increase their ERP commitments to reduce regulatory fines, lagged variables (one and three year lags) for emissions have been incorporated to separate the effect of past emissions on current environmental efforts, further minimizing the risk of reverse causality bias.

[8] This covers carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexaluioride (SF6) if reported by the firm.

4.2.2. Independent variables

There are two main explanatory variables. The first one is the Emission Reduction Policy (*ERP)* Score provided by Refinitiv. The *ERP* captures policy-related firm intentions to reduce GHG emissions in its operations, system, or another set of formally documented processes for controlling emissions and driving continuous improvement. The normalized ERP score ranges from 0 to 100 and is calculated based on the existence of firm documents and reports that are publicly available, such as annual reports, CSR reports, ESG webpages, and other global disclosure systems such as the carbon disclosure project (CDP). The data points are converted to a relative score (LSEG, 2023). Firms are compared with their peer firms to arrive at the percentile score. The ERP serves as a reasonable proxy for stated firm-level climate policies relating to various GHG emissions from the firm's core activities, processes, mechanisms or programs. The same variable has been used in another academic studies (Tanthanongsakkun et al., 2022) by testing the impact of board governance to determine ERP values which further justifies the variable as an appropriate proxy. Example statements from sustainability reports are the following:

- BASF (2020): "Researching and developing completely new processes and technologies to reduce our GHG emissions over the long term."
- Hugo Boss (2021): "Focusing on saving energy, as well as procurement and self-generation from renewable sources"
- Apple (2022): [Reduce emissions in] "supply chain through process innovation, emissions abatement, and the use of non-fossil-based low-carbon fuels."

The second explanatory variable is corporate governance (CG). Corporate governance is a complex mechanism with multiple attributes as discussed in the literature review. A comprehensive corporate governance index is used to concentrate all of the governance mechanisms into a single integrated, yet informative score which reflect the overall quality of a firms' corporate governance. Several methods of measurement of quality of corporate governance have been employed by academia and commercial service-providers to measure the quality of corporate governance (Vig et al., 2018). The decision to use the Refinitiv Corporate Governance Indicator in this study is grounded in its comprehensive and industry-standard methodology and large coverage. It is supported by literature that emphasizes the need for standardized governance measures in cross-country comparisons (Voicu, 2022). As noted by Dragomir (2022), Refinitiv's governance scores are particularly valuable for assessing governance outcomes across developed and emerging markets, enabling robust comparisons across different legal and regulatory environments. CG is a dummy that is constructed by considering the relative sum of the three category weights

management[9], shareholders[10], and CSR strategy[11]. The rating is constructed on a country and year basis, aligning with insights from the NIT and literature suggesting that sound corporate governance may positively influence the relationship between ERPs and actual emission reductions through mechanisms like policy compliance, transparency, and accountability (Wang et al., 2023). The Governance pillar in Refinitiv's ESG ratings primarily reflects internal governance structures and practices within a company (LSEG, 2023). While these internal governance mechanisms are designed to meet the expectations of external stakeholders—including regulators, investors, and the broader community—the Governance pillar itself focuses on the company's internal frameworks and their effectiveness in ensuring accountability, transparency, and ethical conduct. Therefore, it represents the company's internal response to external stakeholder pressures rather than the pressures themselves.

4.2.3. Country-level controls

Given the varying regulatory and economic environments in the sample, country-level governance and economic controls are capturing the interplay between national contexts and corporate environmental performance. National income per capita *(GDP p.c.)* in current USD reflects on the stage of economic development (IPCC, 2022) that may influence a firm's decision to adopt and implement ERPs, as wealthier nations often have more resources to allocate towards enforcing environmental standards and encouraging sustainable practices among businesses. Country-level governance captures the overall quality of governance (*Governance)*. Evidence suggests that good governance on the country level matters (Gani, 2012) with both negative and positive relationship for fossil-fuel and non-fossil fuel exporting countries respectively; Sarpong et al., 2020). By employing Principal Component Analysis (PCA) on the set of governance indicators provided by the World Banks' World Governance Indicators (WGI) (Hassan, 2018)[12], a single composite index encapsulates the underlying governance quality across countries. The first principal component captures the largest proportion of variance in the governance data. This is extracted and used for the composite index of governance.

4.2.4. Firm-level controls

Finally, firm-level controls are account for variations in company characteristics that may influence GHG emissions are added. Firm size (*Size*), measured by the natural logarithm of total assets, captures the potential scale effects of larger firms, which are often associated with higher emissions and higher emission intensity due to greater operational complexities and energy use (Ferris et al., 2018). Tangible assets (*PPE*)

[9] Structure, incl. independence, diversity, committees with a maximum of 35 items
[10] Takeover defences, shareholder rights with a maximum of 12 items
[11] ESG reporting and transparency with a maximum of 9 items
[12] The six Governance indicators are effectiveness, regulatory quality, rule of law, and control of corruption.

represent the firm's investment in physical capital, a factor known to be positively correlated with emission intensity, particularly in industries that are asset-heavy (Berrone & Gomez-Mejia, 2009). Liquidity (*Cash*) and Market-to-Book (*MTB*), reflecting the firm's financial flexibility, is included to control for the firm's capacity to invest in emission-reduction technologies or processes (Moussa et al., 2020; Zhang, 2022). These controls help isolate the impact of ERP on GHG intensity by accounting for individual firm characteristics. Following the literature it is expected, that PPE and Size (Cash, and MTB) is positively (negatively) associated with GHG emission intensity.

Table 2: Variable definitions

Variable name	Label	Description	Supporting literature for operationalization
Variables of interest			
GHG intensity Scope 1+2 (ln)	GHG (ln)	Natural logarithm of Scope 1 (direct) plus Scope 2 (indirect) GHG emissions (CO2e) in tons divided by net revenues in thousands USD, with lower intensity indicating better emission performance.	Lewandowski (2017), Nuber et al. (2021), Haque et al. (2022)
Emission Reduction Policy	ERP	Emission reduction policy (ERP) is a score that captures firm-level policies to reduce emissions within firms' core activities, including processes, mechanisms, or programs. The score is sector and time sensitive, with higher score indicates more ambitious ERPs.	Coen et al. (2022), Haque et al. (2017, 2022)
Corporate Governance	CG	Corporate governance is a dummy with the value 1 if a firm received Governance Pillar Rating A. The variable reflects on firm's governance effectiveness using CSR Strategy (ESG reporting, transparency, up to 9 items), Management (including independence and committees, up to 35 items), and Shareholders (rights and defences, up to 12 items). Details on calculation see LSEG (2023).	Ferris et al. (2018), Durand et al. (2019), Wang et al. (2023), Kaufmann et al. (2011)
Firm level controls			
Firm size (ln)	Size (ln)	Natural logarithm of total assets reported by the firm in million USD.	Al-Tuwaijri et al. (2004), Ferris et al. (2018)
Tangible assets	PPE	Relative share of total reported gross value of property, plant and equipment (PPE) before depreciation divided by the total asset size of the firm.	Wang et al. (2023), Berrone & Gomez-Mejia (2009)
Liquidity	Cash	Relative share of total short term and highly liquid investments divided by total current liabilities.	Moussa et al. (2020), Wang et al. (2023); Provaty et al., (2024)
Market-to-Book	MTB	Relative share of a company's market value to its book value, indicating how much investors value the company relative to its net asset worth.	Moussa et al., 2020; Zhang, 2022
Country level controls			
National income	GDP p.c.	National income expressed as GDP p.c. in thousand USD in current prices in the firm's headquarter.	Rodríguez et al. (2015); Yu et al. (2020)
Governance (World Governance Indicator)	Gover nance	A composite index reflecting the overall quality of governance across countries, derived using Principal Component Analysis (PCA) on governance indicators. The first principal component, capturing the largest proportion of variance, is used as the governance score.	Kaufmann et al. (2011), Hassan et al. (2018); Mooneeapen et al (2022); Yu et al. (2020)

Note: Further variables used for robustness analysis are not shown in this table. This includes, Direct Emission Intensity (Scope 1, DEI); Indirect Emission Intensity (Scope 2, IEI); GHG intensity (S1+S2) expressed as non-logarithmic; Absolut GHG Emissions expressed as not divided by revenue.

4.2.5. Descriptive statistics and model sensitivities

Table 4 shows descriptive statistics. *GHG (ln)* is slightly right skew in the dataset suggesting that some high emitting firms stand opposite of many low emitting firms. For *CG*, the mean value is 0.24 which indicates that almost one quarter of the sample is considered as A-ranked, and else being non-A-ranked firms. Other controls shows comparable distribution with prior studies (e.g., Luo et al., 2021; Haque et al., 2017, 2020, 2022).

Table 3: Descriptive statistics

Variable	Mean	Median	SD	Min.	Max.	N
GHG (ln)	3.91	3.64	1.81	0.01	9.01	18,559
ERP	34.79	34.29	19.62	0.00	100.00	18,559
CG	0.24	0.00	0.42	0.00	1.00	18,559
Cash	0.50	0.30	0.77	0.00	27.90	18,559
Size	22.54	22.07	2.69	16.28	31.81	18,559
PPE	2.73	1.13	4.84	0.00	69.89	18,559
MTB	2.49	1.26	4.24	0.00	72.87	18,559
Governance	0.36	0.92	1.91	-4.99	3.03	18,559
GDP p.c.	6.84e+12	2.79e+12	8.20e+12	1.68e+11	2.57e+13	18,559

Note: All variables are winsorized at 1% and 99% percentage at the industry level. For definitions see table 3. SD: Standard deviation.

