The EU carbon pricing policy:

Impacts on the ESG and financial performance of German industrial firms

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Abstract:

As climate change continues to pose a serious threat to humanity, urgent action is required to tackle this global challenge. The European Union Emissions Trading System (EU ETS), established in 2005, is a carbon pricing policy aimed at reducing greenhouse gas emissions in emission-intensive sectors within the EU, including manufacturing. This study examines how external pressures, particularly regulatory mechanisms, shape organizational behavior and encourage the adoption of socially valued practices. Specifically, it focuses on the role of formal institutions, such as the EU ETS, in influencing firms' ESG and financial performance. Furthermore, the study investigates the connections between regulations, ESG, and economic outcomes.

The quantitative analysis is based on panel data from 108 German manufacturing firms from 2018 to 2023 and employs a fixed-effects multiple regression model. The results show significant relationships, with three findings differing from expectations. Utilizing institutional theory as a framework, the study suggests that carbon pricing policies can have a positive effect on ESG and environmental performance. At the same time, the findings reveal negative associations between carbon pricing policies and financial performance, as well as between ESG performance and financial outcomes. Finally, the study identifies ESG and environmental performance as full mediators in the relationship between carbon pricing policies and financial performance.

This study contributes to the existing literature by offering novel insights into how the EU ETS impacts both environmental and economic performance of German manufacturing firms, particularly during the later stages of the policy. The findings affirm the positive effect of carbon pricing on sustainability goals, while also reflecting short-term financial trade-offs. Ultimately, this research emphasizes the role of institutions in guiding corporate behavior toward more environmentally sustainable practices that support international climate objectives.

Keywords:

Institutional theory; ESG; CSR; EU ETS; Carbon pricing; Environmental regulations; Environmental performance; Financial performance.

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1 INTRODUCTION

One of humanity's greatest challenges today is the escalating threat of climate change. Carbon dioxide (CO_2) emissions have increased drastically in recent decades, primarily driven by anthropogenic activities such as industrialization and globalization (Solomon et al., 2009). The consequences are wide-ranging, including extreme weather conditions, more frequent natural disasters, and growing health risks (Solomon et al., 2009). Economic growth over the years has led to an increasing demand for energy and the depletion of the Earth's natural resources (Adebayo et al., 2023). In particular, the expansion of the manufacturing sector has significantly contributed to the rise in CO_2 emissions, among others (Adebayo et al., 2023; Ullah et al., 2022). For instance, extracting natural resources accounts for about 82% of global energy use and contributes to 51% of worldwide CO_2 emissions (Khan et al., 2020). To combat climate change, the core strategy lies in reducing greenhouse gas (GHG) emissions, which can only be achieved by effectively managing and cutting down CO_2 output (Adebayo et al., 2023).

The United Nations' Sustainable Development Goal (SDG) 13 focuses on climate action and highlights the necessity of addressing climate change and its escalating impacts (United Nations, n.d.-a). On a global scale, major international agreements have laid the groundwork for climate action since the late 20th century (Bel & Joseph, 2015, p. 531). The Kyoto Protocol set binding emission reduction targets for developed countries, while the Paris Agreement aims for net-zero emissions by 2050 (Mor et al., 2023). Building on these agreements, climate policies such as carbon taxes and carbon emissions trading systems have been introduced to address rising CO_2 output (Stavins, 2022). These are collectively known as carbon pricing policies, which serve as essential tools to incentivize emission reductions by assigning a cost to emissions (European Commission, n.d.-c).

The European Union (EU) has implemented its carbon pricing policy at the continental level. In 2005, the EU officially introduced the European Union Emissions Trading System (EU ETS) to cut GHG emissions within the EU member states and the European Free Trade Association countries (Iceland, Norway, and Liechtenstein) (European Commission, n.d.-d). The EU ETS is the world's first and largest carbon trading market and covers industries such as energy, manufacturing, aviation, and maritime transport (European Commission, n.d.-d). It operates on a "cap and trade" principle, whereby the European Commission (EC) establishes a limit on total emissions that decreases over time, which reduces the number of available allowances (European Commission, n.d.-e).

These allowances are called European Union Allowance (EUA), which are sold through auctions and can be traded on the market (Nasdaq, n.d.). The EUA price can indicate how effective the carbon trading market is in lowering GHG emissions (Bel & Joseph, 2015; Narassimhan et al., 2018; Shi et al., 2022).

These mandatory regulatory frameworks, such as the EU ETS, have substantial implications for businesses, specifically in carbon-intensive sectors, as they influence strategic decisions, operational costs, and long-term competitiveness (Longaric et al., 2024; Löschel et al., 2019). Therefore, understanding how firms respond to these regulatory pressures is essential for assessing environmental impacts and broader implications for corporate behavior, including economic outcomes.

1.1 Problem discussion and research questions

Institutional theory offers a valuable perspective for analyzing how external forces, e.g., regulations, norms, and market expectations, influence corporate behavior (Dimaggio & Powell, 1983; Scott, 2013). Environmental regulations like the EU ETS act as coercive institutional pressures, which enforce organizations to follow practices that align with societal and governmental expectations (Dimaggio & Powell, 1983; Koch & Basse Mama, 2019; Lei & Yu, 2024). The EU ETS, as a formal regulatory framework, mandates compliance through market-based mechanisms, by placing a price on CO_2 emissions in carbon-intensive sectors (Koch & Basse Mama, 2019). Regulated companies are therefore incentivized to reduce emissions and improve their sustainability practices to avoid costs as well as to maintain their legitimacy (Berrone et al., 2013; Deephouse, 1996; Scott, 2013).

Recent evidence suggests that firms react to institutional pressures, i.e., environmental regulations, by ensuring compliance and thus investing in sustainable innovations or practices (Lei & Yu, 2024). Numerous studies have consistently found a significant correlation between carbon pricing policies and climate innovation, particularly in low-carbon technologies (Cantone et al., 2023; Cui et al., 2018; Lim & Prakash, 2023). This supports the idea that, as formal institutions, environmental policies can effectively encourage environmental advancements by providing businesses with the necessary "nudge" (Lim & Prakash, 2023; Sunstein, 2014). According to traditional economic theory, regulated firms must allocate resources to comply with these regulations, which can tie up productive inputs and potentially reduce a firm's overall efficiency (Ellerman et al., 2010; Löschel et al., 2019). Nonetheless, another line of research inquiry notes that environmental regulations create incentives for companies to innovate, which in turn, improves their financial performance and efficiency (Porter & Van Der Linde, 1995).

Moreover, as the risks from climate change and the resulting environmental pollution continue to grow, people and organizations worldwide have become more aware of the importance of environmental, social, and governance (ESG) (Baker et al., 2022; Edmans, 2023a, 2023b; Tsang et al., 2023). Existing research recognizes the critical role played by ESG practices in achieving SDG goals, particularly environmental goals like SDG 13 (Lei & Yu, 2024). Green financial policies have been found to enhance corporate ESG development in China significantly, while the positive effect was more noticeable for firms with higher external pressures (Lei & Yu, 2024). Another relevant stream of research conducted in Asia has provided similar evidence, demonstrating that carbon trading schemes can positively affect enterprise ESG performance (Zhang et al., 2023). Other scholars, such as Adamolekun (2024) have shown a significant negative relationship between carbon pricing policies and firm-level GHG emissions, which indicates that higher carbon prices incentivize firms to reduce their emissions. Collectively, these findings highlight the effectiveness of carbon pricing policies as a tool for lowering GHG emissions as well as improving corporate ESG and financial performance (Adamolekun, 2024; Lei & Yu, 2024; Zhang et al., 2023).

Although extensive research has been carried out on the impact of carbon pricing policies on the aspects mentioned, there remains a lack of understanding regarding the interplay between these regulations, ESG performance, and economic outcomes. Previous studies on the relationship between ESG and financial performance present inconsistent findings, with mixed views concerning their impact (Bifulco et al., 2023; Boulhaga et al., 2023; Brogi & Lagasio, 2019; Teti et al., 2022). Moreover, research on the mediating role of ESG performance remains limited, with most existing studies focusing on financial performance or innovation as intermediaries (Zeng et al., 2023; G. Zhou et al., 2022). Building on institutional theory, this study seeks to explain the relationship between these three aspects, with a particular focus on the case of the EU ETS. This research focuses on Germany, the largest economy and the largest emitter of GHG in the EU (Löschel et al., 2019; Wagner et al., 2014). Around 1.730 stationary installations of the EU ETS are based in Germany, which emitted approximately 289 million tonnes of carbon dioxide in 2023. This represents about one-fifth of all regulated CO_2 emissions under the EU ETS (Umweltbundesamt, 2024; Wagner et al., 2014).

Consequently, Germany’s large and influential manufacturing industries are major contributors to GHG emissions. As a result, the country has committed to a long-term energy transition, known as “Energiewende”, focusing on renewable energy sources, energy efficiency, and energy demand management (Federal Ministry for Economic Affairs and Climate, 2015). In addition, Germany introduced its national carbon system in 2021 (Frondel & Schubert, 2021).

Existing research has examined the effects of the EU ETS on Germany’s efficiency, employment, gross output, and exports of regulated firms (Löschel et al., 2019; Wagner et al., 2014). However, little is known about the effect of carbon pricing policies on the ESG and economic performance of German manufacturing firms. Considering the size of Germany’s manufacturing sectors and its strong focus on export markets, the country presents a relevant and contemporary case for assessing whether unilateral regulations such as the EU ETS affect factors like competitiveness or ESG practices in international product markets (Löschel et al., 2019; Wagner et al., 2014). This study contributes to the existing literature by analyzing the impact of the EU ETS through the mediating effect of ESG performance on financial outcomes. The findings may offer insights and practical implications for other countries with similar industrial profiles.

For this research, the annual EUA price will serve as an indicator for carbon pricing policies, specifically the EU ETS in this context. The ESG score and the environmental pillar score derived from it will measure the ESG and environmental performance of corporate industry-based firms. The financial performance itself will be assessed with Tobin’s Q. Finally, the research questions (RQs) are as follows:

RQ 1: How do carbon pricing policies affect corporate ESG performance?

RQ 2: What is the relationship between a company’s ESG performance and its financial outcomes?

The first research question aims to identify if carbon pricing policies, particularly the EU ETS, have an impact on corporate ESG performance, which is measured by the annual ESG score. Moreover, this RQ also considers environmental performance, using the annual environmental pillar score. With that, it seeks to understand whether participation in carbon trading markets and the associated costs or savings influence a firm’s ESG and environmental performance negatively or positively. The second RQ examines the broader relationship between a firm’s ESG performance and its financial outcome. Overall, this RQ aims to assess how a company's ESG performance could be an indicator of its financial outcomes and if there is a correlation between these two aspects.

1.2 Purpose of the study

This study set out to assess the impact of the EU carbon pricing policy on a firm's ESG and financial performance. The primary objective of this research is to explain how external pressures, particularly regulatory mechanisms, shape organizational behavior and drive the adoption of socially valued practices. More specifically, the purpose is to investigate the role of formal institutions, namely carbon pricing policies, in influencing firms to enhance their ESG and environmental performance. In addition, this study explores the relationship between regulations, ESG performance, and financial outcomes to determine whether ESG performance mediates the link between carbon pricing policies and financial performance. By doing so, this research contributes to a deeper understanding of the effectiveness of regulatory pressures in shaping corporate behaviors and promoting sustainable practices.

1.3 Choice of methods and delimitations

For this empirical study, secondary panel data will be sourced from three databases (LSEG/Refinitiv Workspace, Bloomberg, and Orbis) to analyze the impacts of carbon pricing policies on a firm's ESG and financial performance. This approach could present potential limitations in terms of data availability and accuracy, as certain specific data from other databases may have been excluded. In addition, this influences the study's time frame, as not all variables have sufficient data coverage, which therefore limits the data to the years 2018-2023. Moreover, this research will focus on a single country, namely, Germany. Due to this limitation, the findings cannot be generalized to other countries, for instance, with different economic contexts. Furthermore, the study will target industry-based companies as the EU ETS primarily covers large-scale industrial installations. With this, other sectors are excluded, which may significantly contribute to GHG emissions as well. Lastly, for the scope of the study, the term "carbon pricing policies" or "carbon pricing" will refer to the European Union Allowance (EUA) price for CO_2 or CO_2 equivalent under the EU ETS. Therefore, other carbon emission policies or pricing mechanisms, such as national carbon taxes, will not be taken into account, which could also have an impact on a firm's ESG or financial performance.

1.4 Structure of the study

The overall structure of the study takes the form of five chapters. It will commence by exploring institutional theory, its concepts, and how they fit into the study's objective of environmental policies. Institutional theory will form the theoretical foundation for the context of the research. Next, climate change frameworks will be discussed, specifically the EU ETS and carbon pricing policies. In addition, corporate sustainability will be explored, with a particular focus on defining corporate social responsibility (CSR) and environmental, social, and governance (ESG). Based on this theoretical framework, the research hypotheses will be formulated, and the framework for the research will be presented and elaborated on.

