Emission reduction policies, GHG emissions and the role of board governance: What does ESG data tell us?

Michael König-Sykorova[1]

Abstract This paper examines the relationships between emission reduction policies (ERP), board governance (BG), and greenhouse gas (GHG) performance. The findings expand the understanding of how institutions and policies interact in reducing emissions through ex-post analysis, including analysing the transmission channels in the ERP-GHG nexus. The study utilises a firm level dataset from 29 developed and emerging economies, with 16,660 firm-year observations between 2011 and 2022. First, results confirm and expands earlier literature that ERPs are positively associated with GHG performance. Second, the level of BG matters and demonstrates a statistical and economically relevant moderation effect of ERP on GHG intensity. Firms operating under a "good governance" regime are less prone to engage in greenwashing activities. Using three-way fixed effects with time, country, and business sector fixed effects, the results are partly robust to time lags, alternative emission measures, and sub-samples, such as GHG dependent and small/large firms. Discussion includes implications of the reliability of Environmental, Social, and Governance (ESG) data points. Recommendations are provided for climate policy makers, financial market participants, and other interested stakeholders. Outlook for future research is presented.

Keywords climate change, emission reduction policies, GHG emissions, neo-institutional theory, board governance

Section	Words (excluding, tables, captions, footnotes)
Intro	1200
Theoretical F	750
Empirical L. + Hypothesis	1800
Data	1300
Results	1700
Discussion	550
Total	7300

[1] Technische Universität Ilmenau, Germany and Frankfurt School of Finance and Management, Germany.
E-Mail: m.koenig@fs.de

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1. Introduction

(Introduce the topic) July 2023 was the hottest month ever recorded on Earth, as the UN Weather Agency reported. The Copernicus Climate Change Service has found that the global average temperature has not been so warm for at least 120,000 years, with surface air temperature already 1.5 degrees Celsius higher than the average pre-industrial temperature (WMO, 2023). The Intergovernmental Panel on Climate Change (IPCC) reiterated in 2023 that human induced climate change is "unequivocal" and that widespread and rapid changes have already occurred in every inhabited region across the globe, causing already disastrous (non-)economic losses for various businesses. As a global response, the Paris Agreement (PA) signed by 197 member states in 2015 requires all actors, including states, to set up and implement nationally determined contributions (UNFCCC, 2015a: Article 4, NDCs), as well as firms, to align their finance flows with the global climate goals to avoid a climate catastrophe (UNFCCC, 2015a: Article 2.1.c, Zamarioli et al. 2021). Notably, even if all countries implemented their (un-)conditional NDCs[2], global warming above pre-industrial times is still projected to be around 2.8°C by the end of the century. With respect to these insufficient national commitments, and slow developments of international climate politics (see weak outcomes of recent Conferences of the Parties (COP) in Egypt in 2022, and Dubai in 2023), there are growing voices among policy makers, academic researchers, and industry representatives that decarbonization at the firm level must be incorporated into firms' identities via e.g., emission reduction policies in the form of transition plans (Krabbe et al, 2015; IPCC, 2022; NGFS, 2023).As firms play a significant role in addressing climate change, literature documented an exerted pressure on firms to mitigate the detrimental environmental effects of their activities to contribute to the United Sustainable Development Goals (SDGs). and the PA (Adu et al., 2021; Choi et al., 2021). The main purpose of this study is to investigate the relationship between emission reduction policies (ERPs), board governance (BG) and greenhouse gas emissions (GHG) at the firm level.

(Describe the background) The mentioned relationship has been a point of emphasis in the academic literature in recent years. While different studies show mixed results (e.g., Haque et al., 2022, Coen et al. 2022), there is a broad consensus that sustainability concerns, including firms' strategies to decrease emissions substantively will determine the future success of many businesses (Adams et al., 2016). However, switching emission trajectories to improve GHG performance requires major changes on firms' strategic orientation (Hoang, 2023) and comes with certain risks and challenges, such as loosing economic viability and market competitiveness. Higher cost profiles (e.g., high upfront costs), and lack of technological readiness from adopting low-emission activities adds price disadvantages in the short term, neglecting positive but uncertain mid-to-long term effects. ERPs often face credibility and reliability issues due to greenwashing and impression management, as documented by Marquis et al. (2016) and Van Halderen et al. (2016). These tactics are partly used to avoid losing ground to competitors. To avoid such tactics, strong board governance within a firm is crucial and helps to turn symbolic announcements into substantial climate action, which is key for long-term sustainability (Haque et al., 2017).

(Establish the research problem) Various scholars, such as Lagoarde-Segot et al. (2018), Abhayawansa et al. (2022), the IPCC (2022), and Barrata et al. (2023) have highlighted the need for further research to examine the transformative potential of "climate-related strategies" (proxied in this study by ERPs) on GHG performance. In addition, this paper introduces board governance as a moderating variable in the GHG-ERP nexus to further test the effectiveness of ERPs at the firm level. While many scholars demonstrate that firms often engage in impression management by enhancing climate disclosure and communication, without actually improving their GHG performance (Talbot et.al, 2015), there is large theoretical and empirical evidence that firms with higher levels of board governance are less likely to engage in greenwashing activities.

[2] As submitted under the United Nations Framework for Climate Change Convention (UNFCCC Paris Agreements operational mechanism: See: National Determined Contributions (NDCs).

(What limitations in previous work does it address?) Although scholars have conducted a lot of research on symbolic announcements of initiatives or strategies and substantive emissions, only very few studies have included governance measures in the same analytical framework for analysis. These studies analyses board governance from an angle of e.g., CEO experience, (gender) diversity, or board size (e.g., Luo et al., 2014; Moussa et al., 2020; Orazalin et al., 2023, Issa et al., 2023). This paper investigates the impact of board governance structures, as measured by the existence of audit, corporate, compensation, and nomination committees within the ERP-GHG nexus and not measuring governance by specific characteristics (years of experience or share of female board members). The quantitative dataset separates itself from previous research on the ERP-GHG nexus by using the largest firm-level data set to date across 29 emerging and developed countries and 22 business sectors between 2011 and 2022.

(What contribution to knowledge does it make?) The findings of this study intend to make the following contributions to the literature. First, providing empirical evidence to expand the limited literature on the ERP-GHG nexus and thereby enhance the understanding of how institutions and policies interact in reducing emissions through ex-post analysis (e.g., IPCC, 2022). It documents the reliability of environmental and governance ESG data points on the effectiveness in reducing emissions. This provides crucial insights for private investment decisions (e.g., fund managers) and policy makers. Second, it expands knowledge on transmission channels to better understand the role of governance within the ERP-GHG nexus. Insights feed in the sustainability reporting literature with recent developments, including the EU e.g., Corporate Sustainability Reporting Directive (CSRD), or the Corporate Sustainability Due Diligence Directive (CSDDD), as both place specific reporting requirements on board governance, and emphasizing the role of firm governance in achieving sustainability and climate goals. It expands the emission mitigation literature with evidence that, besides technological changes, changes in organizational structures, practices, and strategies are essential to achieve climate targets.

(Specify the objectives) The purpose of this study is to investigate the impact of emission reduction policies (ERP) on GHG performance, as measured by total GHG emission intensity[3]. The theoretical and empirical frameworks of this study build upon existing contributions and conceptualise the neo-institutional theory (NIT) to understand the ERP-GHG nexus with its central logic that guides the material and symbolic relationship of organisations with the environment (Thornton, 2004). It was hypothesized that ERPs are associated with an increase in GHG performance (H1), and that the effect is intensified by high levels of board governance, as measured by the firm governance, including audit, corporate, compensation, and nomination committees (H2). Evidence offers support for the efficiency-and legitimated oriented understanding of the NIT that firms be liable to have substantive ERPs and "walk-the-talk", specifically with existing board committees in place maintaining effective board governance functions

(Map the paper) Section 2 introduces the theoretical background. Empirical literature and hypothesis development are introduced in section 3. Section 4 presents the dataset and section 5 discusses the results, including robustness tests in section 5.1. Section 6 concludes with recommendations for future research and policy implications.