Various tests to account for multicollinearity, heteroskedasticity, and endogeneity have been conducted. To assess statistical differences between the means of GHG and CG, as well as ERP and CG, two-tailed t-test suggests that the observed differences are unlikely to have occurred by chance. Mean values for GHG and ERPs are higher for firms with high CG values. The results revealed a t-value of -xxx (p-value<0.001) and xxx (p-value<0.001), respectively. To ensure the reliability of the regression results, the Variance Inflation Factor (VIF) values for all variables were below the threshold of 10, with a mean VIF of 1.72, indicating no significant multicollinearity issues (See Table Ax). This is specifically relevant for the association between ERP and CG. To determine heteroskedasticity, the Modified Wald test has been conducted to test heteroskedasticity in the analysis. Results indicated first-order autocorrelation (p-value:<0.00, chi2= 172.04), which confirmed relevance to use of robust standard errors in the model specification. To assess potential cross-sectional dependence, the Pesearan CD test has been conducted, which confirmed significant cross-sectional dependence (p-value: <0.00, CD-test: 190.98), requiring the use of Driscoll-Kraay standard errors. Robustness results replicated baseline results using Driscoll-Kraay instead of robust standard errors confirmed baseline results. As part of the robustness checks, the Ramsey RESET test has been applied to assess potential model misspecification in the baseline regression. The test introduces higher-order terms (squared and cubic fitted values) to detect omitted variable bias or incorrect functional form. The results (not shown in the main body) indicate that the quadratic and cubic term is statistically significant ($p < 0.01$), suggesting non-linearity in the relationship between the predictors and the dependent variable. This underscores the importance of capturing more complex interactions in the model. However,

despite the RESET test results, the main findings regarding the marginal effects of ERPs and governance remain qualitatively consistent, as the interaction between governance and ERPs continues to exhibit a significant effect. These results suggest that the model is robust but may benefit from further exploration of non-linear dynamics in future research. Finally, Pearsons' two-way correlation has been conducted (Table Ax,). ERP is weakly linked to lower GHG emissions, indicating that better emission reduction policies may reduce emissions, though the effect is minimal. Similarly, CG is weakly associated with higher GHG emissions, which could be due to larger firms are usually endowed with stronger corporate, but also higher emissions. For firms with strong corporate governance (CG=1), the correlation between emissions and ERP is -0.345 (p-value: xxx) compared to -0.204 (p-value: xxx) for firms without strong governance (CG=0).

5. Results

The results show that ERPs have a statistically significant negative effect on GHG intensity (Table 4, Column 1, 2). By adding governance (*CG*) (Table 4, Columns 3, 4), the direct effect of ERPs on GHG intensity remains significant, suggesting that CG is associated with additional emission reductions.

Table 4: Three-way fixed-effects regression of GHG intensity against ERP and CG

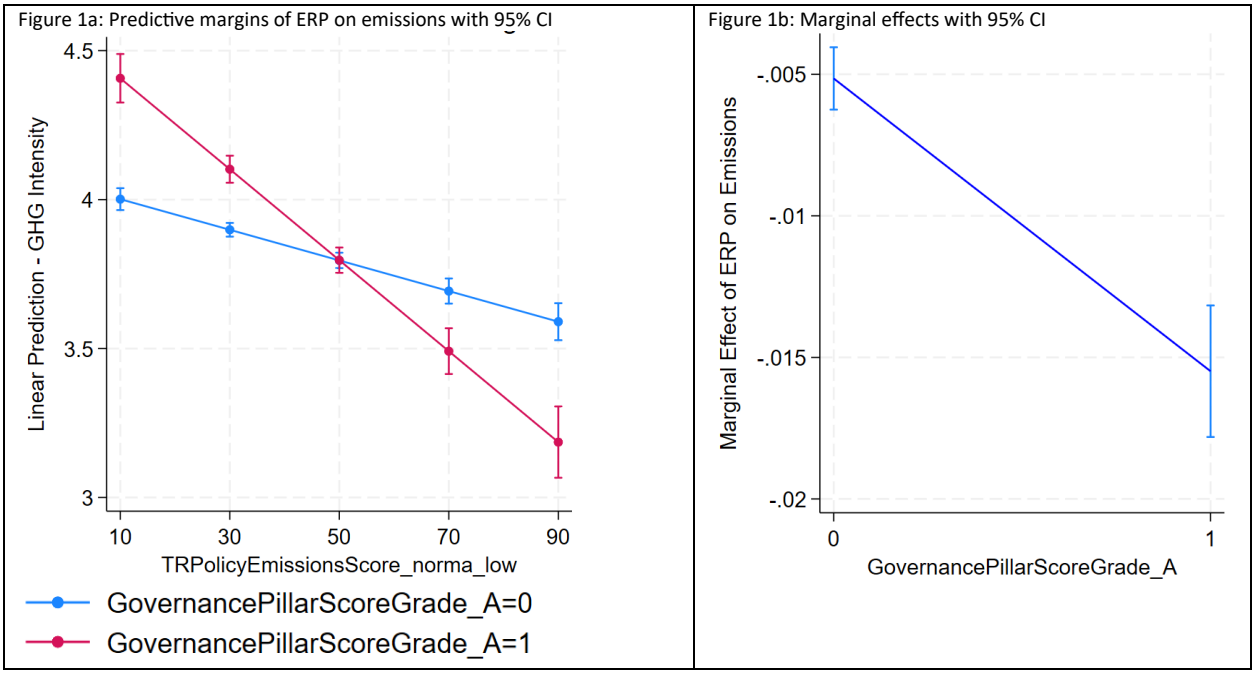
DV: GHG (ln)	(1)	(2)	(3)	(4)
ERP	-0.0071***	-0.0067***	-0.0069***	-0.0051***
	[0.00]	[0.00]	[0.00]	[0.00]
CG	-	-	0.1398***	0.5071***
	-	-	[0.02]	[0.06]
ERP x CG	-	-	-	-0.0101***
	-	-	-	[0.00]
Size	-	0.0626***	0.0546***	0.0539***
	-	[0.01]	[0.01]	[0.01]
PPE	-	0.0858***	0.0848***	0.0844***
	-	[0.00]	[0.00]	[0.00]
Cash	-	-0.0506***	-0.0499***	-0.0446***
	-	[0.02]	[0.02]	[0.02]
MTB	-	-0.0508***	-0.0509***	-0.0505***
	-	[0.00]	[0.00]	[0.00]
Governance	-	0.1132**	0.1133**	0.1140***
	-	[0.04]	[0.04]	[0.04]
GDP p.c.	-	-0.0000**	-0.0000***	-0.0000***
	-	[0.00]	[0.00]	[0.00]
Constant	4.1519***	2.9330***	3.0973***	3.0642***
	[0.02]	[0.22]	[0.22]	[0.22]
Model	3-Way FE	3-Way FE	3-Way FE	3-Way FE
Sample	Full	Full	Full	Full
Obs.	18,559	18,559	18,559	18,559
Time FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes

Sector FE	Yes	Yes	Yes	Yes
R2	0.43	0.48	0.49	0.49
R2 adj.	0.43	0.48	0.48	0.49
R2 adj. (within)	0.01	0.11	0.11	0.11
F-Stat.	158.61	171.25	156.81	141.93

Note: Fixed effects model with Time, Country, Sector fixed effects. Robust standard errors in brackets. *, **, *** denote significance at 10, 5, and 1 percent levels. Variable descriptions see table 3.

The significant negative interaction term between ERP and CG (-0.0101) in Colum 4 confirms the hypothesis (see also Figure 1a). A-ranked corporate governance firms (CG=1) exhibit a steeper decline in GHG emissions as ERPs increase, suggesting that strong corporate governance enhances the effectiveness of ERPs in reducing emissions. In contrast, firms with low governance (CG=0) show a nearly flat relationship, indicating minimal impact of ERPs on emissions without strong governance. While the interaction effect is relatively small from an economic point of view, the large sample size and inclusion of relevant controls point to the plausible economic significance of this relationship. An incremental increase of one ERP point is associated with a reduction of 1.5% (-0.0101 + (-0.0051)). Putting these numbers into practice, for a medium-sized company with 3.5 million USD in revenue and a GHG emissions intensity of 3.96 tons of CO_2 per 1,000 USD (data taken from the descriptives), the baseline emissions are 13,860 tons of CO2e. Under weak governance (CG = 0), the marginal effect of ERP on emissions intensity is (-0.0051), resulting in an decrease of around 70 tons of CO2e (13,860 x 0.0051). In contrast, under strong governance (CG = 1), the marginal effect of one ERP unit is 0,0152 (0.0101 + 0.0051), is associated with a reduction of 210 tons of CO2e. The positive coefficient for corporate governance (0.5071) may reflect enhanced transparency in emissions reporting among well-governed firms (Döring et al., 2023). Alternatively, it could indicate that firms with higher emissions tend to invest more in robust governance structures to manage their environmental impact and maintain legitimacy. This is in line with the theoretical arguments that firms with higher emissions tend to adopt robust governance structures as both a legitimacy-driven response to external stakeholder pressures, and an efficiency-driven strategy to proactively manage climate risks and align with sustainability goals. Figure 1b shows marginal effects of ERP on emissions for A-ranked vs Non-A-ranked firms. On the relevance of adding the interaction term (*ERP x CG*), nested F-test was conducted to assess whether the inclusion of the interaction term significantly improves the model. The result ($F(1, 18500) = 65.51$, $p < 0.001$) confirms that the interaction term is statistically significant, indicating that CG meaningfully influences the relationship between ERP and GHG emissions.

Figure 1: Linear prediction and marginal effects of Emission Reduction Policies (ERP) on GHG Emissions by A-ranked and Non-A-ranked firms



Note: In Figure 1a: Red line are A-ranked firms (CG=1) and blue line are non A-ranked firms (CG=0). For both figures, robust standard errors are used for the margins estimates. Error bars represent 95% confidence intervals.