Subsequently, the next section, Chapter 3, will address the study's methodology along with the research design and statistical methods employed. This empirical part will cover an overview of the data sources and the corresponding variables used in this research. The reliability and validity of the study, along with the data analysis technique, will be discussed in the final section of the methodological chapter. Moving on, the results chapter includes a comprehensive data analysis, starting with the descriptive statistics and the correlation matrix. The baseline regression model that is used for this research will be demonstrated and then applied to the hypothesis and mediation testing. The last section of the thesis, Chapter 5, concludes with a thorough discussion and review of the findings. The study's contributions and practical implications will be presented along with its limitations regarding the utilized methods. Finally, the thesis will close with possible directions for future research.

2 THEORETICAL FRAMEWORK

This chapter outlines the foundational background for the research. It begins with an overview of institutional theory and how it could relate to environmental regulations. Subsequently, the topic of climate change is introduced, and the study's focus on the EU ETS, alongside carbon pricing mechanisms, is discussed. Then, the concepts of CSR and ESG will be reviewed and linked to the research's objective. The chapter wraps up by developing the hypotheses based on the theoretical insights covered in earlier sections.

2.1 Institutional theory

Institutional theory is recognized as a dominant macro theory for understanding the relationships between organizations and their external environment (Aksom & Tymchenko, 2020; Greenwood et al., 2008; Scott, 2008). The literature distinguishes between the "old" institutionalism, developed in the late 19th century, and the "new" institutionalism, which emerged in the 1970s (Rutherford, 1995). Moreover, both schools acknowledge the significance of institutions, which were previously neglected in neoclassical economic theory (Rutherford, 1995, p. 443). Traditional institutionalism primarily focused on political structures and history, while modern institutionalism takes external influences and legitimacy into account (Aksom & Tymchenko, 2020; Greenwood et al., 2008). Due to the contemporary relevance, this chapter and the study will mainly concentrate on the new institutionalism when discussing institutional theory.

The new institutionalism, also referred to as neo-institutional theory, explains how social norms, expectations, and the need for approval shape organizational behaviors (Dimaggio & Powell, 1983; Scott, 1995, 2005). Based on the theory, the organization's external environment defines its institutional environment (Berger & Luckmann, 1966). North (1990a) states that institutional environments set the basic rules in society, which influence the interactions within and between individuals and organizations (p. 3). In addition, they minimize uncertainty by establishing a structured framework for everyday life (North, 1990b). These institutions can be defined as either informal or formal institutions (E. Lee, 2020; North, 1990b). Informal institutions include politics, traditions, and unwritten codes of behavior, such as social instruments and networks, while formal institutions can be regulations, policies, or laws (E. Lee, 2020; North, 1990b). According to E. Lee (2020), both formal and informal institutions shape the market demand and drive the dynamic changes that companies encounter.

In the management and business literature, neo-institutional theory explores the dynamic relationship between organizations and institutions and views strategic choices as a result of this interaction (Peng, 2003). According to Peng (2003), formal institutions, such as regulations and laws, shape corporate behavior by reducing differences among firms to encourage alignment with societal expectations. This occurs because companies often want to be seen as legitimate, and therefore adopt practices that are valued by society to maintain a good reputation (Berrone et al., 2013; Scott, 1995).

Moreover, Scott (2005) claims that the institutional environment has a strong impact on the actions of organizations and individuals. As a result, the likelihood of companies engaging in socially responsible behavior varies across countries due to the combined effect of economic and political systems, which shape how companies act (Campbell, 2007). Institutional theory links company practices, including ESG, to the cultural norms of society (Islam & Deegan, 2010). This means that companies are driven to take on, e.g., ESG initiatives to meet societal expectations, which leads to a trend where companies become more and more similar in their practices (Islam & Deegan, 2010; C. L. Lee & Liang, 2024). In the institutional theory literature, this process is also referred to as isomorphism (Deephouse, 1996; Dimaggio & Powell, 1983). According to Dimaggio and Powell (1983), individuals or organizations within the same institutional environment exchange, disseminate, adopt, or imitate common practices and behaviors. This happens through three isomorphic processes of change, which are known as coercive, mimetic, and normative (Dimaggio & Powell, 1983). Normative isomorphism is driven by social pressures, whereas mimetic isomorphism stems from typical responses to uncertainty. Coercive isomorphism arises from political influence and the need to maintain legitimacy (Dimaggio & Powell, 1983).

Unlike other theories that focus on profits, institutional theory does not primarily prioritize financial performance (Berrone & Gomez-Mejia, 2009). This makes it appealing to environmental management researchers because eco-friendly investments often lack immediate financial returns (Bansal, 2005; Bansal & Clelland, 2004; Hoffman, 1999, 2000). Research in this field has established that industries and companies respond to growing environmental expectations even without clear economic benefits (Delmas, 2002; Hoffman, 1999). For instance, Hoffman (1999) has researched chemical and petroleum industries from 1960 to 1993, and found out that they adapted to increasing pressure to improve their environmental initiatives without pre-defined financial benefits from making these changes. Moreover, Berrone et al. (2010) found that public family-owned businesses respond more strongly to environmental pressures and perform better in environmental practices than non-family firms, even though these actions also did not bring any financial gains to the company.

Furthermore, Scott (1995) identified three main institutional pillars that guide organizational behavior. These can be defined as either regulative (rules and penalties), normative (standards and values), or cognitive (cultural norms) (Scott, 1995). While the three pillars work simultaneously in all institutions, the regulative and normative dimensions are particularly influential in influencing environmental practices and actions (Scott, 1995). Studies revealed that regulatory pressures, which are imposed by government agencies as well as non-governmental organizations, play a major role in encouraging firms to innovate environmentally (Berrone et al., 2013; Scott, 1995, 2005). Regulatory authorities, such as governments, have the power to impose legal requirements on companies, and failure to comply can result in political risks such as increased government monitoring, stricter regulations, and financial penalties (Berrone et al., 2013, p. 893; Deephouse, 1996). Companies are therefore more motivated to comply when enforcement is strong and the risk of facing serious financial penalties is high (Berrone et al., 2013, p. 894).

Institutional theory views environmental regulations as outside forces that push organizations to act in certain ways (Dimaggio & Powell, 1983; Mandaroux et al., 2023; Scott, 2008). Rennings (2000) describes this phenomenon as a “regulatory pull-push effect”, which means regulations can drive organizations to change by either pushing them through threats of legal penalties or pulling them with incentives (Dosi et al., 1988; Mandaroux et al., 2023; Mowery & Rosenberg, 1979). Consequently, this pressure forces companies to follow current environmental laws and regulations (Mandaroux et al., 2023; Rennings, 2000). In addition, the anticipation of stricter future regulations drives firms to comply and innovate further (Mandaroux et al., 2023).

As a consequence, companies invest in environmental innovation, which develops new technologies to protect the environment and also meets regulatory demands (Berrone et al., 2013, p. 894). Unlike other eco-friendly measures that only appear good on the surface but lack real action, environmental innovation is a long-term, committed effort that can significantly reduce pollution (Berrone et al., 2013, p. 894). Although environmental innovation can help companies cut down emissions, it is often expensive and may not bring clear financial benefits (Markman et al., 2004). However, as previously stated, it not only boosts a company's reputation, but also helps avoid penalties for failing to meet regulations.

Stronger institutional pressures and social expectations encourage companies to adopt more sustainable practices and develop environmental innovations (Berrone et al., 2013, p. 891). These innovations are triggered particularly in companies that pollute more than their peers (Berrone et al., 2013, p. 891). This is likely due to their weaker reputation, which motivates them to invest in environmental innovation as a means to improve their image and regain credibility (Berrone et al., 2013). Similarly, recent findings indicate that government-led formal institutions in China have effectively promoted sustainable development, which ultimately led to improved corporate ESG performance (Lei & Yu, 2024). The results suggest that this impact was especially noticeable in companies facing greater external pressures, which is in line with the above-mentioned research of Berrone et al. (2013) (Lei & Yu, 2024).

Despite organizations acting socially responsible without clear financial benefits, previous research indicates that 93% of CEOs view sustainability as a significant aspect that can positively influence a company's prospective success (Brower & Dacin, 2020; Oikonomou et al., 2014). According to Orlitzky et al. (2003), companies adopt eco-friendly practices in their production due to economic incentives. By innovating products and processes, firms reduce the cost of compliance with environmental regulations while strengthening their competitiveness (E. Lee, 2020). Scholars of institutional theory therefore propose that environmental and social performance can provide early adopting firms with a competitive advantage and can also contribute to increased corporate financial performance (Brower & Dacin, 2020; Makridou et al., 2019; Orlitzky et al., 2003). As institutional norms and rules are established within an industry or organizational field, conforming to such rules enhances perceived accountability, lowers competitive risk, and improves the chances of long-term "survival" (Deephouse, 1999; Meyer & Rowan, 1977).

When organizations become more alike and follow similar practices, it becomes easier for them to interact with other organizations, attract talented employees, and gain recognition as trustworthy and legitimate (Dimaggio & Powell, 1983). Over time, as more organizations adopt a certain practice, it becomes more widely accepted and gains greater validity (Deephouse, 1996; Deephouse & Suchman, 2012). As a result, companies that align with institutional norms, instead of deviating from them, are more likely to face lower risks (Deephouse, 1999). Furthermore, research in the environmental literature suggests that shareholders are increasingly penalizing companies for harmful environmental actions (Flammer, 2012). For instance, investors are lowering their value of shares for firms with a high amount of emissions, which are seen as polluters (Berrone et al., 2013). In addition, governments have introduced climate policies that put a price on emissions, while customers take a company's environmental mission into account when choosing what to purchase (Berrone et al., 2013; Hart, 1995).

As a consequence, firms that are seen as environmentally responsible face fewer business risks compared to those that engage in damaging behavior (Bansal & Clelland, 2004). Moreover, failing to adopt corporate social performance in an industry where it is widely established can increase the risk of negative reactions from stakeholders. It may also be seen as a sign that the company is not progressive or lacks effective management, which causes investors, lenders, and potential donors to view the company as having a more uncertain and risky future (Meyer & Rowan, 1977).

Other scholars, for instance, Porter and Van Der Linde (1995) have investigated the relationship between environmental regulations and industrial competitiveness. The conventional thinking views it as a trade-off, where environmental goals are seen as an "economic burden on industry," which diminishes a company's competitiveness (Porter & Van Der Linde, 1995, p. 97). However, Porter and Van Der Linde (1995) argue that this perspective is outdated, as competitive companies are those that are dynamic and able to innovate constantly. According to their notion, competitive advantage results from a firm's capacity for innovation and continuous technical improvement (Porter & Van Der Linde, 1995). Such technical improvements could include, for instance, advanced pollution control technologies, more efficient production processes, or better resource utilization (Dai & He, 2025; Porter & Van Der Linde, 1995). With these advancements, firms can enhance the technological value of products whilst creating new market opportunities. For example, firms can appeal more to environmentally aware consumers by providing environmentally friendly products (Dai & He, 2025).

Therefore, firms should view environmental laws and regulations as competitive opportunities rather than a costly threat (Porter & Van Der Linde, 1995). By integrating sustainable strategies into general management, companies can measure environmental costs and benefit from increased resource productivity (Porter & Van Der Linde, 1995). Subsequently, companies can profit from these regulations, especially if they are implemented before their competitors and thus strengthen their overall competitiveness (Porter & Van Der Linde, 1995).

Considering all of this evidence, institutional theory suggests that institutions play a significant role in shaping how organizations behave, especially in terms of how they respond to external expectations around sustainability (Scott, 1995). The literature shows that organizations tend to align their practices with institutional norms to gain legitimacy and reduce uncertainty, which often leads to similar behaviors across industries through isomorphic processes (Dimaggio & Powell, 1983; Meyer & Rowan, 1977). While both formal and informal institutions influence corporate decision-making, formal rules such as regulations and laws are particularly effective in pushing companies to act on environmental issues (E. Lee, 2020; North, 1990a). These formal institutions can either penalize non-compliance or create incentives, and although financial benefits are not guaranteed, firms often respond to regulatory and reputational pressures (Delmas, 2002; Hoffman, 1999). Finally, by engaging in environmental innovation, companies can create new markets and achieve a significant competitive advantage (Dai & He, 2025; Porter & Van Der Linde, 1995).

Moving forward, the study will emphasize formal institutions, with a specific focus on environmental regulations and how they can influence firm behavior. In the following sections, climate change and carbon pricing policies, the EU ETS, as well as concepts like CSR and ESG, will be discussed to provide further context for how these institutional forces shape corporate sustainability practices.

2.2 Climate change and carbon pricing policies

This sub-chapter reviews the literature related to climate change and the resulting policies to mitigate the effects of this environmental challenge. Carbon pricing policies and the EU ETS are presented and discussed thereafter.