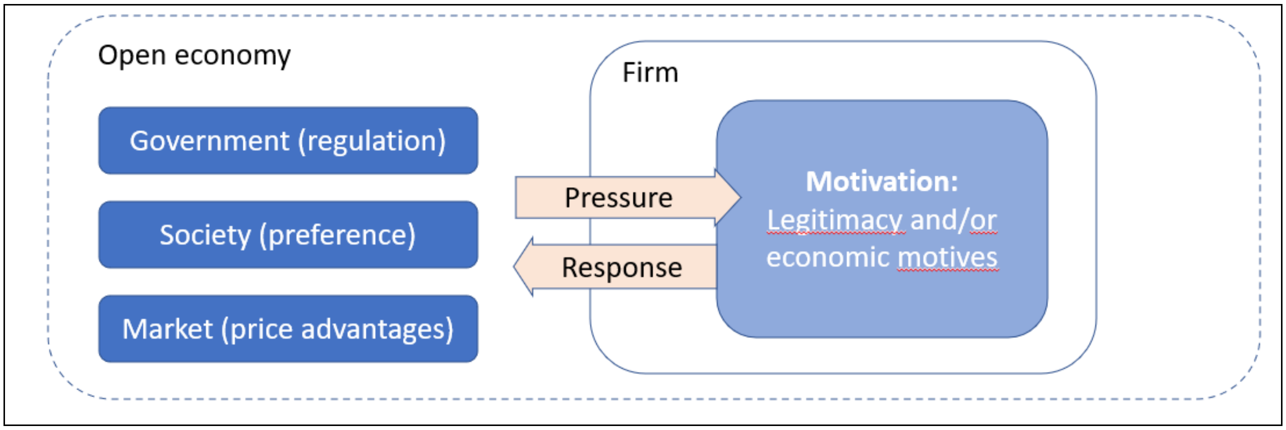
2. Theoretical background

This paper follows previous studies and adopts a multi-theoretical framework to provide a better understanding of the firm-level ERP-GHG nexus (Haque et al., 2017). This corresponds to the call for a more theoretical integration to understand responses to climate change topics more clearly (Shahab et al., 2019 in Konadu et al., 2022). Overall,

[3] Measured as the ratio of a firm's total of Scope 1 (direct) and Scope 2 (indirect) GHG emissions to the net sales revenue.

the neo-institutional theory (NIT)[4] embeds the research question. The NIT suggests that firm-level actions are responses to pressure from governments (e.g., policy making, including standard setting), society (e.g., shift in consumer preferences and market demand, including boycotts) and market developments (e.g., competitive advantages, including technological readiness). Various scholars highlight that responses to climate-related risks and pressures are driven by legitimacy (e.g., reputational)[5] and economic (e.g., efficiency) oriented motives (Scott, 2013) as illustrated in figure 1 below. The NIT considers both efficiency (e.g., agency and transaction costs from economic theories) and moral motives, as well as symbolic and legitimization drivers (e.g., stakeholder theories), which is adequate to capture the initially symbolic nature of ERPs and the potentially substantive GHG reductions.

Figure 1: Neo-institutional theory, simplified illustration



Note: Figure not exhaustive, only-illustrative. Own visualization based on Scott (2013).

An organisation may adopt ERPs as a response to institutional pressures (e.g., stakeholder expectations, see figure 1), which has been demonstrated to be linked to ease of access to resources, less exposure to scrutiny, avoiding negative consequences (e.g., boycotts), and enhancing the firm's reputation (Bansal et al., 2004; de Quevedo-Puente et al., 2007)[6]. For instance, Apple requires all suppliers in its supply chain to follow a 100% renewable energy production. This subsequently accelerated firms' mitigation ambitions and their investments in innovative technologies and practices (UNFCCC, 2015b). Specifically for access to finance, pressure from investment funds and other financial market participants is continuously increasing on firms to integrate sustainability factors into their strategic orientation and operations.[7] Thus, firms may adopt ERPs to steer towards new market opportunities created by the increased demand for green goods and services (Berrone et al., 2009) to stay competitive and economically relevant. However, in the context of firms transitioning towards low-emission activities aligned with the PA, firms need to strategically manage their transition pathways to balance the short-term costs. Investments in climate-related initiatives yield lower profits and the returns from such investments are often not expected to

[4] Neo-institutional theory is one of the main theoretical perspectives used to understand organisational behaviour as situated in and influenced by other organisations and wider social forces—especially broader cultural rules and beliefs (Lounsbury et al., 2020). The NIT is discussed in the latest AR6 IPCC report on climate change mitigation, in relation to transition management and the exploration of ways to guide a socio-technical system from one path to another in Chapter 17 on "Decision-making frameworks for addressing climate change".[#] In addition, not directly spelled out as such, Chapter 5 on "Demand, services and social aspects of mitigation" highlights the importance of institutional setting and pressure towards mitigation options, particularly behaviour and social changes.
[5] Firms naturally increase or defend their legitimacy by conforming to the expectations of institutions where they are operating (Scott, 1995, Aldrich et al., 1994 in Berrone, 2009) and assign considerable effort on their social and environmental obligations towards share- and stakeholders to manifest and enhance their legitimacy (Cho et a., 2007; Mallin et al., 2011 in Moussa et al., 2020).
[6] Both papers cited in Moussa et al. (2020)
[7] For instance, in the 2018 Annual Letter to Chief Executive Officers (CEOs), Chairman Larry Fink of BlackRock, the world's largest investment manager with nearly $6 trillion under management, urged CEOs to both deliver financial performance and contribute positively to society, or risk losing BlackRock's support.

materialize in the short term, not properly reflecting the long-term benefits of sustainable growth and resilience in a low-carbon economy.

However, economic motivations are not necessarily linked to positive environmental outcome (Durand et al., 2019; Herold et al, 2019). Symbolic initiatives communicated internally, and externally to the public, such as ERPs are identified as a key element in the "greenwashing" discussion (Marquis et al., 2016; Van Halderen et al., 2016). While ERPs may be designed to only convey a picture of being climate active and aligned with external expectations, the NIT suggests that "good governance" may moderate the impact of ERPs on emission reductions through policy compliance, transparency and accountability (Wang et al., 2023), and further concerns such as risk management practices (Issa et al., 2023). These factors may create an enabling environment that supports the implementation of ERPs, and "walk-the-talk" to ultimately reduce emissions.

3. Empirical literature and hypothesis development

In recent years, there has been an increasing interest in the scientific literature to examine the impacts of firm climate strategies on firm GHG performance. Key aspects and findings of this relationship are discussed below, and two hypotheses are developed subsequently. H1 states that stronger firm-level ERPs are associated with a decrease in GHG intensity (Emissions per USD revenue). H2 states that the existence of board governance moderates the ERP-GHG nexus and leads to greater GHG reductions. In sum, literature shows that different methods and empirical samples generate mixed findings about the effect of symbolic ERPs on substantive GHG reductions and supports both symbolic ("greenwashing", "impression management") and substantive ("walk-the-talk") outcomes on the ERP-GHG nexus.

3.1. H1: Emission reduction policies (ERP) and GHG performance

From a legitimacy angle, most empirical studies document a negative or insignificant relationship of the ERP-GHG nexus. A study conducted by Haque and Ntim (2017) using a sample of 2,245 firm-year observations for the period 2002 – 2014 from UK listed firms finds that firms largely conform in a symbolic way with environmental policy initiatives and sustainable development frameworks. GHG emissions do not significantly decline. In a more recent study, the same authors (2020) did not find a statistically significant relationship between symbolic, process-oriented carbon performance and actual substantive GHG emissions. The dataset covers 4,379 listed firm-year observations between 2002 and 2016 in 13 industrialised European countries. Coen et al. (2022) analyse 725 sustainability reports covering corporate emissions between 2010 and 2019 from global operating firms listed in FTSE-100 and the Dow Jones 30 Industrial firms. The authors use natural language processing (NLP)[8] and show that voluntary engagement or "climate talk" in initiatives such as CDP, GRI, SBTI, or TCFD are mostly producing symbolic outcomes (greenwashing) without being translated into substantive "climate walk". Their analysis shows that firms that have reactive strategies[9] generally do not "walk-the-talk". In their 2022 study, Albitar et al. examined whether there were notable differences in emission intensity among companies with high, low, and no ESG ratings. Their research was based on data from 1,664 firm-years, spanning from 2016 to 2020, for companies listed on the London Stock Exchange (LSE). They discovered that funds labelled as ESG had similar emission intensities and varied ESG performance when compared to funds not labelled as ESG, according to major external rating providers. Notably, they found that companies that were part of a climate initiative had significantly higher carbon intensity in their portfolios. However, companies that prioritized climate change issues or implemented a decarbonisation strategy did not show significant differences in their emission intensities. Other studies have found evidence of a positive link between ERPs and GHG performance. Haque et al. (2022) show that higher environmental ESG scores are

[8] Extracting keyword data with Wordstat software, based on the dictionary method.
[9] Firms make excuses why they have not improved their climate efforts.

associated with improved GHG performance, measured by direct and indirect emission intensity, in a cross-country sample of 2,444 firm-year observations between 2004 and 2019. The authors suggest that the negative relationship between membership in a sustainability initiative and emission intensity is driven by motives of powerful economic agents such as shareholders and/or executives. They conclude that more research is needed to analyse the moderating effects of firm level governance, such as ownership and board structure, which will be introduced in H2.

The baseline hypothesis H1 updates the empirical framework from Haque et al. (2022) who focussed on a specific part of the ESG, namely the "E-Pillar" as the main determinant of interest (covering multiple environmental dimensions). H1 considers specifically the ERP variable which indicates whether firms have a specific emission reduction policy in place.

H1: *Emission reduction policies (ERP) reduce GHG intensity at the firm level, measured by the ratio of Scope 1 and Scope 2 GHG emissions to revenue.*

$$GHG\ Intensity_{i,t} = \beta_0 + \beta_1 ERP_{i,t} + aX_{i,t} + \beta_4 Country_i + \beta_5 Industry_i + \beta_6 Year + \varepsilon_{i,t} \qquad (1)$$

$GHG\ Intensity_{i,t}$ is firms i’s annual GHG emission intensity, calculated as the sum of absolute Scope 1 (direct) and Scope 2 (indirect) tons of CO_2 emissions divided by net sales or revenue in thousand USD in the respective year t. $ERP_{i,t}$ is a percentile score capturing firms’ ERPs compared to other firms in the same industry and year, including processes, mechanisms, or programs compared to peer companies. $X_{i,t}$ is a vector of fundamental firm-level controls following previous literature. $Country_i$, $Industry_i$ and *Year* capture country, industry and time fixed effects.