Firm-level controls, incl. tangible assets (*PPE*), and firm size (*Size*) shows that asset-heavy, and larger firms have higher GHG emissions, which is consistent with the scale of these companies and confirms prior studies (Haque et al., 2022). On the financials, lower levels of liquidity (*Cash*) and higher investors value (*MTB*) is negatively associated with emission intensity, which may be related to greater financial constraints, limiting their ability to invest in meaningful emission reduction efforts. These firms may be more prone to engage in superficial or symbolic actions to maintain legitimacy without substantial environmental improvements. In contrast, firms with higher cash reserves have more financial flexibility to invest in technologies and processes that can genuinely reduce emissions, which may allow them to "walk the talk" rather than resorting to "cheap talk". On the country variables, while there exist a strong positive pairwise correlation between GDP and Governance (+0.679, p-value: <0.000, Table x, Annex), the country variables provides different magnitudes. Higher income (governance) levels are associated with lower (higher) emission intensity compared to lower income (governance) levels. This pattern aligns with findings in the literature that suggest wealthier nations often have more resources to enforce environmental regulations, which forces firms to adopt more effective emission reduction practices (IPCC, 2022; Rodríguez-Pose et al., 2015). Higher governance scores may reflect firms' enhanced transparency and

accountability, often linked to improved reporting accuracy, which may reveal higher reporting of emissions in well-governed firms due to stricter compliance (Liesen et al., 2015; Wang et al., 2023).

5.1. Robustness

In order to draw more robust conclusions several tests are carried out, incl. variations in measuring emissions (Table 6), variations in corporate governance (Table 7), splitting samples (Table 8), and applying an instrumental variable (IV) approach to address endogeneity concerns (Table 9). In the various specifications, the interaction term between ERP and CG remains significant in all specifications, reaffirming that firms with stronger governance frameworks are more successful in translating ERPs into lower GHG emissions.

Table 5: Overview of robustness tests

Robustness 1a: Variations in the dependent variable (Table 6)	Confirm H1?
Accounting for time differences by using a one (t+1) and three (t+3) period lead of the dependent variable assuming impact materializes in the next period (Column 1, 2).	Yes
Replace the dependent variable with only Scope 1 or Scope 2 GHG emission intensity respectively (Column 3, 4)	Yes
Turn the dependent variable (GHG emission intensity) in a non-natural logarithm form (Column 5).	Yes
Robustness 1b: Variations in the independent variable (Table 7)	Confirm H1?
Replace the governance variable with Governance Pillar sub-sets CSR Grade A and Management Grade A (Column 1, 2)	Yes
Replace the governance variable with Board Governance Committees or Executive ESG Compensation (Column 3, 4)	Yes

Robustness 2: Sample splitting (Table 8)	Confirm H1?
Add an interaction term to differentiate between low and high emission-sectors to account for sector characteristics (Column 1)	Yes
Add an interaction term for higher emitting firms by sector and year (Emissions>p50) (Column 2)	Yes
Add an interaction term for "greenwashing" prone sectors (Column 3)	Partly
Add an interaction term for more firms with higher liquidity by sector and year (Cash>p50) (Column 4)	Partly
Robustness 3: Instrumental variable approach (Table 9)	Confirm H1?
Apply a two-stage least squares (2SLS) approach to address potential endogeneity concerns on the effects of ERPs and CG on GHG emissions. (Column 1, 2, 3)	Yes

Modifications in the outcome variables, results are broadly similar as the baseline for lagged emissions (t+1 in Column 1, and t+3 in Column 2), decomposing GHG emission intensity measures (Scope 1 in Column 3, and Scope 2 in Column 4), and GHG in non-logarithmic terms (Column 5). This indicates that the effect is not dependent on the specific composition and scaling of the dependent variable.

Table 6: Robustness 1a – Alternative measures of GHG emissions

DV: See column	(1)	(2)	(3)	(4)	(5)
	Lagged GHG emissions		Decomposition of GHG emissions		Non-LN emissions
ERP	-0.0042***	-0.0028***	-0.0076***	-0.0020***	-1.3474***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.24]
CG	0.5230***	0.4997***	0.5730***	0.2906***	147.5267***
	[0.07]	[0.09]	[0.07]	[0.05]	[38.74]
ERP x CG	-0.0107***	-0.0097***	-0.0116***	-0.0050***	-3.5569***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.76]
Constant	2.8999***	2.8593***	0.7119***	2.7400***	201.7970**
	[0.22]	[0.29]	[0.21]	[0.17]	[90.03]
Model	3-Way FE	3-Way FE	3-Way FE	3-Way FE	3-Way FE
DV:	Lag 1	Lag 3	DEI (Scope 1) only	IEI (Scope 2) only	Non ln
Obs.	13978	8072	18559	18559	18559
Time FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
R2	0.48	0.50	0.48	0.30	0.26
R2 adj.	0.48	0.49	0.48	0.30	0.26
R2 adj. (w/i)	0.10	0.11	0.10	0.06	0.02
F-Stat.	93.97	57.06	138.66	86.95	33.91

Note: Fixed effects model with Time, Country, Sector fixed effects. Robust standard errors in brackets. *, **, *** denote significance at 10, 5, and 1 percent levels. Variable descriptions see table 3. DEI: Direct emission intensity (Scope 1); IEI: Indirect emission intensity (Scope 2).

Next, the corporate governance variable is replaced (Table 6) with other proxies. The baseline hypothesis is confirmed in all variations. The CSR Grade A (Column 1) variable was used to test whether a firm's emphasis on social responsibility, a critical ESG component, impacts the effectiveness of ERPs. This is in line with research that shows that CSR alignment with stakeholder expectations can motivate substantial environmental outcomes (Haque et al., 2017; Surroca et al., 2018). The Management Grade A (Column 2) variable examined whether governance quality, particularly in management structures, enhances ERP implementation, supported by findings that effective management oversight is crucial for translating policies into tangible results (Martínez-Ferrero et al., 2020; Wang et al., 2023). A narrow definition of corporate governance, focusing on the existence of committees[13] (Column 3) was applied to determine if specific oversight mechanisms are key to successful environmental initiatives, as emphasized by studies highlighting the role of sustainability and audit committees (Elsayih et al., 2021; Peng et al., 2022). Lastly, the inclusion of an ESG executive compensation policy (Column 4) guessing good governance variable assessed the impact of financial incentives linked to environmental targets, justified by evidence that such policies align managerial priorities with environmental performance (Moussa et al., 2020; Albitar et al., 2022). The findings collectively reinforce the robustness of the initial results, demonstrating that the

[13] *Dummy variable* calculated based on four individual questions (see Annex Table 3) maintaining a well governed board via the existence of an audit committee, corporate governance committee, nomination committee, and compensation committee..

baseline hypothesis holds under various specifications of corporate governance.

Table 7: Robustness 1b – Alternative measures of governance

DV: GHG (ln)	(1)	(2)	(3)	(4)
ERP	-0.0040***	-0.0052***	-0.0059***	-0.0036***
	[0.00]	[0.00]	[0.00]	[0.00]
Alternative CG	0.7403***	0.3228***	0.0016**	0.5507***
	[0.05]	[0.05]	[0.00]	[0.05]
ERP x Alt. CG	-0.0143***	-0.0056***	-0.0000**	-0.0096***
	[0.00]	[0.00]	[0.00]	[0.00]
Constant	3.3930***	2.9936***	2.9056***	3.0736***
	[0.22]	[0.22]	[0.22]	[0.22]
Model	3-Way FE	3-Way FE	3-Way FE	3-Way FE
Alt. CG	CSR Grade A	Management Grade A	Board Governance Committees	Exec. ESG Compensation
Obs.	18559	18559	18556	18558
Time FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R2	0.49	0.49	0.48	0.49
R2 adj.	0.49	0.48	0.48	0.49
R2 adj. (w/i)	0.12	0.11	0.11	0.11
F-Stat.	162.31	136.62	131.78	151.20

Note: Fixed effects model with Time, Country, Sector fixed effects. Robust standard errors in brackets. *, **, *** denote significance at 10, 5, and 1 percent levels,. Variable descriptions see table 3.

In order to account for sector specific level effects, the sample is divided in high[14] and low[15] emitting sectors (Table 8, Column 1). Results show similar results for low and high emission technologies with a more pronounced effect for high emission sectors. Next, the analysis delves deeper by separating firms within each sector and year into high- and low-emitting groups (Table 8, Column 2). This step aims to capture sector-dependent firm-level heterogeneity, recognizing that firms within the same sector may differ significantly in their emission profiles due to factors like technological capabilities, production processes, or regulatory pressures. These differences are critical, as sectoral and firm-level characteristics may mediate the effectiveness of ERPs and governance in driving emission reductions. Results show, that firms with higher emissions within the sector and year are more

[14] Sector distribution includes Accommodation and Food Services (2.6%), Agriculture, Forestry, Fishing and Hunting (0.8%), Manufacturing (62.9%), Mining, Quarrying, and Oil and Gas Extraction (9.2%), Real Estate and Rental and Leasing (9.1%), Transportation and Warehousing (8.4%), Utilities (7%).

[15] Sector distribution includes Administrative and Support and Waste Management (5.6%), Arts, Entertainment, and Recreation (1.6%), Construction (14.7%), Educational Services (0.4%), Finance and Insurance (8.4%), Health Care and Social Assistance (2.3%), Information (21.7%), Other Services except Public Administration (0.7%), Professional, Scientific, and Technical Services (16.7%), Retail Trade (18.2%), and Wholesale Trade (9.7%)

Gold et al., (2022) highlights the importance of such contextual factors, which can shape firms' responsiveness to policies and governance mechanisms. As industries' differ in regulatory scrutiny and external pressure, ERP adoption and shape the role of good governance in emission reduction potentials may differ. This aligns with the earlier discussion on greenwashing, where firms in high-scrutiny sectors may adopt ERPs and governance measures as symbolic gestures to maintain legitimacy, and substantive outcomes depend on sector-specific characteristics such as technological capacity and compliance mechanisms. Next, the nature of sectors are analysed to discover impacts for greenwashing prone sectors. Building on Ghitti et al. (2024), more greenwashing prone sectors are identified and added as interaction term (Table 8, Column 3). The covered greenwashing prone sectors[16], incl. mining, oil and gas, real estate and constructions show an high level of greenwashing proxy and are specifically relevant for direct and potentially damaging impact on the environment. These sectors seem to have more chances to greenwash due to lack of scrutiny of external stakeholders (Ghitti et al., 2024). Results in Column 3 show that the marginal effect of ERPs are substantially reduced in greenwashing prone sectors. This aligns with earlier discussions on greenwashing where firms adopt superficial environmental policies to maintain legitimacy without achieving substantive environmental improvements. Finally, in Table 8, Column 4 the focus is shifted to financial flexibility within sectors and year by analysing the interaction of ERP and CG for firms with high cash reserves. The significant coefficient (*ERP x IAT, -0.0024, p-Value: <0.05*) reinforcing the importance of financial capacity in supporting substantive environmental outcomes (Provaty et al., 2024).