2.2.1 Global climate change frameworks

Over the past few decades, anthropogenic (human-induced) pollution has led to severe environmental damage (Adamolekun, 2024; Avagyan, 2021). To address this serious issue and ultimately combat climate change, reducing all GHG emissions, particularly CO_2, is inevitable to mitigate further ecological deterioration (Adebayo et al., 2023; Khattak & Ahmad, 2022; Zhan et al., 2021). As collective efforts are needed to tackle this challenge, the United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992 (United Nations, n.d.-b). The UNFCCC is a multilateral treaty that was adopted to sustain GHG emissions at a level that avoids dangerous anthropogenic interference with the climate (United Nations, n.d.-b). Since coming into force in 1994, it has provided the foundation for subsequent global climate negotiations (United Nations, n.d.-b). Today, 198 countries, along with the EU, are Parties to the UNFCCC (United Nations Framework Convention on Climate Change, n.d.-b). At the annual Conference of the Parties (COP), these countries come together to discuss and address the climate crisis (European Commission, n.d.-c).

The first major milestone of the international treaty at COP 3 is the adoption of the Kyoto Protocol in December 1997, which came into effect in February 2005. With 192 Parties to the Protocol, it legally binds 37 developed countries to reduce their emissions up to an average of 5% compared to 1990 levels over the period of 2008-2012 (Eurostat, 2023; Kuyper et al., 2018; United Nations Framework Convention on Climate Change, n.d.-c). To achieve these targets, the Kyoto Protocol introduced flexible market-based schemes centered on emission trading permits (United Nations Framework Convention on Climate Change, n.d.-a). Nonetheless, a common critique of the Kyoto Protocol is that it required only developed nations to reduce their emissions, however, large emitters like China and the United States had no binding targets.

In response to the limitations of the Kyoto Protocol, the Paris Agreement was adopted at COP 21 in December 2015 and entered into force less than a year later, in November 2016 (United Nations Framework Convention on Climate Change, n.d.-b). Unlike the Kyoto Protocol, the Paris Agreement is the first universal treaty that legally binds all UNFCCC Parties to actively contribute to emission reduction efforts (European Commission, n.d.-c). All Parties agreed to limit the increase of the global temperature to 2°C by 2100, with an ambition of 1.5°C above pre-industrial levels (European Commission, n.d.-c; United Nations Framework Convention on Climate Change, n.d.-b). To reach this climate target, emissions ought to be reduced by 43% until 2030 to ultimately achieve net zero by 2050 (United Nations, n.d.-a). While carbon neutrality primarily targets the removal and reduction of only CO_2, the concept of net zero has a broader approach and addresses all GHG emissions, such as methane (CH_4) and nitrous oxide (N_2O) (Nationalgrid, 2022).

2.2.1 Carbon pricing policies

To achieve the previously mentioned climate targets, governments have adopted carbon pricing policies. According to the World Bank, carbon pricing can be defined as “instruments the public pays for their GHG emissions and ties them to their sources through a price, usually in the form of a price on the carbon dioxide (CO_2) emitted” (Tham & Kang, 2022, p. 2; World Bank, n.d.). Implementing a carbon price helps shift the responsibility back to the GHG emission producers, who hold the power to achieve emissions reduction (Tham & Kang, 2022; World Bank, n.d.). The carbon price can serve as an economic signal that allows polluters to choose whether to continue their conventional activities and pay the associated costs, or to lower their emissions (World Bank, n.d.). With this, environmental targets can be achieved flexibly and cost-effectively (World Bank, n.d.).

There are several carbon pricing mechanisms, with two central types being carbon taxes or Emission Trading Systems (ETS) (World Bank, n.d.). A tax on carbon creates a direct price that affects an entire economy, which should motivate producers to invest in low-carbon technologies in the long run (United Nations Framework Convention on Climate Change, n.d.-a). An ETS is a cap-and-trade framework for GHG emissions, as it establishes a limit on the total emissions allowed (United Nations Framework Convention on Climate Change, n.d.-a).

Carbon trading schemes, which allow organizations to purchase and sell carbon allowances, have been expanding globally (Adamolekun, 2024). As reported by ICAP (2023), approximately one-third of the world is now covered by some kind of emission trading mechanism. Such carbon emission trading systems offer a market-driven method for managing and regulating environmental impact (Dai & He, 2025). Prior research in the literature has demonstrated that carbon pricing policies have varying effects on different outcomes, with notable differences observed across countries (Adamolekun, 2024; Avagyan, 2018). Market-based regulations such as carbon pricing schemes in the EU can lower carbon emissions significantly without causing substantial economic harm to regulated firms or industries (Colmer et al., 2024).

Other studies indicate that the existence of carbon pricing policies can accelerate national green transitions, as countries with these mechanisms tend to see higher investments in wind farms and solar energy (Best et al., 2020). For instance, research has shown that carbon emissions trading can incentivize firms in China to boost their R&D spending, resulting in accelerated development of renewable energy sources (Zhang et al., 2023). Recent studies on low-carbon city pilot programs suggest that carbon pricing policies can boost corporate ESG performance (W. Li & Pang, 2023). Additionally, carbon trading policies play a central role in increasing transparency by encouraging companies to disclose their carbon emissions more openly (Dai & He, 2025; W. Li & Pang, 2023). As a result, this leads to more precise and reliable reporting on carbon footprints and efficiency in corporate sustainability reports (Dai & He, 2025; W. Li & Pang, 2023).

2.2.2 European Union Emissions Trading System (EU ETS)

Among the two main carbon pricing mechanisms, Emission Trading Systems (ETS) have become increasingly prominent in the EU's climate policy. Building on the foundation established by the Kyoto Protocol for emissions trading schemes, the European Commission (EC) developed the design of the EU ETS in March 2000 (European Commission, n.d.-b). In 2005, the European Union Emissions Trading System (EU ETS) was officially launched to reduce GHG emissions in all member states of the EU, plus Iceland, Liechtenstein, and Norway (European Commission, n.d.). The EU ETS is the first carbon market in the world and the largest market-based regulatory mechanism designed to reduce GHG emissions in the EU (Bel & Joseph, 2015; European Commission, n.d.-e). The scheme regulates GHG emissions from about 10,000 installations and operators in the energy sector, manufacturing industry, aviation, and maritime transport (European Commission, n.d.-d).

The EU ETS is the biggest carbon exchange worldwide, covering approximately 40% of the EU's GHG emissions, which operates on the InterContinental Exchange (ICE) (Tham & Kang, 2022). It operates in trading phases, with the trial phase running from 2005-2007, the second phase from 2008-2012, the third phase from 2013-2020, and the current fourth phase spanning from 2021-2030 (European Commission, n.d.-b). Its core principle is "cap and trade", where the "cap" refers to the limit on the total amount of GHG emissions set by the EC. The cap is gradually reduced after each monitoring period, meaning that the supply of allowances to the EU carbon market also diminishes (European Commission, n.d.). This cap and trade system establishes a price on pollution, which theoretically aligns with the marginal cost of emission reductions based on the environmental goals set by policymakers (Genovese & Tvinnereim, 2019, p. 517).

The EU ETS cap is expressed in emission allowances called European Union Allowance (EUA), with each allowance granting the right to emit one tonne of CO_2 or CO_2 equivalent (CO_2 eq) (European Commission, n.d.-e; Nasdaq, n.d.). EUAs are sold through auctions and can be traded within the market. The proceeds from the auctions are allocated towards climate and energy projects, and so far, have been mostly utilized on renewable energy sources (European Commission, n.d.).

Implementing carbon trading markets has proven successful in reducing emissions, and a growing number of countries have adopted this approach to lower CO_2 emissions (Narassimhan et al., 2018; Shi et al., 2022). Despite the common belief that high carbon prices are essential for the EU ETS to function efficiently, previous research suggests otherwise (Bayer & Aklin, 2020). Even with low permit prices between 2008 and 2016, the EU ETS managed to successfully reduce emissions by approximately 1.2 billion tons compared to a scenario without it (Bayer & Aklin, 2020). This impact was specifically prominent in sectors that were directly regulated under the EU ETS (Bayer & Aklin, 2020).

Previous analyses demonstrated that the EU ETS has stimulated low-carbon innovation, which is shown by a rise in patents for environmentally friendly technologies (Cantone et al., 2023). Research on companies involved in the EU ETS reveals that energy efficiency is a key factor in enhancing a company's profitability and competitiveness (Makridou et al., 2019). In addition, reduced CO_2 emissions have also been shown to positively influence profitability, which highlights the beneficial impact of the EU ETS on a firm's financial performance (Makridou et al., 2019).

To conclude with Chapter 2.2., Figure 1 presents a chronological timeline of major developments in international climate change frameworks and the EU ETS. It provides a clear overview of the most important milestones in global climate mitigation efforts, which were covered and discussed in earlier sections of this sub-chapter. The green-filled boxes in the figure represent fundamental events at the international level, while the boxes filled in blue emphasize events specifically related to the EU ETS. If an event occurred at both levels in the same year, the box is split evenly between blue and green.

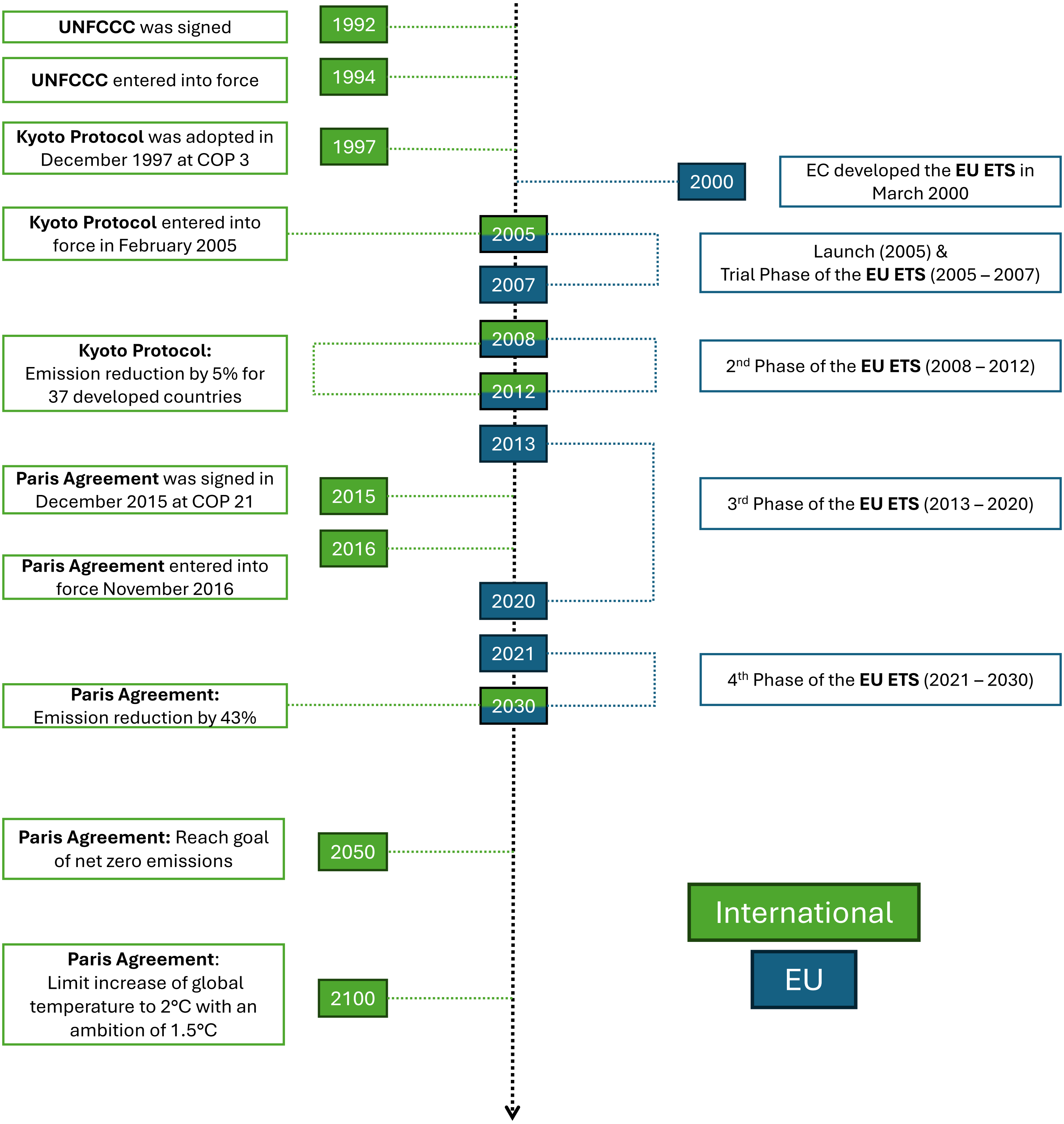

Figure 1 **Timeline of climate change policies and the EU ETS.**

2.3 Corporate sustainability performance

The section that follows discusses the concept of corporate social sustainability (CSR), which laid the groundwork for ESG (Environmental, Social, and Governance) and its following ESG ratings.