3.2. H2: Moderating effect of board governance in the ERP-GHG nexus

Arguing from a pure efficiency perspective, there is no need for outside structures or monitoring to enforce changes in firm behaviour. Efficiency motives are driven purely by the core motivator for commercial firms, which is profit maximization. Thus, as GHG reductions may be driven by cost competitiveness in the mid-to-long term, and improved access to financial resources in the short term (de Villiers et al., 2011), the announcement of GHG strategies may already facilitate efficiency motives. Many studies demonstrate that firms engage in “impression management” by enhancing climate disclosure and communication to utilize short-term advantages, without demonstrating improved GHG performance. They only create a positive image of their planned efforts, even if their emissions do not align with what has been reported (Talbot et al., 2018). In this sense, firm-level board governance is considered a critical element to increase seriousness and effectiveness of climate initiatives. H2 tests whether board governance moderates the relationship between ERP and GHG performance.

(Direct impact of governance on emissions) Academic evidence documents that board governance by itself is a significant driver of GHG performance (Moussa et al, 2020; Xia et al., 2022). Specifically, Haque et al. (2017) find for a sample of 2,245 UK firm-year observations between 2002 and 2014, that board characteristics (board independence and executive compensation) have a significant impact on emission intensity using. . Similar findings are documented by Peng et al. (2022), where board independence and board size positively affect the environmental sustainability performance, and the relationship is negatively moderated by masculinity. The authors use a sample of 150 multi-national corporates from China, Japan, the UK and USA to cover diversity of national cultural characteristics. Berrone et al. (2009) show that long-term pay for board executives is an important incentive for emission prevention, specifically in high-polluting sectors. Kanashiro (2020) shows that firms operating in the U.S. high-polluting industries with an “environmental board committee” are more likely to comply with pressure to reduce GHG emissions. Finally, from a country perspective Danish et al. (2019) document for a BRICS[10] sample

[10] Brazil, Russia, India, China, and South Africa.

that governance (e.g., political stability, voice and accountability, regulatory quality, government effectiveness, control of corruption, and rule of law) has a significant effect on reduced GHG emissions.

(Board characteristics influence the creation of ERPs) Traditionally, board members have often overlooked their environmental responsibilities. This can be explained by various reasons including a general board risk aversion that leads to value protection at the expense of value maximization (Jensen et al., 1976). Phung et al. (2023) analyse a U.S. sample of 11,814 firm-year observations between 2000 and 2020 and explore the influence of extrinsic incentives for top management (that is, motivations driven by rewards) on firms' strategy for environmental innovation. They found a positive correlation between top management compensation and strategies for eco-innovation. Zhao (2023) analyses the Chinese heavy pollution market between 2015 and 2020 and concludes that environmental strategies are a crucial element to balance economic and environmental outcomes. The author shows that senior manager characteristics determine the effectiveness of such strategies with a focus on green innovation.

(Moderating role of governance on the ERP-GHG nexus) Haque et al. (2020) analyse an EU corporate sample of 4,013 firm-year observations between 2002 and 2016, and concludes that firms tend to follow environmental "impression management" techniques by focusing on symbolic disclosures, rather than disclosing the adverse impacts of their activities. However, for the share of female board participation, the authors find positive influence of board diversity on corporate environmental performance, which is in line with several other empirical studies (Glass et al., 2016; Hollindale et al., 2019). Issa et al. (2023) find within a European sample of 1,258 firm-year observations that board and executive gender diversity can influence the GHG-ERP relationship as moderators. Al-Jaifi et al. (2023) documents for a panel sample of 11 Asia-Pacific countries and 14,878 frim-year observations, that board independence moderates the relationship between tenure and gender diversity and environmental performance. Luo et al. (2021) show that a high level of board governance, measured by a corporate governance score, is in line with a high level of responsibility towards social values, and that firms with strong board governance are less likely to take greenwashing measures. Albitar et al. (2022) document for a UK sample that the existence of board-level environmental committees and ESG-linked board compensation are key drivers for the effectiveness of developing and implementing new products and services, improving production processes, services, management strategies, or firm strategies with the aim to reduce environmental risk. The authors conclude that environmental innovation reduces GHG emissions, and the effect is moderated by firm governance. Yu et al. (2020) discover in a sample of 1,925 large-cap firms from 47 countries and territories that governance is the most important driver in discouraging greenwashing. Further drivers are the engagement of institutional investors, the level of corruption in the country's system, and the cross-listing status. The authors conclude that a higher share of independent board directors reduces greenwashing behaviour in a firm. Finally, Baratta et al. (2023) document in a bibliometric analysis that governance structure plays a paramount importance in the ERP-GHG nexus. Firms with high levels of governance are less likely to take actions for greenwashing purposes only, and can therefore underline the seriousness of symbolic public announcements of climate initiatives or strategies.

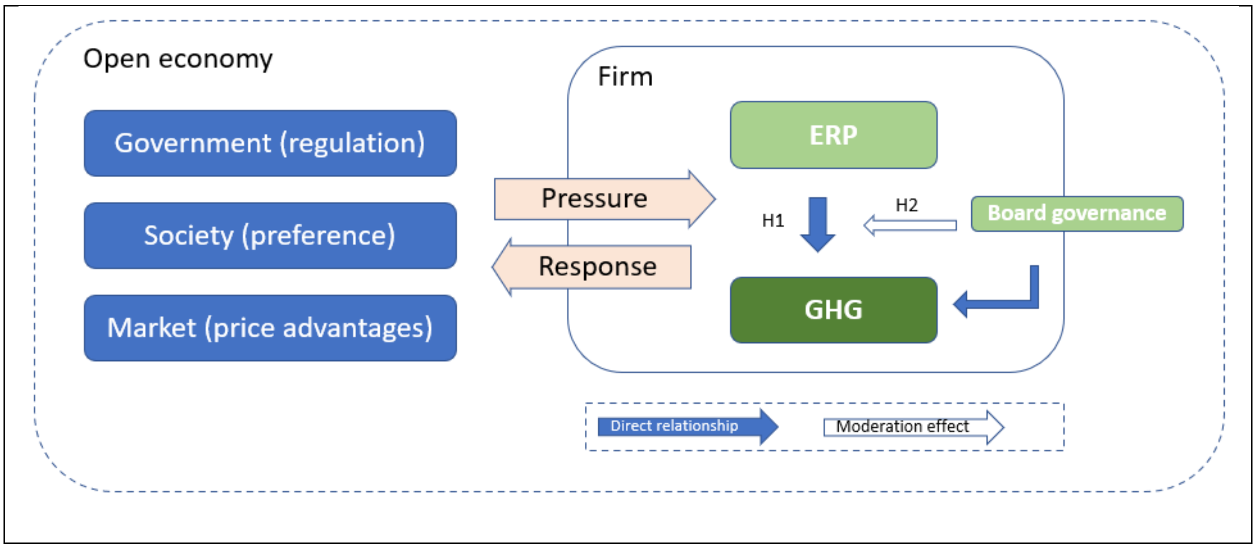
Overall, the literature documents that firm level governance is positively associated with climate action and the relationship between ERP and actual GHG performance may be partly driven by governance factors, as higher levels of governance strengthen the link between ERP and GHG performance. Thus, while from an efficiency and access to financial market perspective firms may adopt ERPs, good governance structures may support firm boards to "walk-the-talk" and not engage in greenwashing activities. Thus, H2 is formulated as follows:

H2: *Firms with a higher level of board governance (BG) record a stronger positive link between emission reduction policies (ERP) and GHG performance, as BG strengthens the "walk-the-talk" behaviour by firms which is associated with less greenwashing.*

$$GHG\ Intensity_{i,t} = \beta_0 + \beta_1 ERP_{i,t} + \beta_2 BG_{i,t} + \beta_3 ERP_{i,t} x\ BG_{i,t} + aX_{i,t} + \beta_4 Country_i + \beta_5 Industry_i + \beta_6 Year + \varepsilon_{i,t} \quad (2)$$

Where board governance policy $BG_{t,i}$ is calculated as a percentile score compared to firms in the same country. It captures firm i's board governance scores based on different items, including the existence of board committee audit, nomination, and compensation as well as respective policy for maintaining effective board governance functions. In sum, the empirical framework illustrated in figure 2 builds on the design of previous studies from Haque et al. (2022, 2020, 2017), Albitar (2020), and Luo et al. (2021) to provide further evidence on the role of board governance on the effectiveness of ERPs.

Figure 2: Conceptual research framework on the relationship between ESG related factors and GHG emissions



Note: Figure not exhaustive, only-illustrative. Own visualization based on Scott (2013).