Table 8: Robustness 2

DV: GHG emissions (ln)	(1)	(2)	(3)	(4)
ERP	-0.0021***	-0.0030***	-0.0065***	-0.0037***
	[0.00]	[0.00]	[0.00]	[0.00]
CG	0.3151***	0.3996***	0.5945***	0.5575***
	[0.10]	[0.06]	[0.07]	[0.08]
ERP x CG	-0.0056***	-0.0065***	-0.0119***	-0.0125***
	[0.00]	[0.00]	[0.00]	[0.00]
IAT		2.0358***		0.0463
		[0.04]		[0.05]
ERP x IAT	-0.0065***	-0.0110***	0.0042***	-0.0024**
	[0.00]	[0.00]	[0.00]	[0.00]
CG x IAT	0.2403**	0.1064	-0.4041***	-0.0721
	[0.12]	[0.09]	[0.13]	[0.11]
ERP x CG x IAT	-0.0059**	-0.0058***	0.0079***	0.0038
	[0.00]	[0.00]	[0.00]	[0.00]

[16] Sectoral dummy that is 1 if the firm operates in one of the following sectors: Real Estate and Rental and Leasing; Construction; Wholesale Trade; Mining, Quarrying, and Oil and Gas Extraction; Professional, Scientific, and Technical Services. The findings from Ghitti et al. (2024) are to some extent supported by Lagasio et al. (2023), who build an index of greenwashing severity (GSI) by scanning sustainability reports of companies in search for ESG words. Higher GSI values indicate a greater likelihood of greenwashing practices, while lower values signal a stronger commitment to genuine sustainability.

Constant	2.6109*** [0.18]	1.8067*** [0.14]	2.6341*** [0.18]	2.5923*** [0.19]
Obs.	18,559	18,559	18,559	18,559
IAT	High emission sectors	High emission firms	Greenwashing sectors	High cash firms
Country FE	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R2	0.49	0.67	0.49	0.49
R2 adj.	0.49	0.67	0.49	0.48
R2 adj. (within)	0.11	0.43	0.11	0.11
F-Stat.	113.48	1053.34	116.43	105.23

Note: Fixed effects model with Time, Country, Sector fixed effects. Robust standard errors in brackets. *, **, *** denote significance at 10, 5, and 1 percent levels,. Variable descriptions see table 3.

While the baseline and robustness tests largely confirm the cross-sectional associations across sectors, countries, and years, concerns about endogeneity continue to pose challenges to establishing causal relationships. For example, under the presented cross-sectional framework, firms with lower GHG emission intensity have greater access to financial resources, as indicated by the negative coefficients for *Cash* (-0.0446, p-Value: <0.01) and *MTB (-0.0505, p-Value: <-0.01)* in the baseline results. These financial advantages, or higher levels of organizational capital, may enable to invest more effectively in implementing ERPs (Provaty et al., 2024). This raises concerns about potential reverse causality. In sum, there are three potential concerns limiting causal inference. First, better financial resources may drive both lower emissions and greater ERP adoption, rather than the policies themselves leading to emission reductions. Second, firms with lower GHG emissions may adopt better governance and ERPs to maintain legitimacy or reputation. Third, unobserved factors (e.g., omitted variable bias), such as firm culture, managerial expertise, or sector-specific technological capabilities, could influence the relationship between ERPs, CG, and GHG emissions.

To address the identified endogeneity issues emerging from reverse causality and omitted variable bias, a two-stage least squares (2SLS) instrumental variable (IV) approach (Table 9) has been applied. Following Marwick et al. (2020), industry-year median values for ERP and country-year mean values for CG level are used as the instrumental variables. The main idea of this approach is that firms are most influenced by the environmental and governance practices of their industry or neighboring peers. By leveraging industry and country aggregates, the instruments are less likely to be influenced by firm-specific GHG emissions or financial performance, thereby mitigating the concern that firms with lower emissions or better financial resources might drive ERP adoption rather than the other way around. The instruments account for unobserved sectoral and regional factors (e.g., industry norms or national policies) that might

simultaneously influence ERP adoption, CG quality, and GHG emissions. These aggregated measures help isolate the effect of firm-level ERP and CG on emissions from other shared influences within industries or countries. Leary and Roberts (2014) demonstrate that companies often align their firm-level policies with those of their peers, suggesting a broader tendency to emulate peer behavior. Hasan et al. (2021) find that organizational capital levels are consistent among firms within the same sector, implying that companies adopt practices prevalent in their industry. Both industry norms and regional peers play significant roles in shaping a firm's environmental policies. Thus, the 2SLS aims to isolate the effect of group-level ERPs and CG on GHG emissions, respectively. In the first instance the group-level GHG emissions ($GHG_{f,t}$), ERP ($Peer_ERP_{f,t}$), and CG ($Peer_CG_{g,t}$) are calculated for firms in each year. Afterwards, the following regression for each industry and country has been employed.

$$\mathrm{Peer_ERP_{f,t}} = \tau_0 + \tau \mathrm{GHG_{f,t}} + \varepsilon_{f,t} \quad (2)$$

$$\mathrm{Peer_CG_{g,t}} = \varphi_0 + \varphi_1 \mathrm{GHG_{g,t}} + \varepsilon_{g,t} \quad (3)$$

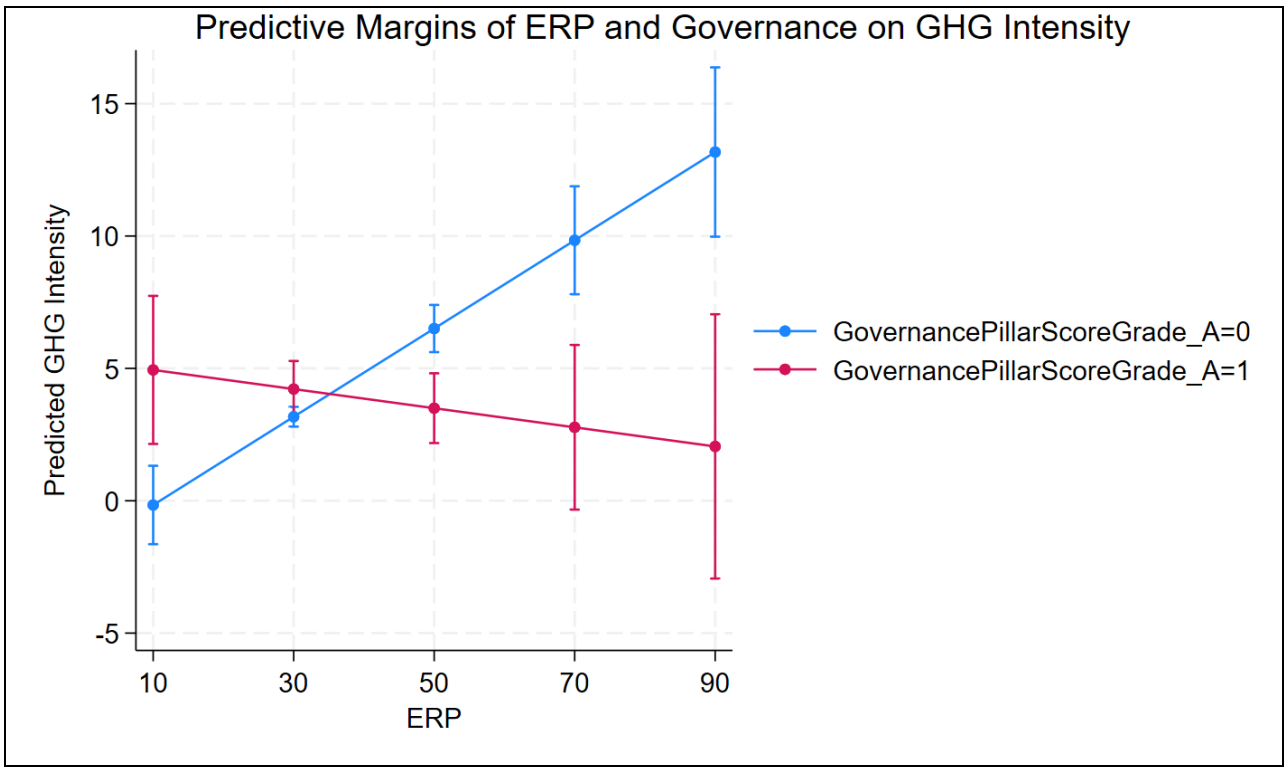
f, and *g* represents the industry and country respectively. *t* expresses the year. Residuals are derived from the above regression which shows the industry-level ERPs and country-level CG unexplained variances by GHG emissions. The residuals (*PEER_ERP_res* and *PEER_CG_res*) are the employed instruments in the 2SLS regression. While these instruments satisfies the relevance condition, a common limitation of most instrumental variable approaches lies in ensuring that the exclusion restriction holds. For instance, an industry-wide improvement in ERPs could motivate firms with comparatively lower ERP adoption to increase their investments to align with industry norms. This alignment may, in turn, contribute to a decrease in GHG emissions, potentially complicating the causal interpretation. Results from the IV approach confirms the baseline with the negative interaction term (-0.2028). However, the results reveal a critical change of the magnitude of ERPs from non-A-ranked firms (CG=0). While the baseline model (Table 4, Column 4) suggests a negative effect of ERPs for non-A-ranked firms, the 2SLS findings indicate a significant positive effect, as shown by the upward trend in the figure. This suggests that weak governance (CG=0) hinder ERP implementation. In contrast, for A-ranked firms (CG=1), ERPs significantly reduce GHG intensity, as reflected in the downward slope (-0.2028).