2.3.1 Corporate Social Responsibility (CSR)

The concept of corporate social responsibility (CSR) has a long history, with signs of businesses caring about society going back centuries (Carroll, 1999). However, formal writings on CSR mostly began in the 20th century, especially over the past 50 years (Carroll, 1999). In the early discussions, CSR was often called social responsibility (SR), as large corporations had not yet become dominant forces in the business world (Carroll, 1999). The publication of Bowen's (1953) "Social responsibilities of the businessman" in 1953 is seen as the starting point of the modern era of CSR. His work suggested that the biggest companies held significant power and influence, which affects the lives of many people (Bowen, 1953). Bowen (1953) defined social responsibility as the duty of the business leaders to adopt policies, make decisions, and take actions that align with the values and goals of society.

After Bowen's (1953) work, the concept evolved significantly over the decades. In the 1980s, scholars like Jones (1980) emphasized CSR as a process, and other researchers focused on measuring CSR's impacts (Aupperle et al., 1985). By the 1990s, Wood (1991) and Carroll (1991) integrated CSR into broader frameworks like corporate social performance and stakeholder theory, and framed it as essential for balancing financial profits with societal duties (Carroll, 1999). During this decade, interest in CSR has been steadily growing and gaining international recognition (Andrés et al., 2019). This trend was likely driven by the global emphasis on sustainable development at the time, combined with the ongoing process of globalization during the 1990s (Carroll, 2015).

As multinational corporations expanded their operations internationally, they encountered diverse business environments overseas (Carroll, 2015). These global expansions presented new opportunities but also intensified competition for emerging markets. At the same time, they brought increasing and often conflicting pressures from both host and home countries (Andrés et al., 2019; Carroll, 2015). Many of these corporations recognized that embracing social responsibility could serve as a reliable and safe way to navigate the difficult challenges and opportunities brought by globalization (Carroll, 2015). Subsequently, the integration of CSR into corporate strategy became more established (Andrés et al., 2019; Carroll, 2015). Over time, CSR has evolved from being seen mainly as philanthropy to a strategic component of sustainable business practices (Kaźmierczak, 2022).

More recently, CSR involves integrating social and environmental concerns into business operations to balance profitability with community and environmental well-being (United Nations Industrial Development Organization, 2020). The concept is multidisciplinary, requiring knowledge from various fields, and has been refined to align with the Sustainable Development Goals (Kaźmierczak, 2022). This evolution has led to the emergence of ESG, which quantifies CSR efforts with measurable criteria for business evaluation (Kaźmierczak, 2022). Unlike CSR, which can sometimes be perceived as superficial, ESG provides standardized data for stakeholders and investors to assess sustainability practices (Kaźmierczak, 2022).

2.3.2 Environmental, Social, and Governance (ESG)

The term ESG, which stands for Environmental, Social, and Governance, has gained growing popularity in recent years (European Commission, 2020b). According to the European Commission (2020b), ESG is defined as a set of criteria used to evaluate the sustainability and ethical impact of a company or investment, with three main areas: environmental practices, social responsibility, and corporate governance.

While ESG and CSR are alike in nature, they are used by different groups (Putzer & Posza, 2024). For example, CSR focuses on a company's commitment, actions, and practices to act responsibly, which is often managed within the company (Putzer & Posza, 2024). On the other hand, ESG is a term used by investors and asset managers to evaluate corporate behavior and identify financial risks and opportunities for growth (Putzer & Posza, 2024). ESG reporting gives investors insight into important factors that are not shown on a traditional balance sheet but that affect a company's risks and opportunities (Halid et al., 2023). As more investors focus on ESG, it becomes a key part of corporate strategies, leading to a demand for better assessment tools (Halid et al., 2023).

While it is not mandatory in annual reports, many companies report their sustainability progress (Şerban et al., 2022). Nonetheless, ESG limits investors' options since several top-performing stocks do not follow ESG principles (Halid et al., 2023; Şerban et al., 2022). Şerban et al. (2022) note that ESG aims to show responsible practices that improve company performance beyond ethical reasons. Although ESG is commonly associated with investment decisions, its relevance extends to various stakeholders, including customers, suppliers, and employees. These groups are increasingly concerned with the sustainability of an organization's activities (European Commission, 2020b).

ESG scores rate companies in environmental, social, and governance aspects (Clément et al., 2023). For instance, environmental aspects focus on factors like resource use, waste management, impacts on biodiversity, and the overall environment. The social dimension addresses the effects on communities and suppliers, employee working conditions, and other social implications. Lastly, governance issues include organizational transparency, the board of directors, and its diversity within the board, relationships with shareholders, and executive compensation (Clément et al., 2023).

ESG scores were created to help investors assess and compare companies using various tangible and intangible data (Escrig-Olmedo et al., 2019). Originally for financial firms, ESG scores became popular as they helped companies boost their reputation and attract capital (Arouri et al., 2019; Cheng et al., 2014). However, they focus more on financial risk than on objectively measuring CSR performance (Viviers & Eccles, 2012). While CSR reflects a company's broader ethical and transparent actions contributing to social and environmental well-being, ESG scores are the best quantitative tool currently available for assessing CSR (Cini & Ricci, 2018; Clément et al., 2023). Limitations arise when ESG scores do not fully capture a company's positive impact or social contributions, which limits the usefulness of recommendations based solely on these scores (Clément et al., 2023). ESG scores are provided by independent ESG rating agencies, with more than 600 agencies issuing ESG scores. Common ESG rating firms are Bloomberg ESG Data Services, MSCI ESG Research, Refinitiv ESG, FTSE Russell, ISS ESG, and Sustainalytics (Escrig-Olmedo et al., 2019).

Many studies have looked at how ESG factors influence major stock markets, which revealed various insights (C. L. Lee & Liang, 2024). Integrating ESG practices can lead to benefits like competitive advantage, lower costs, and stronger customer loyalty (Kim et al., 2022; Porter et al., 2019). Moreover, ESG performance itself is seen as a management strategy for mitigating as well as managing risks (Liu et al., 2024). In addition, it helps companies to stay profitable and protect their reputation (Fafaliou et al., 2022; Gangi et al., 2019). According to Pastor et al. (2020), ESG preferences come from consumer and investor perspectives. Companies in consumer industries that have high emissions or lack innovation can face losses as customers move away from these brands (Tham & Kang, 2022). Likewise, investors who prioritize ESG principles may withdraw from companies with high emissions or poor environmental practices, which raises their cost of capital (Tham & Kang, 2022). Investors often apply exclusion filters to avoid supporting high-carbon firms, as they see ESG performance as a sign of a company's long-term stability and effective risk management (Lee & Liang, 2024; Pastor et al., 2020; Tham & Kang, 2022).

Furthermore, a prior study grounded in institutional theory found that ESG-related contracts can strongly influence executives' decisions (Flammer et al., 2019). Such contracts help improve a company's reputation and support sustainable growth (Flammer et al., 2019; T. T. Li et al., 2021). Moreover, they encourage executives to focus more on stakeholders and have a lasting positive impact on the firm's ESG performance (Flammer et al., 2019). Recent studies also found that environmental regulation policies boost ESG performance in China, using regression analysis on data from 2011 to 2018 (Lu & Cheng, 2023). This underscores the importance of environmental regulations in promoting corporate social responsibility, guiding ESG-focused policies, and encouraging sustainable growth (Lu & Cheng, 2023). Similarly, Wang et al. (2023) analyzed data from 2007 to 2020 using a fixed-effects model and found that low-carbon city pilot initiatives improve ESG disclosures. In addition, Zheng et al. (2023) studied Chinese companies with dynamic least squares and concluded that green patent applications support the ESG development.

Other scholars like Y. Zhou et al. (2023) show that companies with ESG scores above the average are more likely to invest in green innovations, which can signal their commitment to more sustainable practices. In addition, research has revealed that firms with stronger ESG performance tend to achieve much higher financial outcomes, especially during financial crises, such as the COVID-19 pandemic, compared to those with lower ESG performance (Cornett et al., 2016; Lins et al., 2017; Liu et al., 2024; N. Xu et al., 2023). Higher ESG ratings could therefore potentially reflect a company's proactive approach to environmental and social responsibility.

Although the current literature has researched the effects of environmental regulations and ESG practices, the relationship between carbon pricing policies, i.e., the EU ETS, ESG performance, and financial outcomes remains underexplored. This limits understanding of how market-based climate policies may influence corporate sustainability efforts and financial results. Building on institutional theory, as outlined earlier in this chapter, this study explores whether institutional frameworks like the EU ETS can influence corporate behavior, specifically concerning ESG development and financial performance. The following sub-chapter focuses on developing hypotheses based on the literature discussed in the previous sections.

2.4 Hypotheses development

Institutional theory describes how external pressures shape an organization's actions and influence the adoption of specific practices (Dimaggio & Powell, 1983; Meyer & Rowan, 1977). Regulations such as carbon pricing policies can be classified as formal institutions that influence organizational behaviors (E. Lee, 2020; North, 1990b). Carbon pricing policies, specifically, aim to mitigate the negative effects of climate change and encourage environmentally friendly actions (Adebayo et al., 2023; Zhan et al., 2021).

In recent times, companies have faced growing pressure for harming the environment and contributing to climate change (Berrone et al., 2013, p. 891). Studies have shown that the EU ETS and similar schemes have successfully reduced GHG emissions and promoted environmental innovation (Adamolekun, 2024; Lim & Prakash, 2023). Such policies create a "regulatory pull-push" effect (Rennings, 2000), which motivates companies to innovate and invest in eco-friendly practices to meet regulatory requirements and avoid penalties (Mandaroux et al., 2023). Previous research in the ETS literature has revealed that firms in ETS environments tend to demonstrate higher environmental responsibility because of their effective management (C. L. Lee & Liang, 2024; Luo & Tang, 2014). Although these environmental investments are costly and may not provide clear, immediate financial returns, they align companies with societal expectations and enhance their environmental reputation (Berrone et al., 2013; Markman et al., 2004). Consequently, stronger enforcement of regulations increases compliance, which leads to improved environmental performance (Berrone et al., 2013). This forms the basis for the first hypothesis:

Hypothesis 1. *Carbon pricing policies (i.e., EU ETS) can positively impact a firm's environmental performance.*

Furthermore, institutional theory suggests that external influences and the desire for legitimacy drive companies to adopt practices that society values (Dimaggio & Powell, 1983; Scott, 1995). Firms aim to maintain their reputation by aligning with societal norms and expectations, which can include implementing sustainable practices (Berrone et al., 2013; Scott, 1995). Unlike profit-focused theories, institutional theory highlights how external and social pressures shape corporate social behavior (Berrone & Gomez-

Mejia, 2009). Previous research has established that companies operating in stable institutional environments, such as those with established regulations like national ETS, tend to achieve exceptional ESG performance (C. L. Lee & Liang, 2024). In addition, from a regulatory perspective, external factors like visits from investors, social security policies, and tax benefits have been found to strongly encourage companies to act more socially responsibly and improve their ESG performance (Lv et al., 2022; Shu & Tan, 2023; T. Zhou & Gan, 2022).

Many recent studies, as those by Lu and Cheng (2023) have found that environmental regulations positively impact ESG performance, which highlights the role of regulatory policies in promoting corporate sustainability. Similarly, Zheng et al. (2023) showed that green patent applications contribute to ESG development and demonstrated how regulatory-driven innovations can lead to better environmental outcomes. Thus, carbon pricing mechanisms are expected to encourage companies to adopt socially valued practices that improve their ESG performance. This supports the second hypothesis of the study:

Hypothesis 2. *Carbon pricing policies (i.e., EU ETS) can positively impact a firm's overall ESG performance.*

Although environmentally friendly practices may not yield immediate financial returns, companies can still gain a long-term competitive advantage by complying with environmental regulations (Deephouse, 1999; Markman et al., 2004; Meyer & Rowan, 1977). Several previous studies suggest that sustainability is increasingly regarded as a favorable attribute that can enhance a firm's prospects for future success (Brower & Dacin, 2020; Oikonomou et al., 2014). Consequently, businesses should perceive environmental regulations and laws as opportunities to strengthen their competitiveness (Porter & Van Der Linde, 1995).

Companies that are seen as environmentally conscious face fewer business risks than those that engage in harmful practices (Bansal & Clelland, 2004). If a firm ignores corporate social responsibility in an industry where it is the norm, it may risk backlash from its stakeholders (Meyer & Rowan, 1977). This could also give the impression that the company is not progressive and poorly managed, which makes investors, lenders, and potential donors view it as a riskier and less stable investment (Meyer & Rowan, 1977).

Therefore, early adoption of such measures can not only boost resource efficiency but also provide a strategic edge over competitors (Brower & Dacin, 2020; Porter & Van Der Linde, 1995). By accelerating environmental innovation, firms not only reduce their environmental impact, but also boost the technological value of their products whilst creating new market niches (Porter & Van Der Linde, 1995). For example, firms may attract more environmentally conscious customers by offering environmentally friendly products (Dai & He, 2025; Porter & Van Der Linde, 1995).