4. Data

4.1. Sample

The analysis is based on firm-level data provided by the Bloomberg and Thomas Reuters Datastream, including emissions data from Institutional Shareholder Services (ISS) ESG. Data is drawn from firm-reported data by numerous publicly available information sources by Thomas Reuters. The data points are extracted from annual reports, company and NGO websites, stock exchange filings, CSR websites, and news sources. For more details see LSEG (2023). The dataset is structured as an unbalanced panel between 2011 and 2022. To avoid noise in the analysis, percentile-based filtering technique has removed countries and sectors with a low number of observations. Countries with less than 177 observations[11] referring to the 1^{th} percentile, and industries[12] with less than 420 observations referring to the 1^{th} percentile have been removed. In addition, all observations from the financial sector, which operate differently and are subject to different accounting requirements have been removed following (Source). The final sample comprises 16,660 firm-year observations from 29 countries with 4,142 unique firms, from 23 business sectors (Table 1). Country of origin is determined by the location of the firm's headquarters.

[11] Excluded countries due to low coverage: Israel, United Arab Emirates, Bermuda, Colombia, Philippines, Peru, Portugal, Poland, Indonesia, Russia, Chile, Luxembourg, Austria, Turkey, New Zealand

[12] Excluded industries due to low coverage: Academic & Educational Services, Financial Technology (Fintech) & Infrastructure, Collective Investments, Investment Holding Companies, Renewable Energy, Consumer Goods Conglomerates, Personal & Household, Products & Services, Food & Drug Retailing

Table 1: Years, Business sectors, and countries, covered in the dataset

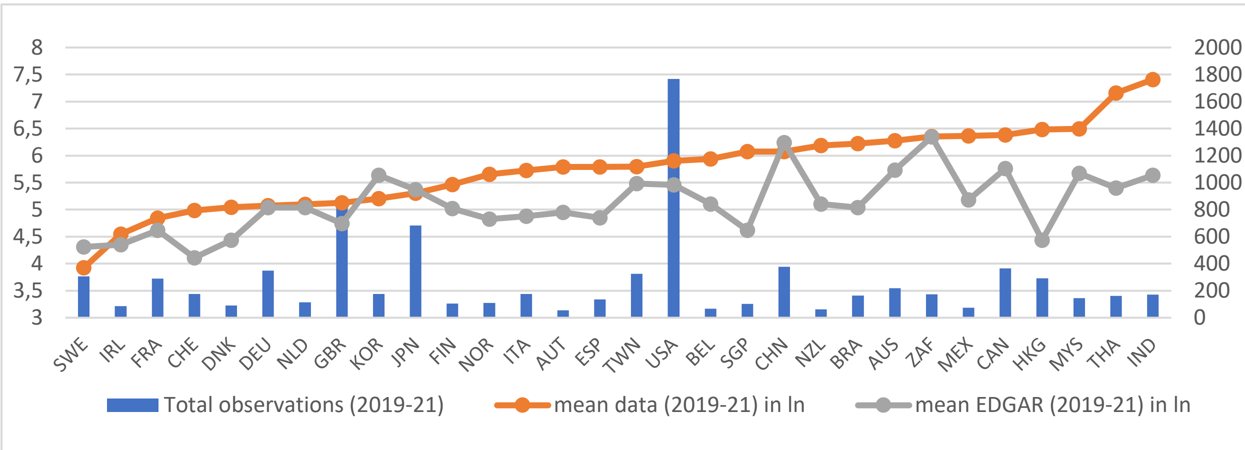
Year	N	Share	Business sector	N	Share	Country	N	Share
2011	423	2%	Applied Resources	326	2%	AUS	498	3%
2012	475	2%	Automobiles & Auto Parts	604	3%	BEL	150	1%
2013	513	3%	Chemicals	762	4%	BRA	364	2%
2014	536	3%	Consumer Goods Conglomerates	173	1%	CAN	722	4%
2015	595	3%	Cyclical Consumer Products	788	4%	CHE	392	2%
2016	1,111	6%	Cyclical Consumer Services	749	4%	CHN	662	3%
2017	1,318	7%	Energy - Fossil Fuels	957	5%	DEU	721	4%
2018	1,595	8%	Food & Beverages	1,100	6%	DNK	200	1%
2019	2,139	11%	Food & Drug Retailing	284	1%	ESP	313	2%
2020	2,748	14%	Healthcare Services & Equipment	516	3%	FIN	259	1%
2021	3,238	16%	Industrial & Commercial Services	1245	6%	FRA	681	3%
2022	2,239	11%	Industrial Goods	1,455	7%	GBR	2,011	10%
			Mineral Resources	1,065	5%	HKG	545	3%
			Personal & Household Products & Services	230	1%	IND	400	2%
			Pharmaceuticals & Medical Research	553	3%	IRL	197	1%
			Real Estate	758	4%	ITA	324	2%
			Retailers	647	3%	JPN	1,450	7%
			Software & IT Services	820	4%	KOR	377	2%
			Technology Equipment	1,270	6%	MEX	140	1%
			Telecommunications Services	527	3%	MYS	312	2%
			Transportation	922	5%	NLD	246	1%
			Utilities	906	5%	NOR	218	1%
						NZL	125	1%
						SGP	201	1%
						SWE	642	3%
						THA	290	1%
						TWN	578	3%
						USA	3,514	18%
						ZAF	398	2%
Sum	16,660	100%	Sum	16,660	100%	Sum	16,660	100%

Note: Sector descriptions see table 11 in the Annex.

In terms of country coverage, the U.S. (17%), Great Britain (10%), and Japan (7%) account for the largest shares of observations. On the business sectors, observations from the industrial goods (7%), and industrial commercial services (6%), technology equipment (6%), and mineral resources (5%) sectors are most frequent, but sectors are more equally distributed than countries. The sector breakdown represents a classification system commonly used by the investment community for navigation, aggregation, and benchmarking. It provides a global standard for identifying peers and tagging research. The used dataset covers around five times more firm-year observations with an observation period between 2011 to 2022 which allows to better account for the existence of specific country characteristics, such as sector emission laws on emission standards, reporting requirements, or market mechanisms, such as carbon pricing regimes. To the best of the author's knowledge, this is the most comprehensive sample used for analysing the relationship between ERPs and GHG performance.

In terms of country representation of the GHG emission intensity metric (used as dependent variable), the dataset is largely aligned with the respective country GHG footprints. This is illustrated in figure 3 by comparing the GHG emission intensity of the sample data (orange line) with net CO2 emission intensity of the production basis (grey line) by the International Energy Agency-Emissions Database for Global Atmospheric Research (IEA-EDGAR)database. In general, GHG emission intensity in the sample data is higher than the country reported, though there are some outliers with lower emission intensity (e.g., CHN, JPN, KOR) compared to country levels. There are two main reasons for this difference. First, the covered industry sectors, including chemicals, transportation, and industrial goods come with high Scope 1 (direct) and Scope 2 (indirect) CO2 kilo emissions per 1,000 USD revenue compared to large parts of service industries which are not covered in the sample data. This skews the GHG intensity measure towards higher levels. Specifically, there is no coverage of pure finance business sectors, including the business sectors Financial Technology (Fintech) & Infrastructure, Investment Holding Companies, Insurance, or Academic & Educational Services. Second, the sample data report GHG emissions as CO2 equivalent emissions, which include the most relevant reported GHG emissions. 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 EDGAR reference data reports only CO2 emissions. To illustrate the absolute coverage of the used data as share of the country emissions, it ranges from 0.05% (0.06%) in China (USA) to 7.36% (5.11) in Switzerland (Singapore) with respect to absolute mean value 2019-2021.

Figure 3: Comparing emission intensity used in the sample (mean 2019-21) with EDGAR emission intensity (mean 2019-21)



Note: Data refers to 2019-21, excluding data between 2011 and 2018 which is covered in the sample dataset. Orange and grey lines mapped on the left axis show emission intensity for used data and reference data (IEA-EDGAR database). Both show mean values between 2019-21. Blue bars mapped on the right axis show observations per country between 2019-21. EDGAR only considers car bon dioxide emissions compared to CO2 equivalent emissions in the dataset. Data represented in logarithmic (ln) values.

4.2. Variables

The main dependent variable is GHG performance. It is measured at the firm level as total GHG emission intensity (Scope 1 and Scope 2 emissions), which is defined as firm-year emissions in kilograms of CO2 equivalent divided by net sales or revenue. The empirical identification follows Lewandowski (2017), Nuber et al. (2021), and Haque et al. (2022) by using GHG intensity, which is represented in logarithmic values to improve the normal distribution of the dataset compared to continuous units. As a robustness check, Scope 1 and Scope 2 emissions are used separately to account for different characteristics of emission types.