Table 9: Robustness tests 3 – Instrumental variable approach

	First stage		Second stage
	(1)	(2)	(3)
	ERP	CG	GHG Emissions
ERP	-	-	0.1667***
	-	-	[0.01]
CG	-	-	7.1309***
	-	-	[0.92]
ERP x CG	-	-	-0.2028***
	-	-	[0.02]
Peer_ERP_res	0.2588***	0.0014**	-
	[0.03]	[0.00]	-
Peer_CG_res	-1.0892	1.0343***	-
	[2.67]	[0.06]	-
Peer_ERP_res x Peer_CG_res	0.5666***	-0.0129***	-
	[0.20]	[0.00]	-
Cash	0.4208	-0.0037	-0.0079
	[0.32]	[0.00]	[0.02]
Size	1.5656***	0.0597***	-0.1542***
	[0.09]	[0.00]	[0.02]
PPE	-0.0797***	0.0069***	0.0883***
	[0.03]	[0.00]	[0.00]
MTB	0.1467***	0.0009	-0.0631***
	[0.05]	[0.00]	[0.00]
Governance	-1.8593***	0.0086	0.3527***
	[0.57]	[0.01]	[0.05]
GDPpc	0.0000	0.0000	-0.0000***
	[0.00]	[0.00]	[0.00]
Constant	-1.5688	-1.1658***	2.1304***
	[2.63]	[0.07]	[0.32]
Model	First stage - ERP	First stage - CG	Second stage
Sample	Full	Full	Full
Obs.	18559	18559	18559
Sector FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
R2	0.23	0.08	0.49
R2 adj.	0.22	0.08	0.49
R2 adj. (within)	0.02	0.05	0.11
F-Stat.	45.95	119.66	143.47
Under-identification test:			
Kleibergen-Paap rk LM statistic			34.010
p-value			0.0000
Weak identification test:			
Cragg-Donald Wald F statistic			6.801
Stock and Yogo (2005) critical value			6.61
Overidentification test:			
Hanson J statistics			0.837
p-value			0.6579

Note: The Hausman test results ($\chi^2(5) = 52.53$, $p < 0.001$) confirm the presence of endogeneity in the model, justifying the use of Instrumental Variables (IV) estimation to obtain consistent and unbiased results.

Figure 2: Instrumental variable approach - Predictive margins of ERP on emissions with 95% CI for A and non-A ranked firms



Note: Red line are A-ranked firms and blue line are non A-ranked firms. For both figures, robust standard errors are used for the margins estimates. Error bars represent 95% confidence intervals.

The applied IV are suited to addressing two out of the three identified endogeneity problems. First, better financial and organizational resources driving both lower emissions and ERP adoption. Second, firms with lower GHG emissions adopting better governance and ERPs for reputational reasons. However, the third concern (unobserved factors like firm culture or managerial expertise), may still be partially unresolved if these factors influence firms in ways that correlate with the instruments. For instance, a firm culture (in the form of e.g., Managerial expertise) can significantly influence environmental strategy, as a firm with a strong environmental ethos may naturally adopt ambitious ERPs, appoint governance structures that prioritize sustainability, and invest in emissions-reducing technologies. Such a firm may achieve lower GHG emissions not solely due to the adoption of ERPs or robust CG, but because its overarching culture drives sustainability across multiple dimensions.

6. Discussion

This study adds to the ongoing debate on the effectiveness of emission reduction policies (ERPs) by incorporating the role of corporate governance (CG) in reducing greenhouse gas (GHG) emission intensity. The findings provide empirical evidence from an extensive dataset spanning 18,559 observations across 28 countries from 2011 to 2022, showcasing the influential effect of governance on ERP outcomes.

The study demonstrates that robust CG is significantly associated with the effectiveness of ERPs in reducing GHG emission intensity. The key findings highlight that CG plays a pivotal role in ensuring ERP effectiveness. Thus, firms with sound corporate governance, measured by A-ranked Governance Pillar from Refinitiv ESG metrics, are associated with a pronounced reduction in GHG intensity through higher ERPs. The consistent negative interaction between ERP and governance across all robustness tests suggests that governance A-ranked firms are better equipped to implement ERPs, translating environmental commitments into substantial outcomes. This supports the legitimacy perspective of Neo-Institutional Theory (NIT), which suggests that firms with sound CG are better positioned to adopt ERPs into meaningful environmental outcomes (Scott, 2013), corresponding to stakeholder pressures.

Several robustness tests has been conducted and confirm the baseline. An instrumental variable (IV) approach has been implemented to addresses potential endogeneity concerns, reinforcing the robustness of these findings. Using peer median levels as instruments, the IV results indicate that ERPs for non-A-ranked firms is significantly associated with higher GHG intensity, which is reduced when turning to A-ranked firms. This emphasizes the critical role of governance in mitigating unintended consequences of ERPs. Sectoral analysis reveals that governance is especially crucial in industries prone to greenwashing, highlighting its importance in mitigating legitimacy risks and fostering genuine environmental impact.

While potential endogeneity may raise concerns for the possibility that firms with lower GHG intensity are better equipped to adopt ERPs, that financial flexibility influences both governance and ERP implementation, or that unobserved factors like firm culture affect the ERP-GHG nexus, these issues are unlikely to affect the study's core argument. Regardless of whether ERP adoption stems partially from firm-level characteristics like financial capacity or cultural factors, the role of CG in contributing to ERPs emissions reductions remains evident and central to the findings. In this context, potential endogeneity does not undermine the conclusion that governance enhances ERP effectiveness. In this framework, the directionality of the relationship between ERPs and GHG emissions is less critical, as the study highlights that strong governance consistently enhances the effectiveness of ERPs, irrespective of causality concerns.

The presented findings are contributing to the growing importance of ESG data, which are soaring relevance since the mid-2010s (Yap et al., 2024) in financial decision making. Corresponding to the need of higher-quality ESG data, as emphasized by Christensen et al. (2021), to accurately assess the real impact of sustainability practices, the reliance on ESG metrics has been tested in this study.

The results provide several policy implications, particularly as firms face increasing sustainability-related risks and regulatory changes in the near future. The findings highlight the key role of CG in making ERPs more effective in reducing GHG emissions. Policymakers may focus on requiring firms operating in certain sectors to disclose not only their operational tools such as transition plans, but also their governance structures, as corporate governance is a crucial component for translating ERPs into real environmental outcomes. This aligns with regulatory initiatives such as the UK's Financial Conduct Authority or the EU Corporate Sustainable Disclosure Regulation (CSRD), which emphasizes governance transparency. Policymakers may also further investigate their role in leading by example and adopting strong governance frameworks in public authorities, and promoting sustainability (Eccles et al., 2015; Giglio et al., 2020).

This study has several limitations opening avenues for future research. First, the observational nature of the data restricts the ability to establish definitive causal relationships between governance and ERP effectiveness, suggesting that future research could apply longitudinal or quasi-experimental methods to isolate these effects and explore their temporal evolution. This means, that impact of CG and ERP over time within a firm will reveal further lines of causality. Second, the analysis excludes Scope 3 emissions, potentially underestimating governance's overall impact on a firm's carbon footprint. A more comprehensive approach that includes indirect emissions from supply chains would provide a fuller understanding of governance's role in emission reductions across the entire value chain. Limited availability of scope 3 reports increases research challenges (Hettler et al., 2024). Third, although sectoral and regional variations are considered, the lack of granularity regarding industry-specific ERP effectiveness—particularly in hard-to-abate sectors with high marginal abatement costs—requires more tailored research methods. Examining industries like cement, steel, or chemicals could provide insights into how governance and policy measures can be optimized for these sectors. Using measures such as the Technology Readiness Level (TRL) may be an entry point. Finally, the reliance on ESG data from a single provider (Refinitiv) introduces potential biases, given that ESG scores can vary significantly across data vendors. Future research may compare the robustness of ERP and governance effects using data from multiple ESG providers to assess consistency and reliability. Additionally, exploring the influence of institutional investors on the ERP-GHG nexus through shareholder activism may deepen the understanding of external pressures driving firms toward more effective sustainability practices.