Thus, complying with environmental regulations ultimately can contribute to increased corporate financial performance (Brower & Dacin, 2020; Porter & Van Der Linde, 1995). Subsequently, the following third hypothesis of the research is proposed:

Hypothesis 3. *Carbon pricing policies (i.e., EU ETS) can positively impact a firm's financial performance.*

Studies in the ESG literature have found that incorporating ESG practices within organizations can yield significant benefits, for instance, competitive advantage, reduced operational costs, and increased customer loyalty (Kim et al., 2022; Porter et al., 2019). Furthermore, ESG plays a major role in mitigating and managing financial risks, which helps them to remain profitable (Fafaliou et al., 2022; Gangi et al., 2019). Efficient risk management promotes business sustainability and helps maintain a strong corporate reputation, which emphasizes the importance of incorporating ESG practices (Jo & Na, 2012; C. L. Lee & Liang, 2024; Song & Han, 2017).

Other studies have indicated that engagement in ESG initiatives is significantly associated with improved financial efficiency (Abdi et al., 2022). In addition, similar research reveals a positive correlation between ESG performance and market outcomes (Dkhili, 2023). Related research has also shown that companies or institutions with stronger ESG performance generally experience significantly better economic performance, particularly during financial crises like the COVID-19 pandemic, compared to those with weaker ESG performance (Cornett et al., 2016; Lins et al., 2017; Liu et al., 2024; N. Xu et al., 2023).

Moreover, through a strong ESG performance, companies show that they have a solid long-term vision (Agoraki et al., 2023; E. D. Baker et al., 2021). This helps them gain social acceptance, build stronger trust with investors, and also create more confidence in their true value (Agoraki et al., 2023; E. D. Baker et al., 2021).

Hence, ESG performance serves as an indicator of a company's long-term success, stability, and risk management (Lee & Liang, 2024; Pastor et al., 2020; Tham & Kang, 2022). Accordingly, the fourth hypothesis of the research is presented:

Hypothesis 4. *A firm's ESG performance can positively impact its financial performance.*

In recent years, customers value a company's environmental mission and take this into account when they choose where and what to buy (Berrone et al., 2013; Hart, 1995). Companies are under increasing pressure to act responsibly, be more green and environmentally friendly (Molina-Azorín et al., 2009, p. 1081). As a result, customers, investors, and other stakeholders are pushing them to minimize their harm to society and the planet (Molina-Azorín et al., 2009, p. 1081). Supporting this view, Molina-Azorín et al. (2009) suggests that managers should therefore consider environmental factors in their decision-making, as it not only aligns with ethical values but also drives long-term economic success (p. 1080). In the modern business landscape, sustainability should no longer be optional but should become a core part of corporate business strategy (Molina-Azorín et al., 2009, p. 1080). Thus, integrating environmentally friendly methods helps boost a firm's reputation among customers (Berrone et al., 2013).

Furthermore, research on firms participating in the EU ETS has shown that energy efficiency is one of the factors that contributes to a company's profitability and competitiveness (Makridou et al., 2019). Low amounts of CO_2 emissions have also proven to have a positive impact on the company's profitability, which can indicate the positive impact the EU ETS has on the firm's financial performance (Makridou et al., 2019). Therefore, enhanced environmental performance has the ability to increase a firm's value and create a competitive advantage (Makridou et al., 2019; Orlitzky et al., 2003). Based on these insights, this leads to the fifth and final hypothesis of the research:

Hypothesis 5. *A firm's environmental performance can positively impact its financial performance.*

The framework for this study is illustrated in Figure 2. It is structured around the two central research questions, which are each addressed by a total of five hypotheses. Research question 1 (RQ1) explores the impact of carbon pricing policies on corporate ESG performance. This question is examined through hypotheses H1 and H2, which investigate two dimensions of how carbon pricing policies influence ESG outcomes. In addition, hypothesis H3 studies the link between carbon pricing policies and the overall financial performance of firms. Moreover, it is hypothesized that ESG, as well as environmental performance, potentially act as mediators between carbon pricing policies and a firm's financial performance.

Finally, research question 2 (RQ2) focuses on the relationship between a company's ESG performance and its financial outcomes. Hypotheses H4 and H5 are dedicated to analyzing this connection and providing insights into how ESG performance may correlate with its financial performance.

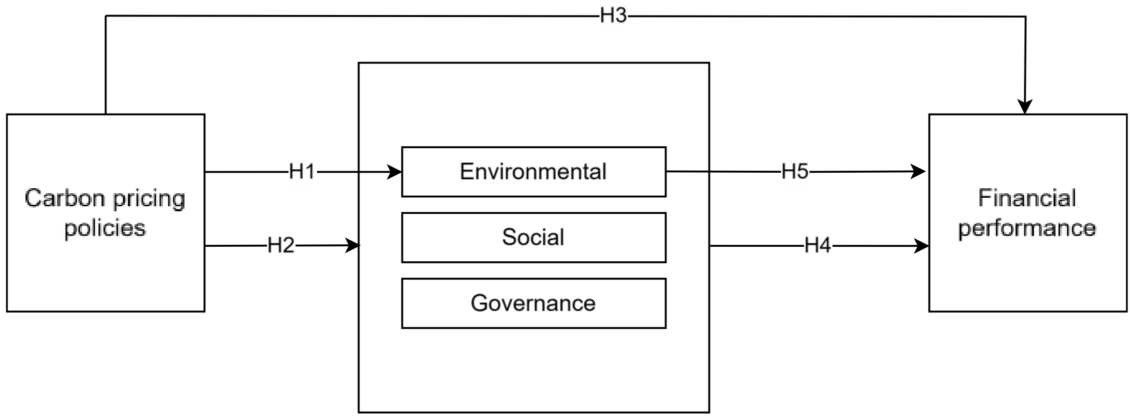

Figure 2 Figure for the theoretical framework.

3 METHODOLOGY

This section outlines the methodology used in this research. It begins by explaining the research design, the data collection process, and the sampling strategy. Then, it introduces the variables and the regression model that is applied in the analysis. Finally, the chapter closes with an evaluation of the data quality, including its reliability and validity.

3.1 Research design

According to Bell et al. (2019), there are two main orientations for conducting business research, often known as research strategies. The authors distinguish between qualitative and quantitative approaches (Bell et al., 2019, p. 35). A quantitative research strategy focuses on the use of numerical data, while qualitative research concentrates on interpreting words and images in data analysis (Bell et al., 2019). This study adopts a quantitative research approach, which is ideal for evaluating existing theories and explaining cause-and-effect relationships (Ghauri & Grønhaug, 2010; Saunders et al., 2019). Given that the majority of research within the field of carbon pricing and ESG performance has utilized quantitative methods, it appears appropriate to adopt this methodology (Adebayo et al., 2023; Lim & Prakash, 2023; Lu & Cheng, 2023; Zhang et al., 2023). Furthermore, since the study focuses on a wide range of industry-based German firms over a fixed time period, a quantitative research method is more suitable than a qualitative one. This is because the required data is available through online databases and can be analyzed using quantitative techniques. Lastly, as this research builds upon established theories and seeks to examine relationships between variables rather than assess unstructured textual content, a quantitative approach seems to be the more reasonable choice (Bell et al., 2019).

Moreover, most research projects usually need to link their research topic to theory in certain ways (Saunders & Lewis, 2018, p. 111). As indicated by Saunders and Lewis (2018), theory development can be reached through three different approaches: Inductive, deductive, or abductive reasoning. A key feature of deduction is the explanation of causal relationships between variables (Saunders & Lewis, 2018, p. 112). This approach involves gathering facts to confirm or disprove hypothesized relationships among variables deduced from prior research (Ghauri & Grønhaug, 2010, p. 16). In contrast to this, inductive research is typically linked to qualitative research and is grounded in empirical evidence, rather than logical reasoning (Ghauri & Grønhaug, 2010, p. 15). An inductive research approach typically begins with empirical observations, which are then used to develop hypotheses and propositions (Saunders & Lewis, 2018, p. 113). Unlike deduction, which starts with theory and tests it against data, induction moves in the opposite direction and derives theoretical insights from observed data (Saunders & Lewis, 2018, p. 113). Lastly, an abductive approach integrates elements of both induction and deduction, and moves back and forth between data and theory (Saunders & Lewis, 2018, p. 113). This study employs a deductive framework, as this is typically the case in quantitative research (Bell et al., 2019, p. 35). It progresses from existing theories (e.g., institutional theory) to data collection and analysis to evaluate whether the findings support the initial five hypotheses of this research (Bell et al., 2019; Saunders et al., 2019).

Finally, research projects can be classified into three categories regarding their purposes: exploratory, descriptive, and explanatory studies (Saunders & Lewis, 2018, p. 115). Exploratory studies seek new insights about novel topics, whereas descriptive ones define certain phenomena (Saunders & Lewis, 2018, pp. 116-17). This research employs an explanatory approach, which goes beyond the descriptive stage (Saunders & Lewis, 2018, p.118). Explanatory research aims to analyze causal relationships between key variables (Saunders & Lewis, 2018, p. 118). By utilizing a deductive approach within the quantitative framework, this explanatory study ought to provide a clearer understanding of the cause-and-effect relationships of the chosen variables (Saunders et al., 2019).

3.2 Data collection

This sub-chapter presents the data collection process and elaborates on how the sample was chosen to fit the purpose of this study. Moreover, research ethics will be addressed.

3.2.1 Data sampling

As stated by Hair et al. (2015), data needs to be collected and analyzed to comprehend the research topic that is being studied. While primary data is usually collected for a particular research project, secondary data refers to information that has been gathered by others for different purposes (Saunders & Lewis, 2018, pp. 85-86). Hair et al. (2015) and Saunders and Lewis (2018) suggest utilizing secondary data sources when they are publicly available, as these often include comprehensive surveys, official up-to-date statistics, and other non-numeric information. One major benefit of secondary data is that it provides access to larger, high-quality datasets while saving both time and financial resources (Saunders & Lewis, 2018, p. 93). In addition, using secondary data offers the opportunity for longitudinal studies as there is a wider range of data available (Bell et al., 2019, p. 297).

This study focuses on exploring the relationships between carbon pricing policies, ESG performance, and the financial outcomes of German industrial firms over a time period of several years. Fortunately, there is a vast amount of panel data for these variables readily available through multiple databases. Given the scope of this research, collecting such data through primary methods like surveys or interviews would be unfeasible. As a result, it is more suitable and efficient to gather the necessary dataset through secondary data sources. The data collection process focused on gathering data for the above-mentioned three areas. The final dataset was assembled using data from the London Stock Exchange Group (LSEG) Workspace (previously known as Refinitiv Eikon/DataStream), Bloomberg, and Bureau van Dijk's company database Orbis. These databases were selected due to their accessibility through Quantum via Hanken School of Economics, their remote access, and their comprehensive data coverage of companies across continents. In addition, prior studies within the carbon pricing and ESG literature have also utilized data from Bloomberg, LSEG/Refinitiv Workspace, and Orbis.

During the data collection process, it became evident that there were no consistent long-term records of ESG scores available for German industrial firms across the selected databases. As a result, this research focuses on the time window from 2018 to 2023, as this is the time period during which ESG ratings for these firms were accessible on LSEG/Refinitiv Workspace. Following that, financial data, including daily carbon prices and financial performance metrics, were sourced from Bloomberg Financial Data. The company database Orbis was then used to extract firm-level data on, e.g., company age and number of employees.

The initial sample included a total of 694 publicly listed German companies categorized using the Global Industry Classification Standard (GICS) from LSEG/Refinitiv Workspace (LSEG, n.d.-a). The GICS framework divides companies into 11 sectors, 25 industry groups, 74 industries, and 163 sub-industries (LSEG, n.d.-a). It is a widely accepted framework and accounts for roughly 95% of global equity market capitalization across 125 countries (LSEG, n.d.-a). To align with the study's focus on manufacturing and industrial companies, the sample was narrowed to a total of 187 German firms within the GICS sectors of industrials, energy, materials, and utilities. Among this sample, a maximum of 108 companies have available ESG performance data for the years between 2018-2023.

Initially, the dataset consisted of four separate Excel files. These files were then consolidated using the respective International Securities Identification Number (ISIN) codes (LSEG, n.d.-b). Data can be organized in two ways: wide format and long format (Longhi, 2014). In the wide format, each unit of analysis is represented in a single row, with separate columns representing different time periods (Longhi, 2014). Nevertheless, using this format is suboptimal, as the number of variables can become difficult to manage as it increases (Longhi, 2014). In contrast, the long format is more practical for research, as observations for each unit over time are stacked in a single column as opposed to being spread across multiple columns in the wide format (Longhi, 2014). At first, some of the extracted data was formatted in a wide format. Due to the above-mentioned reasons, it was then converted to long format to facilitate the analysis with statistical software such as Stata or IBM SPSS. A detailed list of all 108 German firms included in the research and their distribution by GICS sector is provided in Appendices 1 and 2.