The explanatory variable is the Emission Reduction Policy (ERP) score provided by Refinitiv, which gathers data from firm documents and reports that are publicly available, including but not limited to annual reports, such as general meetings, Corporate Social and Responsibility (CSR) reports, ESG webpages, and other global disclosure systems such as the carbon disclosure project (CDP). An example of five firms (Hugo Boss, Carl Zeiss, BASF, Apple, Volkswagen) for the year 2021 are presented in the Annex. The data points are then converted to a percentile score calculation (equation 3). Details are available in the methodology paper of the London Stock Exchange Group (LSEG, 2023). In short, firms are compared with their peer groups to arrive at the percentile score using equation 3. 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 ERP is defined as a measure which captures policy-related firm intentions to reduce GHG emissions in its operations, system, or a set of formal, documented processes for controlling emissions and driving continuous improvement.

$$\text{ERP} = \frac{\text{Number of firms with a worse value} + 0.5*(\text{Number of firms with same value,incl.the current one})*100}{\text{Number of firms with a value}} \quad (3)$$

The second explanatory variable is Board Governance (BG) provided by Refinitiv. It is assessed based on five individual questions (table 2). With the data metrics shown in table 2, the firm strives to maintain a well governed board via an audit committee, corporate governance committee, nomination committee, and compensation committee. The governance variable BG is represented as a percentile score variable using the same formula as used for the ERP value. For instance, for a set of 10 firms within the same sector, and same year the minimum value is 50 if all firms have the exact same value. Example: 50 = (0 + 0.5*(10)) *100/ 10.

Table 2: 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 appears as false, the board policy measure will be false, as it is assumed, that the firm does not have a policy for maintaining effective board functions.

Finally, by following other studies a set of firm-level fundamentals is employed as control variables. Firm size (Size) measured by total assets in million USD in natural logarithmic serves as a proxy for social pressure or expectations for climate action (Al-Tuwaijri et al., 2004). Further controls are financial leverage (Lev), calculated by total debt divided by total assets (Ferris et al., 2018), firm value (Tobin's Q), market-to-book ratio (MTB), tangible assets (PPE), and liquidity (Cash) (among others see Haque et al., 2022; Choi et al., 2021; Qian et al., 2017).

4.3. Descriptive statistics, robustness and diagnostic

Table 3 describes the variables used in the empirical framework and table 4 provides the descriptive statistics.

Table 3: Variable definitions

Variable name	Label	Description
GHG Scope 1 and 2 intensity	GHG Intensity	Greenhouse gas (GHG) emission intensity is the natural logarithm of the ratio of Scope 1 (direct) and Scope 2 (indirect) GHG emissions in tons divided by net sales or revenues in thousands USD, with lower intensity indicating better emission performance.
Emission Reduction Policy	ERP	Emission reduction policy (ERP) captures firm-level policies to reduce emissions within firms' core activities, including processes, mechanisms, or programs.
Board Governance	BG	Board governance (BG) measured as relative percentile scores captures the level of maintaining effective board functions compared to peers within the same country.
Firm size	Size	Logarithmic value of total assets reported by the firm in million USD.
Leverage	Lev	Total value of all short- and long-term borrowings reported by the firm, divided by the size (total assets) of the firm.
Firm value	Tobin's Q	Sum of firm size less book value plus market value divided by firm size.
Market to book value	MTB	Market to Book (MTB) value
Tangible assets	PPE	The total reported gross value of property, plant and equipment before depreciation is divided by the size (total assets) of the firm.
Liquidity	Cash	Total short term and highly liquid investments divided by total current liabilities

Systemic differences across countries, business sectors, and time are captured via fixed effects in the empirical framework as shown in the identification of H1 and H2 (section 3.1, 3.2). Business sector fixed effects appear to be critical given the diverse nature of policies across industries and due to the different nature of production. For instance, firms subject to government policies to reduce GHG emissions on the one hand would make larger reductions than firms not subject to such policies. On the other hand, firms under the supervision of government agencies might be more likely to be engaged in "hard-to-abate" activities, than those outside government scrutiny. Global trends in the development of GHG emission intensity that change over time, for example increased emissions due to global GDP growth, is covered by time fixed effects. The descriptive results are comparable with those of prior country and global studies, such as Luo et al. (2021), and Haque et al. (2017, 2020, 2022).

Table 4: Descriptive statistics

	Mean	Median	SD	Min.	Max.	N
GHG Intensity	4.06	3.76	1.83	0.09	9.72	16,660
ERP	66.92	65.88	7.39	52.38	96.07	16,660
BG	54.76	52.07	5.97	50.00	81.60	16,660
Size	22.60	22.19	2.58	16.28	31.81	16,660
Lev	1.56	0.72	3.78	<0.01	101.14	16,660
PPE	2.88	1.25	4.89	<0.01	69.89	16,660
Cash	0.46	0.29	0.55	<0.00	5.92	16,660
Q	2.83	1.38	8.03	<0.00	xxx	16,660
MTB	2.29	1.21	3.69	<0.00	72.87	16,660

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

5. Result

On H1, there is an inverse relationship between ERPs and GHG intensity of emissions (table 5), suggesting that when firms make symbolic announcements, it positively correlates with their actual performance in reducing GHG emissions. On H2, while an initial analysis (table 6) with a linear specification of BG suggested that there was no moderating effect of BG on the ERP-GHG nexus, following a more flexible specifications of the BG variable, however, revealed a complex non-linear moderating effect. High BG measures strengthened the relationship between ERP and GHG intensity at low and medium levels of ERP but had no impact at high levels of ERP. Table 5 shows estimation results of the panel fixed effects regression of GHG emission intensity against the explanatory variables. The study includes several specifications. Column 1 (only ERP, no controls, no fixed effects), column 2 (including controls, no fixed effects), columns 3-5 (including controls, and one fixed effect per specification), and finally column 6, which presents ERP alongside the controls and the three fixed effects (sector, country, and year). The results reveal that at the 1% level, the ERP has a statistically significant negative association with GHG emission intensity for all specifications. Higher ERP scores are associated with lower levels of GHG emission intensity. The empirical estimation results are consistent with hypothesis 1, that ERPs are inversely associated with GHG emission intensity, indicating a positive association between symbolic announcements and firms‘ substantive GHG performance. On the economic significance, column 7 documents that an incremental increases by 1 unit ERP is linked with a 2.46% reduction in the GHG emission intensity. Calculating the ranges with one standard deviation (+/-7.37, see descriptive statistics in table 4) shows a substantive emission reduction range of up to 17.83%. Notably, except for MTB, all financial fundamentals are positively associated with GHG emission intensity. Thus, bigger firms (measured by firm size, Tobin's Q, Cash, or PPE) have a higher GHG emission intensity (Scope 1 and 2) compared to smaller firms.

Table 5: Three-way fixed-effects regression of GHG intensity against ERP (Hypothesis 1)

DV: GHG Intensity	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ERP	-0.0918***	-0.0733***	-0.0733***	-0.0014	-0.0679***	-0.0990***	-0.0246***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Size	-	0.0533***	0.0533***	0.0633***	0.0676***	0.0310***	0.0255***
	-	[0.00]	[0.00]	[0.00]	[0.01]	[0.00]	[0.01]
Lev	-	0.0085*	0.0085*	0.0163***	0.0134***	0.0123***	0.0255***
	-	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
PPE	-	0.1334***	0.1334***	0.0723***	0.1288***	0.1205***	0.0716***
	-	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Cash	-	0.1859***	0.1859***	0.0907***	0.1749***	0.2690***	0.1035***
	-	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]
Q	-	0.0107***	0.0107***	0.0045*	0.0091***	0.0102***	0.0041*
	-	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
MTB	-	-0.0716***	-0.0716***	-0.0355***	-0.0760***	-0.0632***	-0.0433***
	-	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]	[0.00]
Constant	10.1987***	7.4115***	7.4115***	2.5120***	6.7495***	9.6029***	4.9181***
	[0.12]	[0.16]	[0.16]	[0.17]	[0.22]	[0.18]	[0.26]
Model	POLS	POLS	POLS	Sector	Country	Time	3-Way FE
Sample	Full	Full	Full	Full	Full	Full	Full
Obs.	16,660	16,660	16,660	16,660	16,660	16,660	16,660
R2	0.14	0.28	0.28	0.51	0.34	0.33	0.55
R2 adj.	0.14	0.28	0.28	0.50	0.34	0.33	0.55
R2 adj. (within)	0.14	0.28	0.28	0.07	0.26	0.32	0.07
Log-likelihood	-32490.94	-30975.13	-30975.13	-27854.83	-30252.57	-30385.42	-26977.17
F-Stat.	2804.11	637.45	637.45	116.16	561.14	814.93	112.69

Note: Robust standard errors in brackets. Variable descriptions see table 3. The Pooled Ordinary Least Square (POLS) Models in column 1, 2, 4, and 5 ignores the panel structure of the data, meaning it does not account for the three fixed effects (Wooldridge, 2010).

Next, table 6 shows estimation results of the regression of GHG emission intensity against the explanatory variables, introducing the board governance (BG) as direct independent and indirect variable in the interaction form. As standalone variable, BG is associated with lower GHG emission intensity for all specifications. Introducing the interaction term ERP x BG in column 4-6 documents that there is an additional significant positive effect. The overall marginal effect of ERP and BG remains negative, even at the maximum observed values of both variables. On the economic and significance of BG and ERP, column 6 supports a range that fits the results for both.