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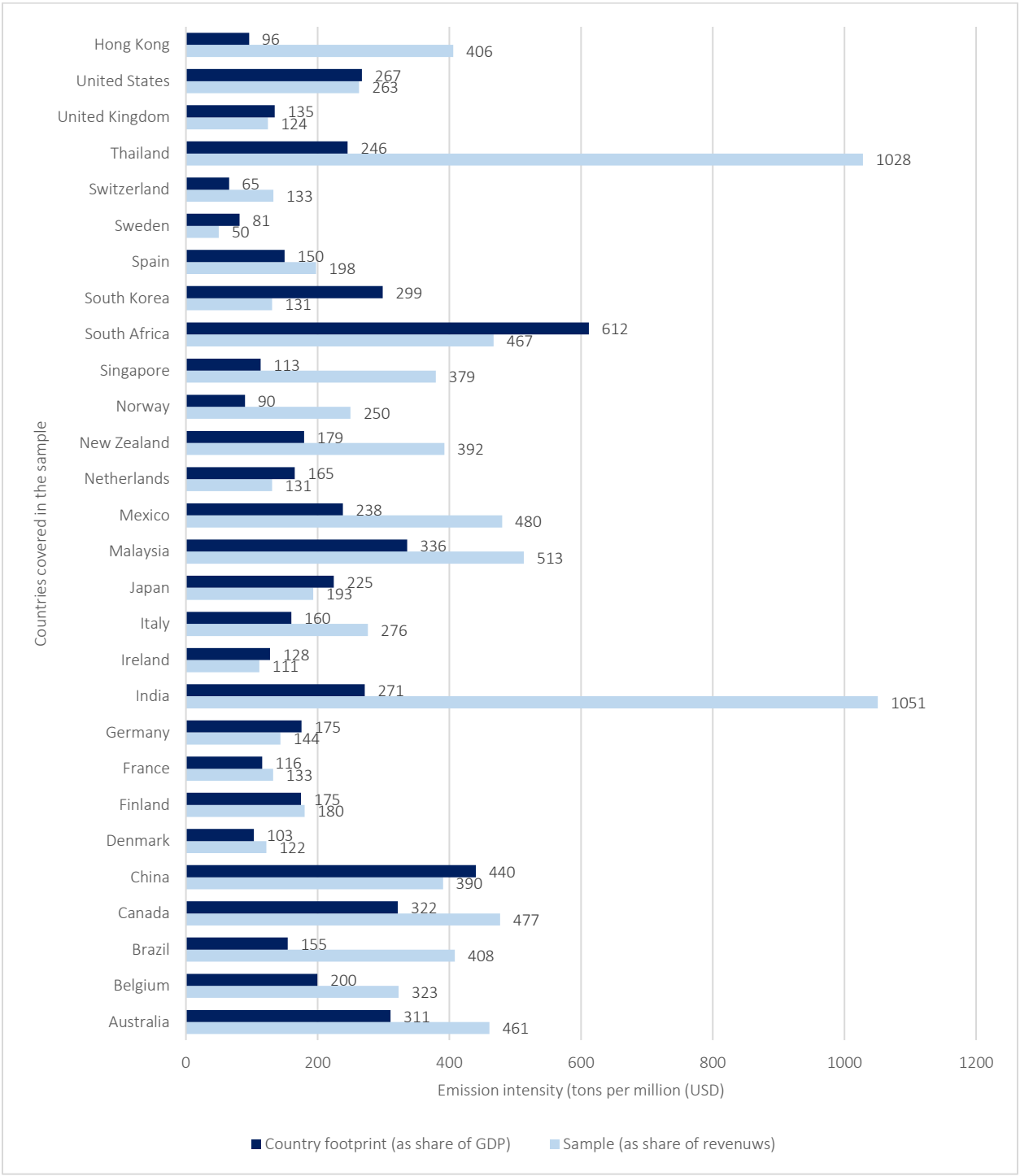
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8. Appendices

Figure 3: Comparing emission intensity used in the sample (mean 2019-22) with EDGAR emission intensity (mean 2019-22)



Note: Data refers to 2019-22, excluding data between 2011 and 2018 which is covered in the sample dataset. Light blue bars show emission intensity used in this study in tons of CO2e emitted per million dollar of revenues. Sample metric covers CO2e, including

carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexaluioride (SF6) if reported by the firm. Reference data for country emission intensity is shown in the dark blue bars show country footprint. Tons of CO_2 emitted per million dollar of GDP. Fossil fuel and industry emissions are included. Land-use change emissions are not included. GDP data is adjusted for inflation and differences in the cost of living between countries. "IEA-EDGAR". Both show mean values between 2019-21. EDGAR only considers carbon dioxide emissions compared to CO2 equivalent emissions used in this study. Data is represented in logarithmic (ln) values.

Table 10: Pairwise correlations (full sample, n= 18.559)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) GHG_Scope1_2_ln	1.000							
(2) TRPolicyEmissi~a	-0.228	1.000						
	(0.000)							
(3) GovernancePill~A	0.093	0.048	1.000					
	(0.000)	(0.000)						
(4) governance_index	-0.145	0.074	0.020	1.000				
	(0.000)	(0.000)	(0.006)					
(5) GDPpc	-0.132	-0.013	0.032	0.679	1.000			
	(0.000)	(0.070)	(0.000)	(0.000)				
(6) Cash	-0.077	0.011	-0.038	0.020	0.046	1.000		
	(0.000)	(0.118)	(0.000)	(0.007)	(0.000)			
(7) Firm_Size_LN	0.053	0.035	0.075	-0.211	-0.315	-0.073	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(8) PPE	0.421	-0.113	0.069	0.064	0.031	-0.099	-0.141	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
(9) MarkettoBook	-0.204	0.055	-0.025	-0.043	0.012	0.103	-0.122	-0.123
	(0.000)	(0.000)	(0.001)	(0.000)	(0.089)	(0.000)	(0.000)	(0.000)

Table 11: Pairwise correlations only for governance A-ranked firms (CG=1, n=4.368)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) GHG_Scope1_2_ln	1.000						
(2) TRPolicyEmissi~a	-0.345	1.000					
	(0.000)						
(3) governance_index	-0.077	0.058	1.000				
	(0.000)	(0.000)					
(4) GDPpc	-0.074	-0.057	0.666	1.000			
	(0.000)	(0.000)	(0.000)				
(5) Cash	-0.050	0.143	-0.005	0.018	1.000		
	(0.001)	(0.000)	(0.762)	(0.246)			
(6) Firm_Size_LN	-0.061	0.050	-0.190	-0.324	-0.051	1.000	
	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)		
(7) PPE	0.428	-0.160	0.085	0.066	-0.084	-0.256	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
(8) MarkettoBook	-0.213	0.118	-0.078	-0.012	0.128	-0.091	-0.121
	(0.000)	(0.000)	(0.000)	(0.441)	(0.000)	(0.000)	(0.000)

Table 12: Pairwise correlations only for governance non-A-ranked firms (CG=0, n=12.856)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) GHG_Scope1_2_ln	1.000						
(2) TRPolicyEmissi~a	-0.204	1.000					
	(0.000)						
(3) governance_index	-0.169	0.077	1.000				
	(0.000)	(0.000)					
(4) GDPpc	-0.155	-0.004	0.683	1.000			
	(0.000)	(0.648)	(0.000)				
(5) Cash	-0.080	-0.010	0.026	0.054	1.000		

	(0.000)	(0.220)	(0.002)	(0.000)			
(6) Firm_Size_LN	0.077	0.027	-0.219	-0.317	-0.076	1.000	
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)		
(7) PPE	0.416	-0.105	0.056	0.016	-0.103	-0.109	1.000
	(0.000)	(0.000)	(0.000)	(0.058)	(0.000)	(0.000)	
(8) MarkettoBook	-0.200	0.041	-0.033	0.020	0.098	-0.129	-0.122
	(0.000)	(0.000)	(0.000)	(0.015)	(0.000)	(0.000)	(0.000)

Pesaran CD test

Table 13: Variance inflation factor

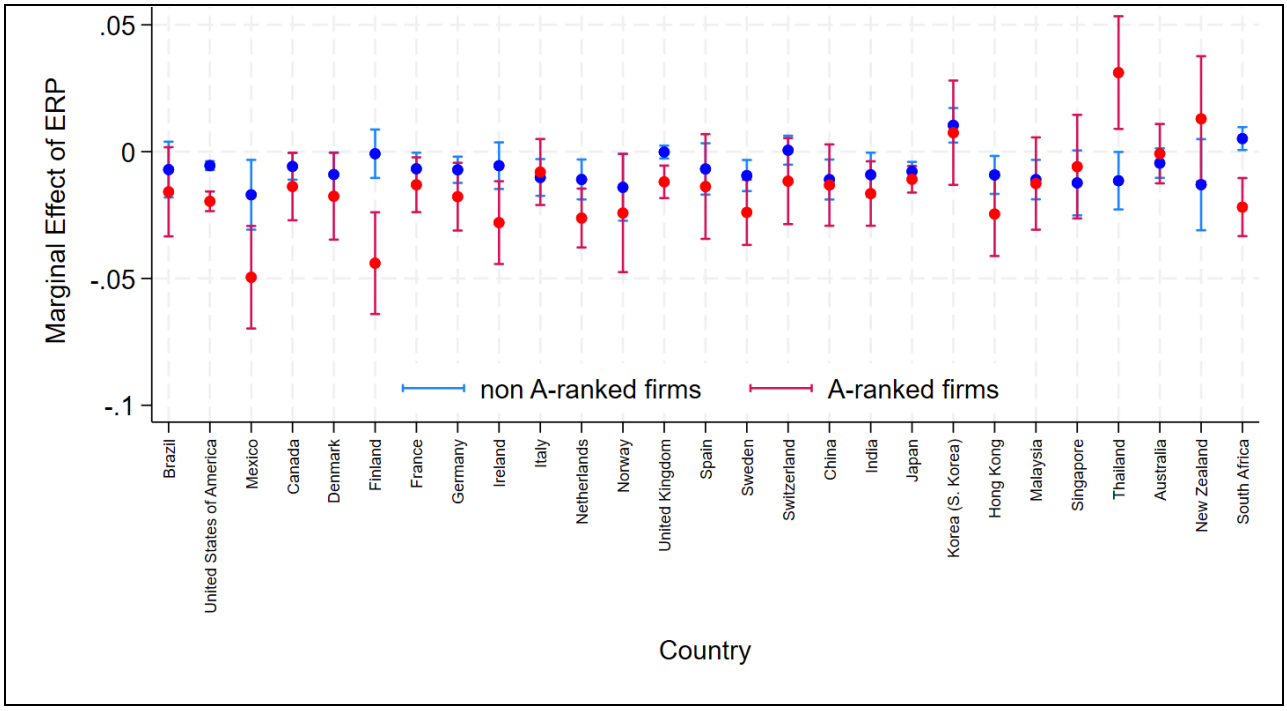
Variable	VIF
ERP	1.17
GP	1.02
Size	1.24
Lev	1.27
PPE	1.30
Cash	1.06
Q	2.95
MTB	3.12
GDPpc	2.07
Governance index	1.97
Mean VIF	1.72

Table 14: Robustness 3 – Marginal effects of ERP on GHG emissions (dy/dx) for various sectors (see figure in the main text), separated by governance level

	Governance=1					Governance=0			
Sectors	dy/dx	SE	z	P-value		dy/dx	SE	z	P-value
Accommodation (n=382)	0,0210	0,0052	4,02	0,00		0,0044	0,0021	2,08	0,04
Construction (n=1,050)	-0,0108	0,0094	-1,15	0,25		-0,0003	0,0021	-0,14	0,89
Finance (n=596)	-0,0046	0,0051	-0,91	0,36		0,0000	0,0014	-0,01	0,99
Information (n=1,551)	-0,0045	0,0043	-1,05	0,29		0,0040	0,0012	3,39	0,00
Manufacturing (n=9,205)	-0,0130	0,0029	-4,47	0,00		0,0019	0,0007	2,57	0,01
Mining (n=1,351)	0,0042	0,0032	1,29	0,20		0,0006	0,0023	0,28	0,78
Professional (n=1,190)	-0,0068	0,0048	-1,43	0,15		-0,0006	0,0013	-0,48	0,63
Real Estate (n=1,332)	0,0205	0,0112	1,83	0,07		0,0023	0,0019	1,18	0,24
Retail (n=1,298)	0,0063	0,0029	2,16	0,03		0,0019	0,0014	1,38	0,17
Transport (n=1,226)	0,0059	0,0141	0,42	0,68		0,0099	0,0064	1,54	0,12
Utilities (n=1,029)	-0,0005	0,0152	-0,04	0,97		-0,0487	0,0254	-1,91	0,06
Wholesale (n=693)	0,0033	0,0067	0,50	0,62		0,0031	0,0027	1,13	0,26

Note: Table presents the marginal effects of ERP on GHG emissions (dy/dx) for various sectors, separated by governance level (Governance = 1 and Governance = 0). Each sector's estimated marginal effect, standard error (SE), z-value, and p-value are reported for both governance levels. The "Difference" column represents the difference in marginal effects between Governance = 1 and Governance = 0 for each sector. P-value indicates significance level.