3.2.2 Research ethics

In quantitative research, it is often the case that ethical considerations arise during the study (Saunders et al., 2019). However, the use of secondary data offers a distinct advantage in this regard, as there is no need to seek permission or rights from potential respondents (Saunders & Lewis, 2018). This makes it a less intrusive method of data collection (Saunders & Lewis, 2018). In addition, issues related to confidentiality are minimized or entirely avoided (Saunders & Lewis, 2018, p. 94).

Nonetheless, there are still several factors to consider when collecting and working with secondary data. For instance, the use of certain databases and variables, as they could have perhaps been chosen for a specific reason and therefore could be manipulated by the researcher to suggest a particular result for the study. Subsequently, the researcher must be mindful of such ethical concerns (Saunders et al., 2019). In this study, all the data were sourced from publicly accessible databases. Despite this, there are specific limitations in the dataset due to the availability and accessibility of some required data. Importantly, no personal information or unpublished data was utilized. Solely data explicitly made public by companies was incorporated into the research. The variables were chosen due to similar research in prior literature, as they were proven to be suitable for such a kind of analysis.

3.3 Measurement of variables

As mentioned in the data collection chapter, the dataset includes data sourced from LSEG/Refinitiv Workspace, Bloomberg, and Orbis. This section will further elaborate on the variables used in the research and how they are measured. In statistical research, data can be classified as either non-metric (qualitative or categorical) or metric (quantitative) (Fávero et al., 2023). Metric data involves numerical values that come from counting or measurement, such as age or interest rates (Fávero et al., 2023). On the other hand, non-metric data describes qualities that cannot be measured numerically. For instance, non-metric data can be represented by categories or binary responses such as “yes” or no” (Fávero et al., 2023). Generally, qualitative variables are usually measured using nominal or ordinal scales, while quantitative variables are classified using interval or ratio scales (Fávero et al., 2023). This research includes a total of 11 variables: four variables serve as dependent and/or independent variables, while the remaining seven are control variables. All the variables are metric, with nine of them measured on ratio scales and two variables (ESG score and environmental pillar score) measured on interval scales.

3.3.1 Independent and dependent variables

The main independent variable of this study is the implementation of carbon pricing policies, with a focus on the EU ETS. To represent these policies, the price of an EUA is used as a key indicator. Data on the daily EUA futures price was sourced from the Bloomberg terminal, and annual averages were calculated. Each trading unit corresponds to 1000 emission allowances, and each allowance grants the right to emit one metric ton of carbon dioxide or its equivalent (Bloomberg, 2024).

A central dependent variable is Tobin’s Q, which is widely used to measure the market performance of a firm (Brower & Dacin, 2020). According to Kang et al. (2016), Tobin’s Q is the most suitable financial metric for assessing the long-run advantages and potential costs associated with a firm’s corporate social performance. Previous studies have utilized Tobin’s Q to measure corporate financial performance (Brower & Dacin, 2020; Kang et al., 2016). It can be calculated with the following formula:

$$Tobin's\ Q = \frac{Total\ Market\ Value}{Total\ Assets.}$$

The second dependent/independent variable is the overall ESG score, which evaluates a company's ESG performance based on verifiable reported data (LSEG, 2024). This study employs ESG scores from LSEG/Refinitiv Workspace, as LSEG is recognized for its extensive ESG database comprising over 630 ESG metrics (LSEG, 2023). These scores are organized into 10 main categories (illustrated in Figure 3 below) that align with the three core pillars: environmental, social, and corporate governance (LSEG, 2024). LSEG ESG scores are provided both as percentage ranks and letter grades, ranging from D- to A+ (LSEG, 2023). For analytical purposes, the study will utilize the numerical values of the ESG scores.

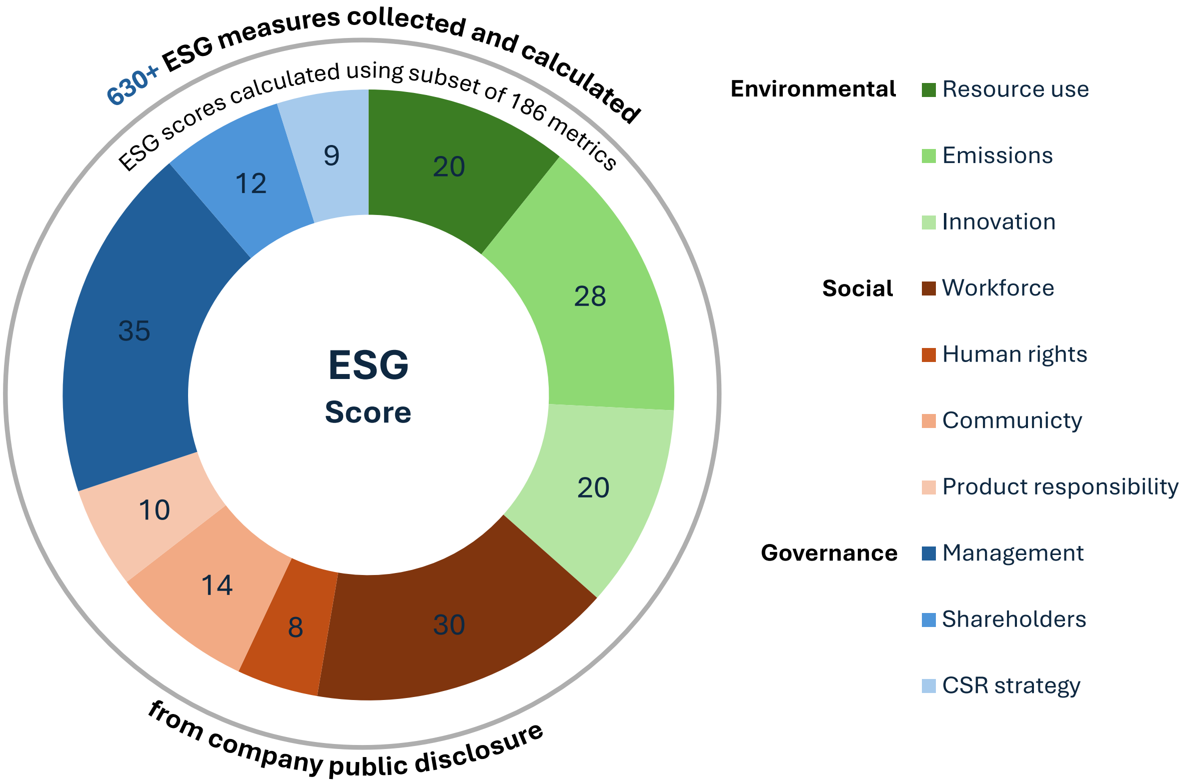

Figure 3 ESG category definitions. Figure adapted from LSEG (2023).

The LSEG ESG scoring methodology is detailed in Figure 4 below. Apart from the ESG score, LSEG also provides an ESGC score, which integrates the ESG score with adjustments for controversies to reflect any negative media coverage by reducing the overall ESG score (LSEG, 2023). As the study's objective is focused on the ESG performance, the ESGC score will not be employed and further discussed. Consequently, this section of the scoring methodology has been greyed out in the adapted version (see Figure 4).

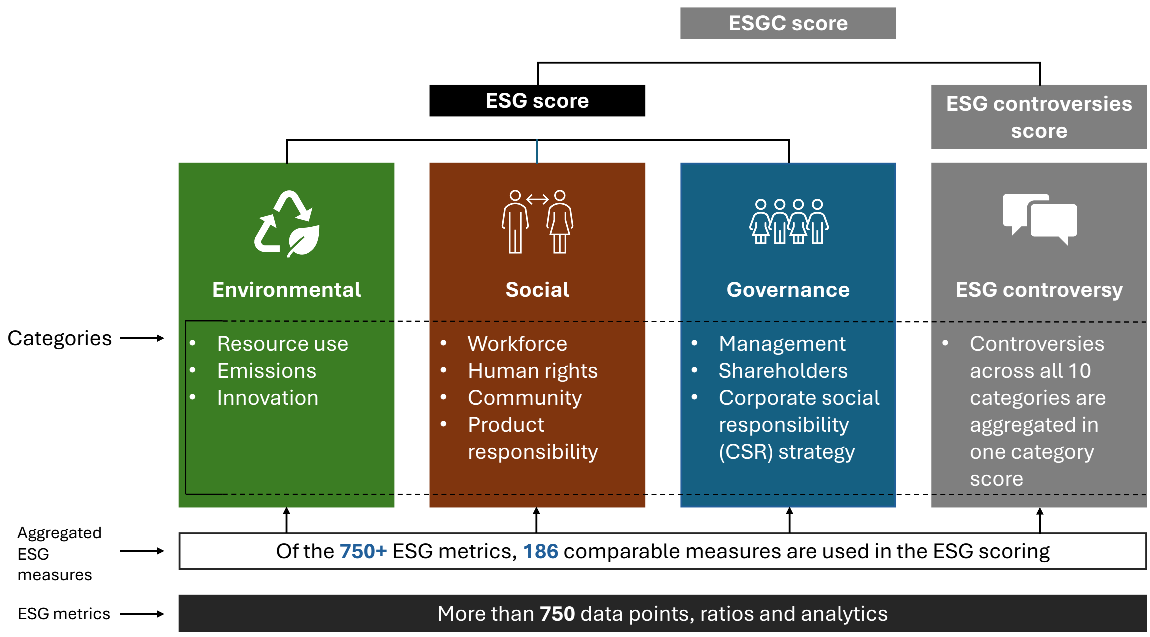

Figure 4 ESG scoring methodology. Figure adapted from LSEG (2023).

Each of the 10 categories contributes to one of the three pillar scores (LSEG, 2023). These pillar scores represent a relative sum of category weights, which vary by industry. The final pillar weights are normalized to percentages ranging from 0 to 100 (LSEG, 2023). The environmental pillar score is composed of three categories: resource use, emissions, and innovation (as illustrated in Figure 4). This study will specifically use the environmental pillar score as the third dependent and independent variable to measure environmental sustainability performance. The focus on the environmental pillar alone allows for examining its specific impact, separate from the overall ESG performance, to determine whether environmental sustainability on its own has a significant effect.

3.3.2 Mediator variables

In this research, the variables ESG score and environmental pillar score serve as dependent and independent variables, respectively. However, there is a possibility that both of them may act as mediators between carbon pricing policies and financial performance, as indicated earlier in Figure 2 in the theoretical chapter. Based on Baron and Kenny (1986), the term mediator suggests the function of a third variable, which demonstrates the underlying mechanism through which the independent variable affects the dependent variable. In other words, the mediator explains the relationship between the predictor and the outcome variable (Baron & Kenny, 1986, p. 1176). Figure 5 depicts the basic causal chain in mediation (Baron & Kenny, 1986, p. 1176). In this model, there are three variables with two ways (b and c) towards the dependent variable.

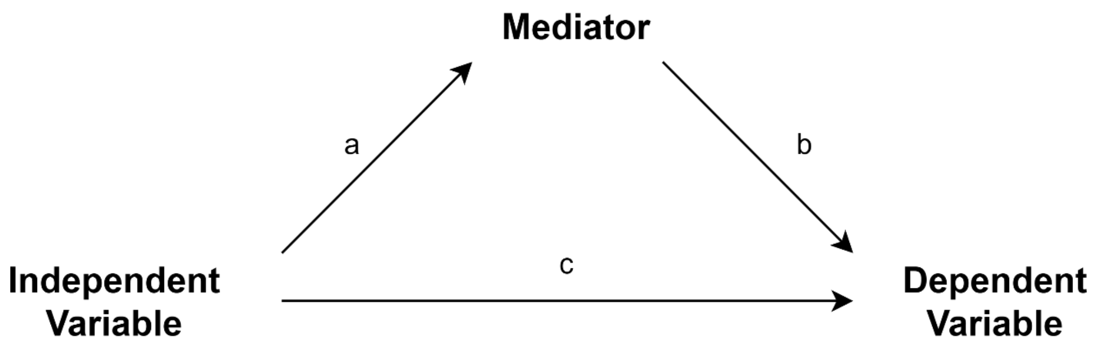

Figure 5 **Basic causal chain in mediation. Figure adapted from Baron & Kenny (1986, p. 1176).**

Path c represents the direct effect of the independent variable, while Path b shows the mediator's influence on the outcome variable (Baron & Kenny, 1986, p. 1176). As stated by Baron and Kenny (1986), three conditions must be met for a variable to be considered a mediator (p. 1176). The first condition (Path a) is that the predictor (independent) variable must significantly affect the mediator. Next, the second condition (Path b) expresses that the mediator should have a significant impact on the outcome, which is the dependent variable. Lastly, the third condition states that, when the mediator is considered, the direct relationship between the independent and dependent variable should either weaken or disappear entirely. Strong evidence for mediation is seen when the direct effect (Path c) goes to zero. Then, the mediator is dominant and fully explains the effect. If the effect is reduced but not zero, this suggests partial mediation and implies that there are other mediating factors (Baron & Kenny, 1986, p. 1176).