Table 6: Three-way fixed-effects regression of GHG intensity against ERP, and Board Governance (Hypothesis 2)

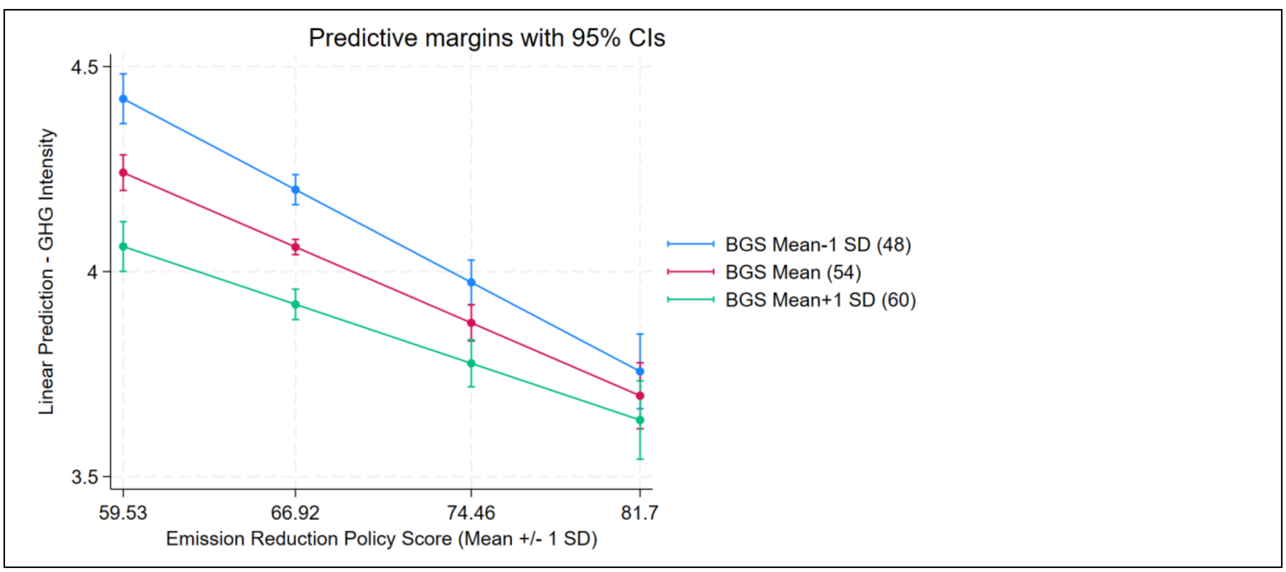
DV: GHG Intensity	(1)	(2)	(3)	(4)	(5)	(6)
ERP	-0.0955***	-0.0767***	-0.0250***	-0.2567***	-0.1980***	-0.0746***
	[0.00]	[0.00]	[0.00]	[0.02]	[0.02]	[0.01]
BG	-0.0455***	-0.0576***	-0.0227***	-0.2450***	-0.2075***	-0.0846***
	[0.00]	[0.00]	[0.00]	[0.02]	[0.02]	[0.02]
ERP # BG	-	-	-	0.0030***	0.0022***	0.0009***
	-	-	-	[0.00]	[0.00]	[0.00]
Constant	12.9394***	9.3859***	6.2449***	23.7428***	17.5466***	9.5878***
	[0.18]	[0.18]	[0.30]	[1.18]	[1.09]	[0.99]
Model	POLS	POLS	3-Way FE	POLS	POLS	3-Way FE
Controls	No	Yes	Yes	No	Yes	Yes
Sample	Full	Full	Full	Full	Full	Full
Obs.	16,660	16,660	16,660	16,660	16,660	16,660
R2	0.16	0.31	0.56	0.16	0.31	0.56
R2 adj.	0.16	0.31	0.55	0.16	0.31	0.56
R2 adj. (within)	0.16	0.31	0.08	0.16	0.31	0.08
Log-likelihood	-32277.58	-30651.79	-26944.52	-32236.43	-30623.63	-26937.64
F-Stat.	1564.24	643.94	111.91	1096.01	584.12	100.52

Note: Robust standard errors in brackets. Variable descriptions see table 3. All controls are statistically significant at the 1%-level and positive, except MTB which is significant and negative associated with GHG Intensity.

(Controls) Among the fundamental control variables in table 4 (H1) and table 5 (H2), market-to-book (MTB) is consistently negatively associated with GHG intensity. Leverage, and tangible assets (PPE) are positively related to GHG intensity. On PPE, the high concentration of emission-intensive technologies in the input structure of the analyzed industries explains this well. In addition, there is some evidence confirming the relationship between MTB, leverage and GHG intensity in H1 and H2. Bui (2020) shows that GHG intensity is positively correlated with cost of capital, since investors tend to incorporate GHG emissions in the risk assessment of firms. Higher cost of capital might therefore lead to lower MTB, which in turn must be compensated with higher leverage to pay for capital (PPE) and bearing interest. Furthermore, Cormier et al. (1993) documents that better emission records increase market valuation and attributes this to potential liability which firms with poor emission records face. In a similar vein, Sharfman and Fernando (2008) found that firms with risky environmental management strategies are facing more expensive debt and higher cost of capital, due to the risk of environmental penalties.

Figure 4 illustrates the predictive margins of the relationship between ERP, BG, and GHG emission intensity, including 95% confidence intervals (CIs). It can be stated that there is a clear reduction in GHG emission intensity with increasing levels of ERP for firms across all levels of BG. There are two notable insights. First, higher BG levels are associated with lower baseline emissions, which highlights the direct positive association between BG and GHG performance. Second, increasing BG levels decreases the marginal effect of ERP on emission intensity (see positive coefficient of the interaction term in table 6, column 6). Thus, firms with weak board governance benefit from ERPs to a greater extent, which is contrary to the hypothesis, that strong governance supports the ERP-GHG nexus. From an economic perspective this may be explained by the dynamic and non-linear interaction of BG on GHG intensity. In other words, firms with greater levels of BG already start with lower baseline emissions, which means that making further reductions are less likely to succeed. From a statistical perspective, it can be stated that the statistical significance (based on the 95%-CI) is diminishing with higher ERP levels as CIs are overlapping. While for lower ERP levels, the BG level matters significantly, there is no statistically significant relationship between BG and GHG intensity at high levels of ERP. This raises concerns that the identified effect is driven by the correlation between the ERP and BG, as might be the case if all firms with high BG measures also had high ERP measures. The likelihood-ratio test (LRT) confirms, that adding squared terms of ERP and BG to the model fits significantly better than the model containing only the linear term, which motivates to a deeper analysis of BG – especially taking its left-skewed distribution of BG into account.[13]

Figure 4: Predictive margins with 95% confidence intervals (CIs)



Note: Based on estimation results from column (6), table 6.

(Differentiating marginal effects between ERP and BG on GHG) First, to confirm the within dynamics between ERP and BG, the sample is divided in 2x2 ERP-BG sub-samples for pairwise correlations (table 7) to test if the relationship remains the same. Correlations are identified for <ERP median and <BG mean, and vice versa with changing direction of correlation from negative to positive. In addition, running H2 again after splitting the sample in the four quadrants from table 7 documents an insignificant coefficients (ERP x BG) for the sub-samples with low BG levels (not shown in the paper to save space).

[13] Around 15% of the data sample ranges between BG values of 60 (mean+1 SD) and the 81 (maximum value).

Table 7: Pairwise correlation

	<ERP mean	>ERP mean
<BG mean	0.0477** (3,483)	-0.0144 (4,988)
>BG mean	-0.00883 (5,810)	-0.0856*** (2,650)

* p < 0.05, ** p < 0.01, *** p < 0.001. Mean values for BG (ERP) are based on countries (sectors) according to the LSEG (2023) data processing and calculations.

Following Albitar et al. (2022), the empirical identification has been slightly adjusted to transfer BG to a dummy variable to assess the different effect between low and high BG levels. Concretely, this step is justified by the following two reasons: First, there is a non-linearity relationship between ERP, BG, and GHG intensity, where a categorical variable captures this effect. This is accompanied by a likely threshold effect of the variables of interest. Second, categorizing the BG variable makes it more robust to outliers, as the dummy is less sensitive to extreme values. Table 8 shows the main findings. First, column 4 documents that without the moderating model (interaction term), the ERP variable and BG dummy variable respectively are significant at the 1%-level. Second, column 5 documents, that the BG dummy variable turns insignificant, whereas the interacting effect (-0.0069**) is significant at the 5%-level. Interpreting column 4 and column 5 combined, it speaks largely for a "mediation" effect as shown by Hu et al. (2017).