Figure 4: Marginal effects of ERP on Emissions by Country and Governance Level



Note: Figure presents the marginal effects of ERP on GHG emissions (dy/dx) for countries, separated by governance level. Error bars represent 95% confidence intervals. Firms classified under low governance are represented by blue markers, whereas red markers denote firms with high governance levels in the respective country.

Table 15: Marginal effects of ERP on GHG emissions (dy/dx) for countries (see figure above), separated by governance level

	Governance=1					Governance=0			
Country	dy/dx	SE	z	P-value		dy/dx	SE	z	P-value
Brazil	-0,0158	0,0090	-1,77	0,08		-0,0071	0,0056	-1,26	0,21
United States of America	-0,0196	0,0020	-9,94	0,00		-0,0055	0,0009	-6,12	0,00
Mexico	-0,0495	0,0103	-4,80	0,00		-0,0170	0,0070	-2,42	0,02
Canada	-0,0137	0,0068	-2,02	0,04		-0,0058	0,0027	-2,16	0,03
Denmark	-0,0176	0,0087	-2,01	0,04		-0,0090	0,0044	-2,03	0,04
Finland	-0,0440	0,0102	-4,30	0,00		-0,0008	0,0049	-0,17	0,87
France	-0,0131	0,0055	-2,37	0,02		-0,0067	0,0032	-2,09	0,04
Germany	-0,0178	0,0068	-2,61	0,01		-0,0072	0,0026	-2,71	0,01
Ireland	-0,0280	0,0083	-3,36	0,00		-0,0055	0,0047	-1,18	0,24
Italy	-0,0080	0,0066	-1,21	0,23		-0,0102	0,0037	-2,76	0,01
Netherlands	-0,0262	0,0059	-4,42	0,00		-0,0110	0,0040	-2,73	0,01
Norway	-0,0242	0,0119	-2,04	0,04		-0,0141	0,0067	-2,09	0,04
United Kingdom	-0,0119	0,0033	-3,64	0,00		-0,0002	0,0013	-0,12	0,90
Spain	-0,0138	0,0105	-1,31	0,19		-0,0068	0,0052	-1,32	0,19
Sweden	-0,0239	0,0066	-3,65	0,00		-0,0094	0,0031	-3,01	0,00
Switzerland	-0,0116	0,0087	-1,34	0,18		0,0006	0,0029	0,19	0,85

China	-0,0132	0,0082	-1,61	0,11		-0,0110	0,0040	-2,73	0,01
India	-0,0165	0,0065	-2,55	0,01		-0,0091	0,0044	-2,06	0,04
Japan	-0,0109	0,0027	-4,07	0,00		-0,0078	0,0019	-4,07	0,00
Korea; Republic (S. Korea)	0,0075	0,0105	0,71	0,48		0,0104	0,0035	2,99	0,00
Hong Kong	-0,0246	0,0084	-2,91	0,00		-0,0092	0,0038	-2,41	0,02
Malaysia	-0,0126	0,0093	-1,35	0,18		-0,0110	0,0040	-2,78	0,01
Singapore	-0,0059	0,0104	-0,57	0,57		-0,0123	0,0065	-1,89	0,06
Thailand	0,0312	0,0113	2,75	0,01		-0,0115	0,0058	-1,98	0,05
Australia	-0,0008	0,0060	-0,13	0,89		-0,0045	0,0030	-1,52	0,13
New Zealand	0,0130	0,0126	1,03	0,30		-0,0130	0,0092	-1,42	0,16
South Africa	-0,0219	0,0058	-3,74	0,00		0,0051	0,0023	2,23	0,03

Figure 5: Marginal effects of ERP on Emissions by Year and Governance Level

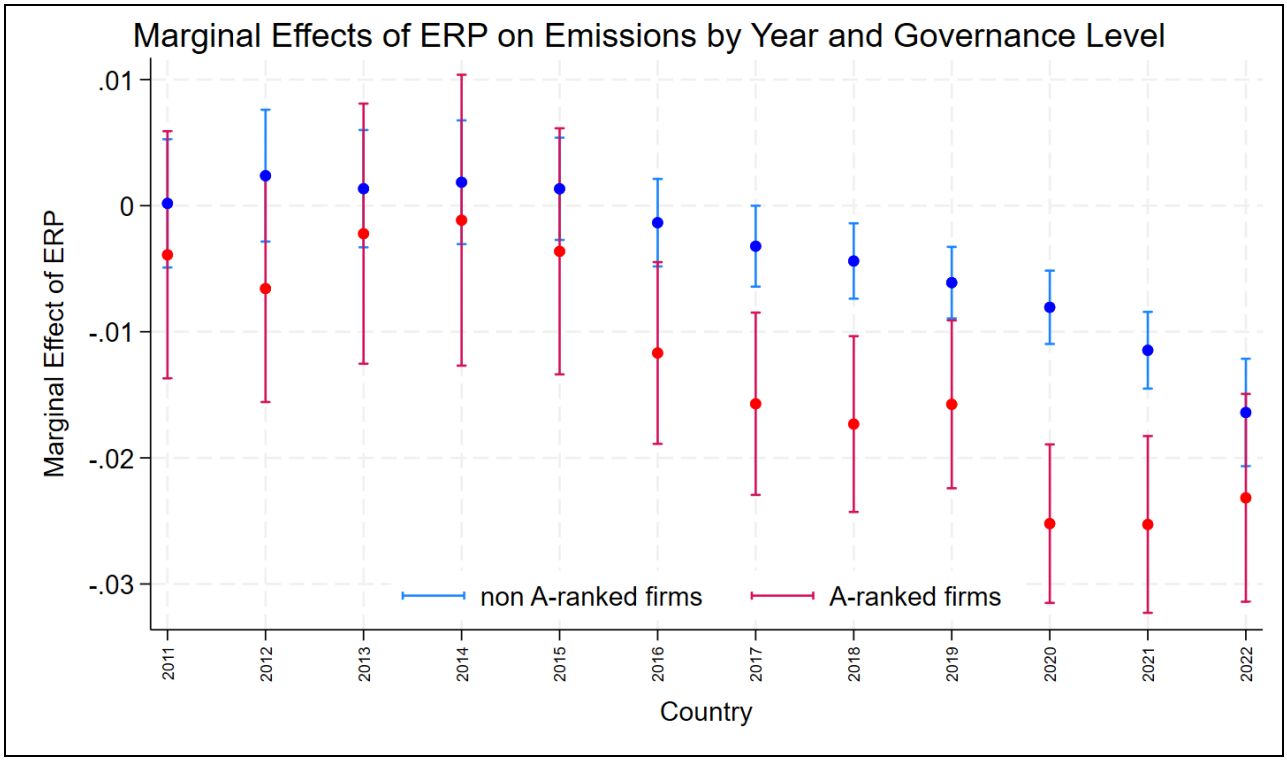


Table 16: Greenwhasing index (Ghitty 2024)

Sector	GW-NWG Adj	Delta green
Real Estate and Rental and Leasing	32,33	-1,61
Construction	29,96	-2,1
Wholesale Trade	28,18	-4,05

Mining, Quarrying, and Oil and Gas Extraction	24,74	-1,02
Professional, Scientific, and Technical Services	22,42	-4,36
Retail Trade	21,25	-4,17
Utilities	20,26	-2,97
Finance and Insurance	19,29	-3,98
Information	17,07	-6,16
Manufacturing	16,8	-5,16
Transportation and Warehousing	15,25	-4,85
Accommodation and Food Services	9,96	-7,58

Table 17: T-Test for emissions and sectors for CG=1 and CG=0

Sector	Mean Difference	P-value (two-tailed)	Significant
Accommodation and Food Services	-0.67	0.7762	No
Construction	-1.33	0.3311	No
Finance and Insurance	-0.12	0.987	No
Information	-4.32	0.0025	Yes
Manufacturing	-3.5	0.000	Yes
Mining	-1.63	0.1005	No
Professional	-4.62	0.0214	Yes
Real Estate and Rental and Leasing	-8.01	0.0001	Yes
Retail Trade	-5.07	0.0003	Yes
Transportation and Warehousing	-0.45	0.6366	No
Utilities	-0.58	0.2937	No
Wholesale Trade	-2.81	0.0831	No