In this study, the predictor is the annual EUA price, while the outcome variable is Tobin's Q, which serves as a measure of financial performance. The ESG/environmental pillar score is hypothesized to act as the mediator. Accordingly, the modified mediation model used in this research is shown in Figure 6 below.

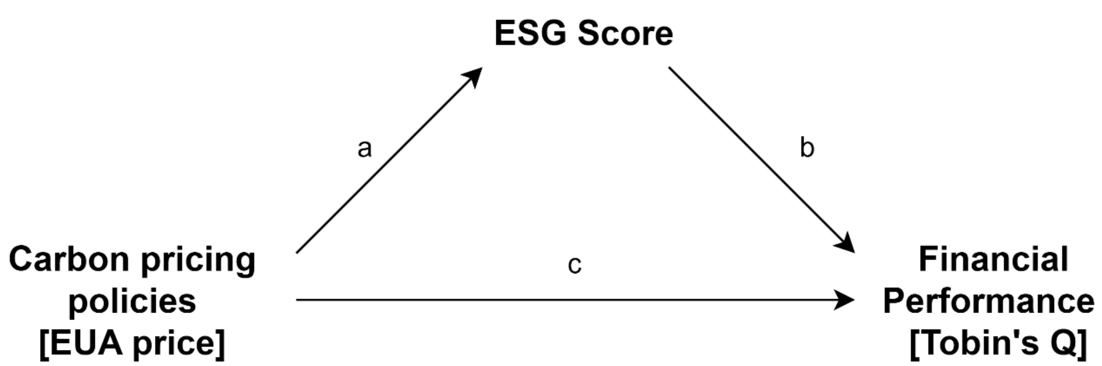

Figure 6 **Mediator model modified for this study, adapted from Baron & Kenny (1986).**

To test for mediation in this research, the mediation analysis method by Baron and Kenny (1986) will be applied. According to them, three sets of regressions should be estimated, which correspond to the above-mentioned three conditions. In this case, these three steps are:

- **Step 1:** EUA price → Tobin's Q
- **Step 2**: EUA price → ESG/Environmental Pillar Score
- **Step 3:** EUA price + ESG/Environmental Pillar Score → Tobin's Q

In the first step, it is essential to determine whether there is a significant relationship between the independent and dependent variables. If there is no such relationship, mediation cannot occur, as indicated by Baron and Kenny (1986). For this research, this means regressing the EUA price on Tobin's Q. Secondly, the EUA price is regressed on the ESG score and the environmental pillar score separately, to examine whether these potential mediators are significantly associated with the independent variable. In case there is no relationship found, the mediator may simply be an unrelated third variable (Baron & Kenny, 1986). Finally, in the third step, the EUA price, along with the ESG and environmental pillar scores, are regressed on Tobin's Q. This is done to assess whether the EUA price's effect on Tobin's Q diminishes or disappears when accounting for the mediators. If the EUA price's effect disappears while the ESG and environmental pillar scores maintain a significant effect on Tobin's Q, it signifies full mediation. If the effect of the EUA price is still there to some degree, partial mediation is indicated.

3.3.3 Control variables

Seven control variables related to firm characteristics will be included to account for potential influencing factors. An overview of the variables with their definitions and sources is given in Table 1 below. The variables for a firm's age and size were obtained from the Orbis database. Research suggests that the size and age of a firm can impact its sustainability efforts and financial performance (Abdi et al., 2022, p. 5057). Larger firms often have greater financial resources, which allows them to invest more in sustainability projects compared to smaller companies (Abdi et al., 2022, p. 5057). Likewise, a firm's age plays a role as well, as younger firms may prioritize financial growth over strengthening their social and environmental reputation (Abdi et al., 2022, p. 5057).

The last five variables, market capitalization, revenue, research & development (R&D) expenses, leverage, and return on assets (ROA), were all extracted from the Bloomberg Terminal. R&D expenses are recognized as an indicator of a firm's innovation capacity in the literature. Increased investment in R&D often leads to the development of sustainable alternatives, which in turn can improve environmental and overall ESG performance (Zhang et al., 2023, p. 22). Further, leverage has been widely used as a measure of a firm's financial risk. Research has shown a negative relationship with ESG performance, which indicates that higher leverage signifies lower ESG (Dkhili, 2023).

ROA is another control variable and serves as an indicator of a firm's operational profitability. Studies reveal that firms with higher profitability are expected to have greater opportunities to invest in environmentally friendly initiatives (Abdi et al., 2022, p. 5059). Both market capitalization and revenue are additional control variables that serve as alternative financial metrics for assessing a firm's financial performance. Similar to ROA, more financial resources can potentially enable firms to allocate greater investments towards sustainability projects and environmental improvements (Xu & Kim, 2020).

Table 1 List of all independent, dependent, and control variables with their definition and the respective databases.

Independent variable (X)	**Unit**	**Definition**	**Database**
European Union Allowance (EUA) Carbon Future Price	€ per 1000 units	Future price of 1000 EUAs	Bloomberg
Mediator variables (X & Y)			
ESG Score	0-100	Score from 1-100	LSEG/Refinitiv Workspace
Environmental Pillar Score	0-100	Score from 1-100	LSEG/Refinitiv Workspace
Dependent variable (Y)			
Tobin's Q	Ratio	Market cap/Total assets	Bloomberg
Control variables			
Firm age	Year	Year - Year of incorporation	ORBIS
Size of a firm	Absolute number	Number of employees	ORBIS
Market Capitalization	€ in million	Total market value of all of a firm's outstanding shares	Bloomberg
Revenue	€ in million	Amount of sales generated by a firm	Bloomberg
R&D expenses	€ in million	Research & development costs	Bloomberg
Leverage	Ratio in %	Total debt/Total assets	Bloomberg
Return on Assets (ROA)	Ratio in %	Net income/Total assets	Bloomberg

3.4 Data analysis

In business research, it is crucial to understand, explain, and predict relationships between variables (Ghauri & Grønhaug, 2010, p. 177). One of the most common analytic methods for examining these relationships is regression analysis, which will be applied in this study (Ghauri & Grønhaug, 2010, p. 177). This technique typically involves one dependent variable, which is the outcome that is being explained by one or more independent variables (Ghauri & Grønhaug, 2010). Generally, all the variables in regression analysis are presumed to be metric, which is also the case in this research. The purpose of regression is to explain how variations in the independent variables influence changes in the dependent variable (Hair et al., 2019). This research employs multiple regression analysis, as it includes control variables that are treated as independent variables within the multivariate model. As panel data is handled, this study uses a fixed-effects model to account for unobservable time-invariant factors (White et al., 2013). Precisely, industry and firm-level effects are controlled for in this fixed-effects approach. All the analyses in this study are conducted using the statistical software Stata/SE 16.0 by StataCorp. Table 2 below provides the abbreviated names of the variables used in this study's regression model.

The regression equation is as follows, where y represents the dependent variable, x denotes the independent variables, b_i is the intercept, $b_1 \dots b_n$ are the regression coefficients and ε signifies the error term for the firm i over t periods:

$$y_{it} = b_i + b_1 x_1 + \cdots + b_n x_n + \varepsilon_{it.}$$

Table 2 Regression names of the variables.

Independent & dependent variables	**Variable names in regression**
EUA Carbon Future Price	EUA
ESG Score	ESG
Environmental Pillar Score	ENV
Tobin's Q	TOBINSQ
Control variables	
Firm Age	lnAGE
Size of a firm	lnSIZE
Market Capitalization	lnMKTCap
Revenue	lnREV
R&D Expenses	lnRDEXP
Leverage	LEV
Return on Assets	ROA

Following this, the equations for each hypothesis, as outlined in the theoretical section 2.4, are presented below:

Equation E_1 for H1:

$$ENV_{it} = \beta_i + \beta_1 EUA_{it} + \beta_2 lnAGE_{it} + \beta_3 lnSIZE_{it} + \beta_4 lnMKTCap_{it} + \beta_5 lnREV_{it} + \beta_6 lnRDEXP_{it} + \beta_7 LEV_{it} + \beta_8 ROA_{it} + \varepsilon_{it}$$

Equation E_2 for H2:

$$ESG_{it} = \beta_i + \beta_1 EUA_{it} + \beta_2 lnAGE_{it} + \beta_3 lnSIZE_{it} + \beta_4 lnMKTCap_{it} + \beta_5 lnREV_{it} + \beta_6 lnRDEXP_{it} + \beta_7 LEV_{it} + \beta_8 ROA_{it} + \varepsilon_{it}$$

Equation E_3 for H3:

$$TOBINSQ_{it} = \beta_i + \beta_1 EUA_{it} + \beta_2 lnAGE_{it} + \beta_3 lnSIZE_{it} + \beta_4 lnMKTCap_{it} + \beta_5 lnREV_{it} + \beta_6 lnRDEXP_{it} + \beta_7 LEV_{it} + \beta_8 ROA_{it} + \varepsilon_{it}$$

Equation E_4 for H4:

$$TOBINSQ_{it} = \beta_i + \beta_1 ESG_{it} + \beta_2 lnAGE_{it} + \beta_3 lnSIZE_{it} + \beta_4 lnMKTCap_{it} + \beta_5 lnREV_{it} + \beta_6 lnRDEXP_{it} + \beta_7 LEV_{it} + \beta_8 ROA_{it} + \varepsilon_{it}$$

Equation E_5 for H5:

$$TOBINSQ_{it} = \beta_i + \beta_1 ENV_{it} + \beta_2 lnAGE_{it} + \beta_3 lnSIZE_{it} + \beta_4 lnMKTCap_{it} + \beta_5 lnREV_{it} + \beta_6 lnRDEXP_{it} + \beta_7 LEV_{it} + \beta_8 ROA_{it} + \varepsilon_{it.}$$

3.5 Reliability and validity

As stated by Bell et al. (2019), reliability refers to the degree to which a measurement of a concept remains consistent (p. 172). In the research literature, it implies the extent to which data collection methods and the resulting analysis can produce the same results (Saunders & Lewis, 2018, p. 135). For instance, other researchers employing identical methods and procedures should be able to replicate the findings and conclusions based on the same dataset (Saunders & Lewis, 2018, p. 135).

To assess the reliability of this quantitative study, it is necessary to evaluate the consistency and stability of the regression results. This can be done by following the statistical assumptions, which regression analysis relies on (Hair et al., 2019, p. 94). The most fundamental of these is multivariate normality, which implies that the data follows a bell-shaped curve, which corresponds to the normal distribution (Hair et al., 2019, p. 94). To ensure normality within the dataset, several variables have been transformed by taking their logarithm, as their original distributions were highly skewed. For this study, the variables for age, size, market capitalization, revenue, and R&D expenses have been normalized using the log function in Stata. Leverage, ROA, environmental pillar score, ESG score, and Tobin's Q are already in ratio format, which is why transformation was not necessary in these cases.

Homoscedasticity is the second assumption, which means that the variance of the residuals must remain constant across the predicted values (Hair et al., 2019, p. 97). In case it is unequal across the independent variables, the relationship is considered heteroscedastic (Hair et al., 2019, p. 97). In this research, robust standard errors are used in the regression analyses to account for potential heteroscedasticity in the dataset. Another premise in multivariate methods is linearity, which simply states that the relationship between the independent and dependent variables ought to be linear (Hair et al., 2019, p. 99). To evaluate this assumption, Q-Q plots were generated in MS Excel, and the distribution was seen as acceptable for all variables. Finally, the last assumption is no multicollinearity, which means that the predictors should not correlate strongly with each other, as otherwise the regression coefficients are unstable (Hair et al., 2019). The study initially included a total of 12 variables, whereas eight of them served as control variables. However, one control variable was highly correlated with the other independent variables, which led to its removal from the initial dataset. This is to ensure that there is no near-perfect multicollinearity, which could result in less reliable statistical inference (Bell et al., 2019). Nonetheless, it is worth noting that some control variables still correlate higher than desired. Since the experimental variables remain unaffected, the overall impact of the regression results is minimal, and the decision was made to keep these variables.

In contrast to reliability, the term validity refers to the extent to which data collection methods truly capture the intended concept, as well as whether the study's findings genuinely reflect the phenomena they imply to be about (Bell et al., 2019; Saunders & Lewis, 2018). For this study, secondary data were sourced from widely recognized and reputable platforms. As highlighted by Ghauri and Grønhaug (2010), data collected by international organizations is generally of high quality and reliability, as it is gathered and compiled by experts using rigorous techniques (p. 94).

For instance, LSEG (formerly Refinitiv) Workspace was used to collect ESG data from all firms. LSEG (2024) claims to operate one of the most extensive ESG data collection systems worldwide, which is designed to be fully transparent. The database is regularly updated and aligns with standard corporate reporting practices (LSEG, 2024). Furthermore, LSEG (2024) achieves nearly 100% data quality by combining algorithmic and human-driven processes. The data is gathered from publicly accessible sources, such as company websites and annual reports, which are provided by the firms themselves (LSEG, 2024). Moreover, the credibility of LSEG data is further strengthened by its frequent use in academic research, which demonstrates its strong validity. This can be seen in the carbon pricing literature, as researchers such as Adamolekun (2024), Abdi et al. (2022), Broeders et al. (2024), and Compagnie et al. (2023) have relied on LSEG data in their analysis.