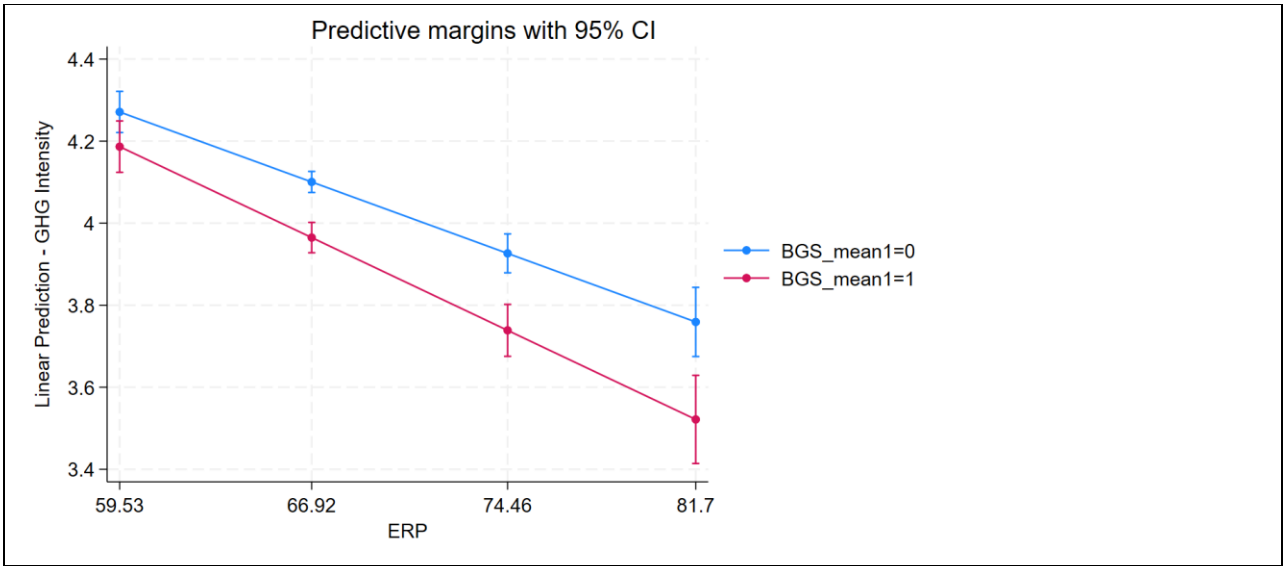
Table 8: Three-way fixed-effects regression of GHG intensity against ERP, and BG mean (Hypothesis 2)

DV: GHG Intensity	(1)	(2)	(3)	(4)	(5)
ERP	-0.0997***	-0.0992***	-0.0779***	-0.0249***	-0.0231***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
BG mean	-0.7264***	-0.6051**	0.0319	-0.1318***	0.3250
	[0.03]	[0.26]	[0.25]	[0.03]	[0.21]
BG mean # ERP	-	-0.0018	-0.0092**	-	-0.0069**
	-	[0.00]	[0.00]	-	[0.00]
Constant	10.9884***	10.9509***	8.0450***	5.0219***	4.9030***
	[0.12]	[0.14]	[0.19]	[0.26]	[0.27]
Model	POLS	POLS	POLS	3-Way FE	3-Way FE
Controls	No	No	Yes	Yes	Yes
Sample	Full	Full	Full	Full	Full
Obs.	16,660	16,660	16,660	16,660	16,660
R2	0.17	0.17	0.30	0.56	0.56
R2 adj.	0.17	0.17	0.30	0.55	0.55
R2 adj. (within)	0.17	0.17	0.30	0.08	0.08
Log-likelihood	-32144.71	-32144.60	-30716.02	-26963.25	-26960.60
F-Stat.	1732.19	1152.84	563.80	103.94	93.17

Note: Robust standard errors in brackets. Variable descriptions see table 3. No controls shown.

On the economic significance, column 5 in table 8 documents that a 1 unit increase in ERP is associated with a reduction of 2.31% in GHG emission intensity. The additional effect of ERP for firms belonging to BG above is 0.69%, which adds 30% (0.69/2.23) to the ERP and shows substantive emission reduction range of 22.17% [(2.31+0.69) *. 7.39=22.17]. Figure 5 illustrates the hypothesized moderating effect clearly, and strengthens the hypothesis that ERPs are specifically in good governance regimes associated with better GHG intensity and confirms H2.

Figure 5: Predictive margins for ERP x BG mean with 95% confidence intervals (CIs)



Note: Based on estimation results from column (5), table 8.

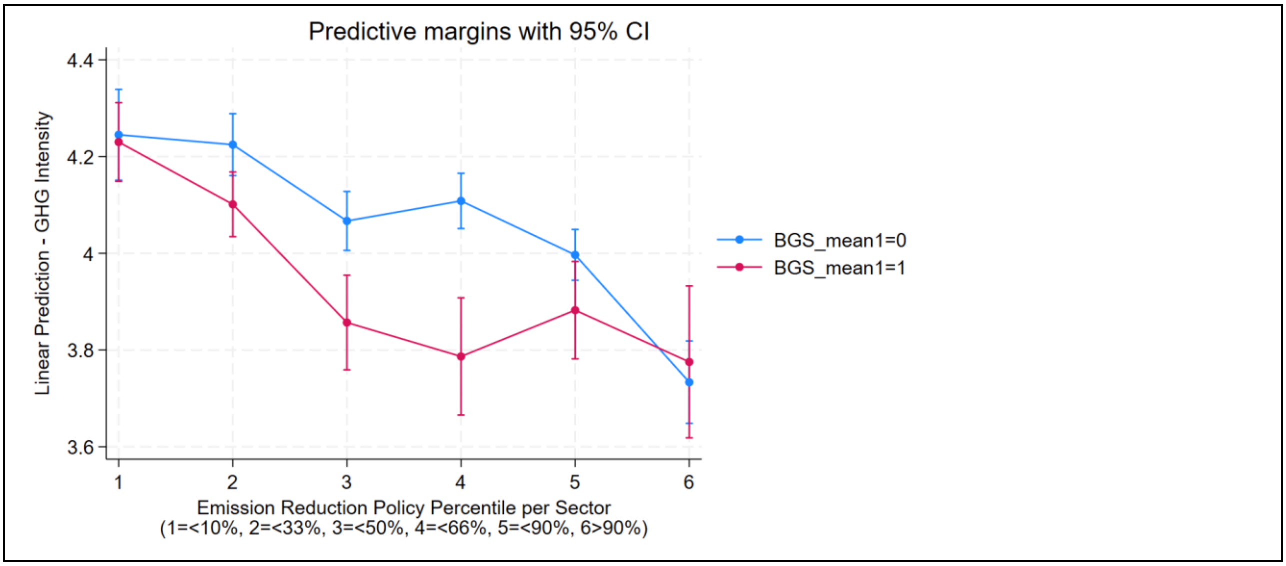
Finally, the ERP value also has been grouped to allow for more granular analysis on the marginal moderating effects. ERP factor categories with firms belonging to percentile groups within their sectors below 10%, 33%, 50%, 66%, 90%, and above 90% are established. BG remains separated by its mean value. Estimations with ERP percentile groups (*ERP factor*), BG mean, and five interaction effects for all ERP factors (ERP factor x BG mean) are documented in table 9. Three insights indurate the findings. First, the higher the ERP group, the higher the incremental effect on GHG intensity, compared to the reference group (ERP percentile below 10) for both, high and low BG firms. Second, same as in table 8, column BG mean is not statistically associated with GHG intensity (except for column 3, at the 10%-level). There is no statistical direct effect of BG that firms belong to above BG mean value matters on GHG intensity. Third, and of most interest, the association between ERP percentile groups and GHG intensity is sensitive to BG dummy. Mostly, the higher the ERP percentile group, the larger the coefficient of the interaction term, which largely demonstrates the moderating role of BG on the ERP-GHG nexus. This replicates basically the same result in table 6, that BG matters for lower levels of ERP but not at higher levels of ERP. The specification captures the BG moderation effect clearly at the lower levels, and explain the previous two conflicting results in table 6 and 8. In addition, the effect is not driven by large emitting (table 9, column 3) or big firms (table 9, column). The impact of BG on the effectiveness of ERPs on GHG Intensity is vanished for firms at the upper ERP percentile group. This is majorly driven by the large marginal effect firms belonging low BG group.

Table 9: Three-way fixed-effects regression of GHG intensity against ERP percentile factor groups, and BG mean (Hypothesis 2)

DV: GHG Intensity	(1)	(2)	(3)	(4)
ERP_factor=2	0.0185	-0.0204	-0.0374	-0.0699
	[0.06]	[0.06]	[0.06]	[0.06]
ERP_factor=3	-0.1712***	-0.1782***	-0.1637***	-0.1575**
	[0.06]	[0.06]	[0.06]	[0.07]
ERP_factor=4	-0.1416**	-0.1367**	-0.0749	-0.1230*
	[0.06]	[0.06]	[0.06]	[0.07]
ERP_factor=5	-0.2653***	-0.2482***	-0.2038***	-0.2910***
	[0.06]	[0.06]	[0.07]	[0.07]
ERP_factor=6	-0.5176***	-0.5115***	-0.4797***	-0.5593***
	[0.07]	[0.07]	[0.08]	[0.09]
BG mean	0.0116	-0.0149	0.1202*	-0.0129
	[0.06]	[0.06]	[0.07]	[0.07]
ERP_factor=2 x BG mean	-0.1624**	-0.1085	-0.1644**	-0.1215
	[0.07]	[0.07]	[0.08]	[0.09]
ERP_factor=3 x BG mean	-0.2541***	-0.1951**	-0.1242	-0.2787***
	[0.09]	[0.08]	[0.09]	[0.11]
ERP_factor=4 x BG mean	-0.3323***	-0.3067***	-0.3205***	-0.4056***
	[0.09]	[0.09]	[0.11]	[0.11]
ERP_factor=5 x BG mean	-0.1079	-0.0995	-0.1631*	0.0447
	[0.09]	[0.09]	[0.09]	[0.10]
ERP_factor=6 x BG mean	0.0336	0.0568	0.0136	0.0350
	[0.11]	[0.11]	[0.12]	[0.13]
Constant	4.2410***	3.5097***	5.3029***	5.0202***
	[0.05]	[0.18]	[0.22]	[0.37]
Model	3-Way FE	3-Way FE	3-Way FE	3-Way FE
Sample	Full	Full	Big firms	GHG dependent firms
Controls	No	Yes	Yes	Yes
Obs.	16,660	16,660	8,330	8,328
R2	0.52	0.56	0.48	0.59
R2 adj.	0.52	0.56	0.48	0.59
R2 adj. (within)	0.01	0.08	0.04	0.11
Log-likelihood	-27529.40	-26936.59	-11356.29	-12949.18
F-Stat.	15.41	52.89	16.28	42.37

Note: Robust standard errors in brackets. Variable descriptions see table 3. Column 3, and 4, focusses only on “Big firms” (above p50 firm size) and “GHG depending firms” (above p50 firm size). Controls are not shown.