Table 18: Sector descriptions

TRBC Business Sector Name	Definition
Applied Resources	Refers to companies or industries that specialize in utilizing various resources. These companies often focus on applying knnowledge, tools, and resources to create innovative products or services.
Automobiles & Auto Parts	Encompassess businesses involved in the manufacturing, distribution, and sale of vehicles and their respective components.
Banking & Investment Services	Involves financial institutions that provide various financial products and services. This includes traditional banking activities like savings accounts, loan provision, etc.
Chemicals	This involves companies in the production, development, and distribution of various chemical substances.
Consumer Goods Conglomerates	Refers to collection of diverse consumer-oriented businesses owned or controlled by a larger corporation.
Cyclical Consumer Products	Industries that produce goods whose demand is sensitive to economic fluctuations. Like manufacturing and selling non-essential or luxury consumer items.
Cyclical Consumer Services	Sector whose businesses that offer non-essential services such as travel, entertainment, dining and leisure activities.
Energy- Fossil Fuels	Pertains to industries involved in the exploration, extraction, refining, and distribution of non-renewable energy sources like coal, oil, and natural gas.
Food & Beverages	Many of these companies belong to the consumer staples segment, which tends to be less cyclical and subject to smaller market fluctuations.
Food & Drug Retailing	Encompasses businesses involved in the sales and distribution of food products, pharmaceuticals, and related items directly to consumers.
Healthcare Services & Equipment	Involves companies that provide a wide range of healthcare-related services and produce medical equipment and supplies.
Industrial & Commercial Services	It is a broad range of businesses that provide services to other companies and industries rather than producing tangible goods.
Industrial Goods	The industrial goods sector includes stocks of companies that mainly produce capital goods used in manufacturing, resource extraction, and construction.
Mineral Resources	They specifically focuses on industries involved in the exploration, extraction, processing, and trading minerals from the Earth.
Personal & Household Products & Services	This sector includes businesses that produce and provide goods and services aimed at personal care, household necessities, and lifestyle enhancement.
Pharmaceuticals & Medical Research	The pharmaceutical industry is responsible for discovering, producing, and marketing drugs for use in the healthcare sector. These drugs are used to treat and cure short- and long-term medical conditions. This is considered to be one of the largest sectors in the global economy.
Real Estate	Real Estate Sector has the following segments: Residential Real Estate, Commercial Real Estate, Industrial Real Estate. The different segments have different metrics that investors and analysts use to gauge the health of the real estate industry.
Retailers	Ranging from food to electronics, from luxury specialists to discounters, the retail sector is a diverse and dynamic one and extremely susceptible to changing consumer tastes.
Software & IT Services	It involves companies dedicated to developing, distributing, and maintaining software applications and providing a wider range of information technology services.
Technology Equipment	Category of stocks relating to the research, development, or distribution of technologically based goods and services. This sector contains businesses revolving around the manufacturing of electronics, creation of software, computers, or products and services relating to information technology.
Telecommunications Services	The telecommunication sector is made up of companies that make communication possible on a global scale, whether through the phone, the internet, over airwaves, or cables. These companies create the infrastructure that allows data as text, voice, audio, or video to be sent anywhere in the world.
Transportation	The transportation sector is a category of companies that provide services to move people or goods, as well as transportation infrastructure.
Utilities	Utilities include large companies that offer multiple services such as electricity and natural gas or specialize in just one type of service, such as water.

Table 19: ERP raw data examples

Hugo Boss AG, 2021, Sustainability Report 2021
Climate Action. As it moves towards becoming climate neutral, HUGO BOSS continues to pursue its scientifically sound reduction targets recognized by the Science Based Targets initiative: Accordingly, by the year 2030 the Company intends to reduce its Scope 1 and Scope 2 emissions from primary energy use and electricity supply by at least 51% (base year: 2018). For Scope 3 emissions, which mainly originate from transportation, production and the manufacture of raw materials, a reduction of 30% in the same period is envisaged. In order to achieve its climate targets, HUGO BOSS is particularly focusing on saving energy, as well as procurement and self-generation from renewable sources. The following chapter describes the Company, in particular its activities in the area of Scope 1 and Scope 2 greenhouse gas emissions, as well as logistics.
Carl Zeiss, 2021, Sustainability Report 2020/21
Climate Protection at ZEISS. Guidelines, structures and processes. When it comes to reducing its emissions, ZEISS takes a three pronged approach that involves prevention, reduction and if there are no other options or if not economically viable - compensation. ZEISS views Scope 1 and Scope 2 emissions as top priorities the best way to reduce emissions is to not produce them in the first place. To this end ZEISS has given top priority to energy-saving measures. ZEISS Energy Management is tasked with keeping energy-related KPIs stable or improving them, even if production quantities increase. 100 companies in the ZEISS Group in the European Union and the UK have been certified as per the ISO 50001 international standard for energy management. The focus is on all of the company's (production) processes, machines, systems and equipment, along with its buildings and infrastructure.
BASF SE, 2021, BASF Report 2020
Energy and climate protection Customers suppliers BASF. As an energy-intensive company, we are committed to energy efficiency and global climate protection. We want to further reduce emissions along the value chain. To achieve this, we rely on efficient technologies for generating steam and electricity, for example, and the increased use of renew-able energies. We make our production processes as energy efficient as possible with the help of comprehensive energy management. We are researching and developing completely new processes and technologies to reduce our greenhouse gas emissions over the long term. In addition, our climate protection products make an important contribution toward emission reduction and resource efficiency.
Apple Inc., 2021, Environmental Social Governance Report 2022
Direct emissions abatement. We will reduce direct greenhouse gas emissions in our facilities and our supply chain through process innovation, emissions abatement, and the use of non-fossil-based low-carbon fuels. Carbon removal: Working in parallel with our emissions reduction efforts, we will scale up investments in carbon removal projects, including nature-based solutions that protect and restore ecosystems around the world. Low-carbon design to reduce the carbon footprint of our products, we're increasing efficiency and transitioning to materials from recycled sources and those made using low-carbon energy. In 2021, we continued to improve the carbon efficiency of the integrated circuits we use in our products - components we've prioritized because they are carbon-intensive. For example, switching to the Apple M1 chip for the 13-inch MacBook Pro reduced the energy needed to manufacture and use the device, driving down the product's carbon footprint by over 8 percent.
Volkswagen AG, 2021, Sustainability Report 2021
Climate Protection in Manufacturing. Since 2010, Volkswagen has increased vehicle production from 7.3 million to 8.0 million vehicles (an increase of 10%). Although absolute energy consumption increased by 6%, at the same time absolute greenhouse gas emissions reduced by 27%. Volkswagen wants to continue this trend and reduce greenhouse gas emissions in production by 50.4% in absolute terms compared to 2018 by 2030, which corresponds to a 1.5 C trajectory. By 2021, absolute greenhouse gas emissions had already been decreased by20.7%. Key to this are increasing energy efficiency and switching to a renewable power supply as important components of the decarbonization strategy. Nine production sites are already operated on a carbon-neutral basis, including compensation measures: Brussels and Győr (Audi), Zwickau and Dresden (Volkswagen), Zuffenhausen and Leipzig (Porsche), Crewe (Bentley Motors), Vrchlabi (SKODA) and Santa Agata (Lamborghini).

Potential journals Submitting it to:

- **Journal of Business Ethics**

- **Energy efficiency.**
- **Journal of Cleaner Production:**

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	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ERP	-0.0082***	-0.0018**	-0.0103***	-0.0055***	-0.0009	-0.0066***	-0.0063***	-0.0036***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
CG	0.5392***	0.3581***	0.4495***	0.4262***	0.3597***	0.5221***	0.4213***	0.5743***
	[0.07]	[0.10]	[0.06]	[0.06]	[0.10]	[0.06]	[0.08]	[0.08]
ERP x CG	-0.0114***	-0.0059***	-0.0109***	-0.0075***	-0.0046**	-0.0112***	-0.0081***	-0.0124***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Size	0.0765***	0.0269**	0.0419***	0.0547***	-0.0806***	0.1092***	0.1125***	0.0003
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
PPE	0.0814***	0.1084***	0.0453***	0.0766***	0.0385***	0.1361***	0.1558***	0.0662***
	[0.00]	[0.01]	[0.00]	[0.01]	[0.00]	[0.01]	[0.01]	[0.00]
MTB	-0.0677***	-0.0316***	-0.0489***	-0.0296***	-0.0392***	-0.0468***	-0.0436***	-0.0537***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.00]	[0.00]	[0.01]
Governance	0.1747***	-0.0553	0.0803*	0.0591	-0.1385	0.1872***	0.0900	0.1849***
	[0.06]	[0.07]	[0.05]	[0.05]	[0.09]	[0.06]	[0.07]	[0.07]
GDP	0.0000	-0.0000	-0.0000	0.0000	0.0000	-0.0000	-0.0000	0.0000
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Constant	2.7980***	2.2632***	4.2308***	1.7632***	5.4049***	1.4234***	1.3553***	3.8095***
	[0.24]	[0.26]	[0.21]	[0.19]	[0.34]	[0.21]	[0.26]	[0.25]
Model	3-Way FE	3-Way FE	3-Way FE	3-Way FE	3-Way FE	3-Way FE	3-Way FE	3-Way FE
Sample	High emitting sectors	Low emitting sectors	High emissions	Low emissions	Greenwashing sectors	Non-Greenwash sectors	Cash high	Cash low
Obs.	12108.00	6451.00	9200.00	9359.00	4671.00	13888.00	9311.00	9248.00
# FE	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
R2	0.38	0.33	0.61	0.52	0.60	0.47	0.51	0.49
R2 adj.	0.38	0.32	0.61	0.52	0.60	0.47	0.50	0.49
R2 adj. (within)	0.11	0.11	0.11	0.10	0.06	0.15	0.13	0.09
Log-likelihood	-21103.81	-9679.45	-13218.53	-13323.24	-7379.46	-23379.01	-15490.42	-15452.80
F-Stat.	115.72	50.07	99.42	88.48	39.00	203.96	106.76	64.77

Table 20: Board governance items

#	Item	Question
1.	Governance	Does the firm have a corporate governance board committee?
2.	Audit	Does the firm have an audit board committee?
3.	Nomination	Does the firm have a nomination board committee?
4.	Compensation	Does the firm have a compensation board committee?
5.	Board policy	If any of the items #1-#4 are not fulfilled, the board policy measure is 0.