Figure 6: Predictive margins for ERP factor groups by BG mean with 95% confidence intervals (CIs)



Note: Based on estimation results from column (2), table 9.

5.1. Robustness

Several robustness tests are applied to verify the assessed results. First, a one-period lead of the dependent variable is used (table 10, column 1). Second, the dependent variable is replaced by Scope 1 (column 2). Third, the dependent variable is not expressed as natural logarithm (column 3). Forth, the sample is limited to big and small firms respectively (column 4, 5). Fifth, the sample is limited to high and low GHG dependent firms respectively (column 6, 7). While the robustness specifications are generally in line with the hypnotized H2, the statistical significance levels is much lower compared to the baseline results. In the specification 1 and 3, with the lead GHG intensity by one period and the GHG intensity as non-logarithmic units, only the interaction effect of one ERP percentile group with BG mean appears significant. For column 2 (using Scope 1 emissions only) two percentile group interaction terms are reproducing the baseline effects. On the sample splits (firm size in column 4 and 5, and GHG dependency in column 6 and 7), the effect is most pronounced for big firms and high GHG dependent firms.

Table 10: Robustness test – Three-way fixed-effects regression of GHG intensity against ERP, and Board Governance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ERP factor=2	-0.0304	-0.0099	-101.9560*	-0.0676	0.0363	-0.0358	-0.0081
	[0.07]	[0.06]	[60.22]	[0.06]	[0.11]	[0.06]	[0.05]
ERP factor=3	-0.2183***	-0.271***	-185.023***	-0.1536**	-0.1923*	-0.1548**	-0.0499
	[0.07]	[0.07]	[64.05]	[0.07]	[0.10]	[0.06]	[0.05]
ERP factor=4	-0.2126***	-0.197***	-166.1630**	-0.1146	-0.1997**	-0.0708	-0.0763
	[0.07]	[0.07]	[68.15]	[0.07]	[0.10]	[0.06]	[0.05]
ERP factor=5	-0.3484***	-0.404***	-209.642***	-0.2822***	-0.2480**	-0.1922***	-0.1195**
	[0.07]	[0.07]	[66.51]	[0.07]	[0.10]	[0.07]	[0.05]
ERP factor=6	-0.5928***	-0.739***	-372.100***	-0.5551***	-0.5088***	-0.4586***	-0.1393**
	[0.08]	[0.08]	[68.84]	[0.09]	[0.11]	[0.08]	[0.06]
BG mean	-0.0672	0.0829	80.2524	-0.0048	0.1105	0.1194*	-0.1018**
	[0.09]	[0.07]	[62.35]	[0.07]	[0.12]	[0.07]	[0.05]
ERP factor=2 x BG mean	-0.1219	-0.1580**	-51.9913	-0.1260	-0.1790	-0.1600**	0.0158
	[0.10]	[0.08]	[64.50]	[0.09]	[0.12]	[0.08]	[0.06]
ERP factor=3 x BG mean	-0.1077	-0.1327	-47.8003	-0.2857***	-0.1974	-0.1270	-0.0598
	[0.11]	[0.09]	[70.71]	[0.11]	[0.13]	[0.09]	[0.07]
ERP factor=4 x BG mean	-0.3474***	-0.319***	-135.6758	-0.4185***	-0.1117	-0.3215***	0.0210
	[0.12]	[0.11]	[96.10]	[0.11]	[0.16]	[0.11]	[0.07]
ERP factor=5 x BG mean	0.0486	-0.1249	-174.7532**	0.0360	-0.5294***	-0.1638*	-0.0129
	[0.11]	[0.10]	[82.67]	[0.10]	[0.17]	[0.09]	[0.07]
ERP factor=6 x BG mean	0.1500	0.1142	-117.6004	0.0422	0.2695	0.0137	-0.0091
	[0.13]	[0.13]	[85.60]	[0.13]	[0.24]	[0.12]	[0.10]
Constant	4.0936***	1.9266***	770.7550***	5.1801***	2.7854***	5.4686***	2.4475***
	[0.22]	[0.20]	[133.28]	[0.37]	[0.34]	[0.22]	[0.16]
Model	3-Way FE	3-Way FE	3-Way FE	3-Way FE	3-Way FE	3-Way FE	3-Way FE
Sample	Lead DV	Scope 1	No log	Big firms	Small firms	High GHG	Low GHG
Obs.	12405.00	16660.00	16660.00	8329.00	8330.00	8330.00	8330.00
x FE	3.00	3.00	3.00	3.00	3.00	3.00	3.00
R2	0.56	0.59	0.30	0.59	0.56	0.49	0.25
R2 adj.	0.56	0.59	0.29	0.59	0.56	0.48	0.24
R2 adj. (within)	0.08	0.07	0.01	0.11	0.08	0.04	0.05
Log-likelihood	-19979.41	-29186.29	-137133.80	-12952.71	-13519.42	-11332.44	-9310.63
F-Stat.	43.29	51.13	13.55	42.42	31.42	18.64	23.45

Note: Robust standard errors in brackets. Variable descriptions see table 3. No controls shown.

6. Discussion

This research examined how emission reduction policies (ERP) influence GHG emission intensity. The analysis is based on three-way fixed effects regressions of 16,660 firm-year observations between 2011 and 2022 from 29 emerging and developed countries. The findings suggest that higher levels of ERPs have a statistical and economic association with decreased GHG intensity. The identified rrsults of the ERP-GHG nexus are consistent with previous studies that indicate the effectiveness of implementing ERPs in mitigating GHG emissions (Haque et al., 2022; Qian et al., 2017). The ERP-GHG nexus has been further investigated by adding board governance into the same analytical framework. While already few studies show that bard experience and gender diversity is mediating and moderating the ERP-GHG nexus, this study conceptualizes board governance by maintaining effective board functions. Findings largely confirm that board governance moderates the effect of ERP on GHG intensity, and the results reveal, that the linear association between symbolic emission reduction policies and GHG reductions is more severe for firms with higher board governance compared to their peers. Approaching at the final answer to the research questions required a translation of the linear data in factor groups following a more flexible specification of the board governance. The empirical results revealed a complex non-linear moderating effect which are in line with crucial parts of the neo-institutional theory (NIT). Thus, board governance is significantly influencing the effectiveness of ERPs, and thus, “good governance“ may moderate the impact of ERPs on emission reductions through board policies in compliance, transparency and accountability. This implies that firms operating under a “good governance” regime are less prone to pure symbolic announcements, without “walking-the-talk”. The results provided in this study may pave the way for policy makers and regulators to explore new ways beyond disclosure-oriented regulations. For instance, as outlined in the "Green New Deal", policy packages that enforce ERPs can play a crucial role in the achievement of global climate goals. Especially, as some evidence highlights that emission trajectories are determined by symbolic initiatives, the introduction of reporting requirements of e.g., mandatory transition plans (as a specific type of emission reduction policy), would make firms which do not walking the talk, more vulnerable to reputational and compliance risks. From a reliability of ESG data point perspective, the findings confirms that the ESG score is a valid measure for the investment community for navigation, aggregation, and benchmarking with the aim to support emission reductions in the near future. The identified non-linear relationships between BG, ERP, and GHG intensity requires further research, which is underscored by rather weak robustness of the baseline results. A more granular analysis should take place for specific sectors to stress the identified anomalies to produce robust results in further enhance the understanding of how firm level policies interact in reducing emissions substantively. Specifically, firm characteristics (size of the firm, or GHG dependency) and climate outcomes are not yet deeply studied and accounted for ideocratic sector characteristics. For instance, firms with particularly high ERP are more likely to operate in “hard-to-abate” sectors (e.g., cement, steel, chemicals), so that emission reductions would not occur even in the presence of strong corporate governance structure. Finally, the time horizon of ERPs may be better captured, as the impact of ERPs on GHG emissions may being assessed prematurely, while firms expect substantial reductions in the medium to long term.

7. Literature

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8. Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation othis work the aused ChatGPT (PT4), and Copilot in order to efficiently and refine text. After using theses tools, the author reviewed and edited the contet as needed and takes full responsibility for the content of the publication.

9. Annex

Table 11: 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, loan, 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 busineses that produce and provide goods and services aimed at personal care, household necessities, and lifestyle enchancement.
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 12: Examples of Emission Reduction Policies

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).