Moreover, company-specific attributes such as firm size and year of incorporation were obtained from the Orbis database. As stated by Moody's (2025), Orbis is a leading company database that provides financial and business information on a large number of public and private firms. Notably, peer-reviewed studies by Abrell et al. (2022), (Dewaelheyns et al., 2023), and Koch and Themann (2022) have utilized Orbis to source company characteristics in studies related to carbon pricing or the EU ETS.

Finally, the majority of the study's data (e.g., EUA price and financial indicators) were sourced from the Bloomberg Terminal. According to Bloomberg Finance L.P. (2024), the Terminal provides extensive data on markets, industries, firms, and other financial instruments through its research professionals. 97% of their customers indicate that Bloomberg supplies superior data, which is highly relevant for their research (Bloomberg Finance L.P., 2024). In the academic literature around carbon pricing, scholars such as Gilson et al. (2022) and Y. Zhang et al. (2023) have used Bloomberg to collect their financial data for their research.

4 RESULTS

In this chapter, the final data is analyzed using the statistical software Stata/SE 16.0. First, the descriptive statistics and correlation matrix are presented and discussed. After that, the five hypotheses of the study will be tested utilizing multiple regression analysis. Further, mediation analysis will be carried out by applying the three-step method of Baron and Kenny (1986) as explained in the previous chapter. Finally, a summary of the results is provided in the last section.

4.1 Descriptive statistics

Table 3 Descriptive statistics.

	Mean	Std. Dev.	min	max	Median
ENV	47.776	25.413	0	95.643	46.466
ESG	51.205	21.856	1.143	91.979	51.493
TOBINSQ	.921	1.230	.063	13.061	.615
EUA	47.337	27.422	15.929	83.905	39.246
lnAGE	3.87	1.016	0	5.617	3.951
lnSIZE	8.368	1.844	0	12.861	8.582
lnMKTCap	7.011	1.817	2.95	11.645	6.828
lnREV	7.414	1.851	2.648	12.521	7.105
lnRDEXP	3.298	2.149	-4.141	8.732	3.39
LEV	23.126	14.871	0	73.678	22.513
ROA	3.802	6.713	-19.872	52.078	3.601

Table 3 displays the descriptive statistics for all variables used in this study. As stated in the methodological chapter, five variables have been transformed using the natural logarithm, which is denoted by “ln” before the variable’s name. Therefore, the interpretation of these variables shifts, as now the relationship is a measure of proportional change, also called elasticity (Hair et al., 2019, p. 105). In this case, an increase in one unit of these variables results in a percentage change of the dependent variable, ceteris paribus (i.e., all other things being equal) (Hair et al., 2019). In addition, since the data is now on a logarithmic scale, the values appear smaller. Consequently, these transformed variables have a narrower range and therefore show a lower standard deviation than the other variables.

On the other hand, it is observable that both ESG and environmental pillar score combined exhibit a wide distribution, with scores ranging from 0 to a maximum of 91.98. The mean ESG score is 51.2, while the average environmental pillar score is lower at 47.7 points. As the data is more spread for these two scores, the standard deviation is relatively high, between 21 and 25, respectively. In the same way, the EUA price fluctuates as well, with prices shifting from 15.93€ to 83.91€ per 1000 units of CO_2 or equivalent. Subsequently, the standard deviation here is the highest in the table with a value of 27.42. The mean EUA price within the study's time period is about 47.34€. Lastly, it can be seen that the mean for Tobin's Q is at 0.921, which indicates that the average market value of a firm is roughly close to the cost of its assets (Tharavanij, 2024). The firm with the lowest value shows a Tobin's Q of 0.063, which indicates high inefficiencies or undervaluation (Tharavanij, 2024). In contrast, 13.07 is the highest value for Tobin's Q in this study, which suggests that this specific company is greatly valued by the market and is higher than its total asset value (Tharavanij, 2024).

4.2 Correlation matrix

Table 4 reports the correlation matrix of the eleven variables of this research. As the name suggests, it shows the intercorrelations among all variables, with 1 indicating perfect correlation and 0 no correlation at all (Hair et al., 2019, p. 122). What is striking in this table is the high correlation between ESG and the environmental pillar score, with a value of 0.89. However, as previously stated in the methodology, the environmental pillar score is part of the ESG score, which is why this correlation is anticipated and hence not problematic for the forthcoming analysis.

Moreover, some control variables such as market capitalization and revenue also display higher correlations of over 0.8 in two cases. Nevertheless, since they are financial metrics capturing similar aspects and hence are intrinsically related, their strong correlation does not pose any significant concerns here. Apart from this, the remaining variables have low correlation coefficients and consequently do not indicate any serious correlation that could affect the regression results.

Table 4 Correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) ENV	1.00										
(2) ESG	0.89	1.00									
(3) TOBINSQ	-0.16	-0.14	1.00								
(4) EUA	-0.01	-0.01	-0.06	1.00							
(5) lnAGE	0.08	0.02	-0.05	0.02	1.00						
(6) lnSIZE	0.61	0.63	-0.17	0.02	0.22	1.00					
(7) lnMKTCap	0.63	0.69	0.10	0.05	-0.02	0.69	1.00				
(8) lnREV	0.70	0.74	-0.22	0.06	0.06	0.82	0.86	1.00			
(9) lnRDEXP	0.46	0.52	-0.02	0.05	0.00	0.64	0.71	0.71	1.00		
(10) LEV	-0.01	-0.02	-0.21	-0.01	-0.16	0.06	0.04	0.00	0.04	1.00	
(11) ROA	-0.05	-0.03	0.41	0.07	0.05	0.03	0.19	0.03	-0.05	-0.25	1.00

4.3 Baseline regression model

This section presents the specific regression model used in this analysis and explains its development. First, the effect of a single independent variable on the dependent variable is examined. Then, in the second step, control variables are included to assess any changes in the coefficients and the overall model. Finally, fixed effects are added to the regression to account for unobservable factors as described in the methodology.

For simplification, all three steps are demonstrated by using the environmental pillar score in this section (ENV on EUA). The full regression model is then applied to the ESG score and Tobin's Q to show the three basic regressions. These are the following:

1. ENV on EUA
2. ESG on EUA
3. Tobin's Q on EUA

4.3.1 Single predictor model

In the first step, the dependent variable, the environmental pillar score, is regressed on the EUA price, which is the only independent variable in this study. No control variables or fixed effects are included to examine the sole effect of the predictor variable on the outcome variable. Table 5 presents the regression output adapted from Stata. The model fit statistics in the top half of the table demonstrate how well the regression model represents the data and hence can indicate the reliability of the model's estimates (Hair et al., 2019). For instance, it is evident that the p-value for the F-test is 0.7996, which is higher than the significance level of 0.05. This suggests that this model is not statistically significant. In this case, it means that the EUA price by itself does not have a strong relationship with the environmental pillar score. This is further supported by the p-value for the EUA price of 0.800, which is also greater than the threshold of 5%.

Moreover, the value of R-squared is quite low with a value of 0.0001. R-squared represents the proportion of variance in the dependent variable that is explained by the independent variables. A higher R-squared value indicates greater explanatory power of the model (Pevalin & Robson, 2009, p. 283). Subsequently, this model merely explains 0.01% of the variance. Based on these statistics and results, the single predictor model is therefore not suitable for the purpose of this analysis.

Table 5 Regression output for ENV on EUA.

Number of obs.	525
F (1, 523)	0.06
Prob > F	0.7996
R-squared	0.0001
Adj. R-squared	-0.0018
Within R-sq.	0.0001
Root MSE	25.4356

ENV	**Coef.**	**Robust Std. Err.**	**t**	**P>t**	**[95% Conf. Interval]**	
EUA	-.0104557	.0411749	-0.25	0.800	-.0913443	.0704328
_cons	48.32886	2.477609	19.51	0.000	43.46157	53.19614

4.3.2 Incorporating control variables

Moving on, this model now considers additional independent variables, which serve as control variables. The model fit statistics show that the p-value of the F-test is 0.000, which is lower than the threshold of both 0.05 and 0.01 and therefore statistically significant. Additionally, the value for R-squared increased to 0.4653 by adding seven control variables. This implies that 46.53% of the variance of ENV can now be explained by the independent variables. Moreover, the p-value for the EUA price decreased to 0.084, which is marginally significant at a 10% level, but not at a 5% level. It is also apparent that the coefficient for the EUA price, which was negative in section 4.3.1, has changed to a positive value of 0.059. This value indicates that for each one-unit increase of the EUA price, the environmental pillar score increases by 0.059, ceteris paribus.
Overall, this model with added control variables is statistically significant in predicting the dependent variable ENV. Consequently, this regression model displayed in Table 6 fits the data to a greater degree than the previous single predictor model in Chapter 4.3.1.

Table 6 Regression output for ENV on EUA with control variables.

Number of obs.	378
F (8, 369)	49.02
Prob > F	0.0000
R-squared	0.4653
Adj. R-squared	0.4537
Within R-sq.	0.4653
Root MSE	17.9603

ENV	Coef.	Robust Std. Err.	t	P>t	[95% Conf. Interval]	
lnAGE	.8299034	.8423703	0.99	0.325	-.826545	2.486352
lnSIZE	.3832869	.694913	0.55	0.582	-.9831994	1.749773
lnMKTCap	2.183551	1.176038	1.86	0.064	-.1290258	4.496127
lnREV	7.923272	1.296738	6.11	0.000	5.373348	10.4732
lnRDEXP	-.2428225	.6595606	-0.37	0.713	-1.539792	1.054147
LEV	-.0042352	.0914865	-0.05	0.963	-.1841354	.1756651
ROA	-.2380002	.1453027	-1.64	0.102	-.5237255	.047725
EUA	.0593963	.0342277	1.74	0.084	-.0079096	.1267022
_cons	-34.83419	6.081924	-5.73	0.000	-46.79377	-22.87461

4.3.3 Applying fixed effects

To conclude, Table 7 depicts the final model of the regression, which includes both control variables and fixed effects. The latter is introduced to account for firm-specific and industry-specific factors in this research, which may influence the relationship between the outcome and predictor variables. As a result of this, it is evident that the number of observations has declined to 373 as some firms have been excluded due to missing data when applying firm and industry fixed effects. Looking at the model fit statistics, the F-test shows a p-value of 0.000, which implies a statistically significant regression model. Additionally, R-squared increased considerably to about 0.93, meaning that 93% of the variation can be explained by the independent variables. The adjusted R-squared is at about 90.59%, which is fairly high and suggests a strong fit of the statistical model.

Shifting focus to the coefficients, the regression output shows that the EUA price is now significant with a p-value of 0.000. It is still a positive relation towards the environmental pillar score, signifying that a one-unit increase of the EUA price results in an increase of 0.142 of the ENV. Solely AGE and REV have a negative relationship towards ENV, while the rest of the variables all show positive coefficients. Moreover, it is noticeable that the value of the intercept (_cons in the regression output table) changed from being negative to positive compared to the model without fixed effects in section 4.3.2. Because of this, the model has potentially become more accurate by adding fixed effects, as these unobserved factors might have changed the intercept.

Given that this model is statistically significant and proves to be more fitting for this panel data analysis, the forthcoming hypothesis and mediation testing will be conducted using fixed-effects multiple regression analysis. For completeness, the regression tables for the two other dependent variables (ESG and TOBINSQ) are shown in Tables 8 and 9.

Table 7 Regression output for ENV on EUA with control variables and fixed effects.

Number of obs.	373
F (8, 290)	7.61
Prob > F	0.0000
R-squared	0.9267
Adj. R-squared	0.9059
Within R-sq.	0.2143
Root MSE	7.4030

ENV	Coef.	Robust Std. Err.	t	P>t	[95% Conf. Interval]	
lnAGE	-4.901238	4.581774	-1.07	0.286	-13.91898	4.116509
lnSIZE	4.395082	1.734888	2.53	0.012	.9805143	7.80965
lnMKTCap	2.536803	1.519326	1.67	0.096	-.4534998	5.527106
lnREV	-4.9167	3.268916	-1.50	0.134	-11.35051	1.517108
lnRDEXP	2.062042	1.141943	1.81	0.072	-.1855038	4.309589
LEV	.1402965	.0919141	1.53	0.128	-.0406069	.3211999
ROA	.0321979	.1146425	0.28	0.779	-.193439	.2578348
EUA	.142118	.0244832	5.80	0.000	.0939307	.1903052
_cons	35.19269	31.87623	1.10	0.270	-27.5454	97.93078

Tables 8 and 9 provide the final regression model with the ESG score and TOBINSQ serving as the dependent variables, respectively. Both tables show statistically significant results for the model itself as well as for the relationship between EUA price and the dependent variables (p = 0.000; p = 0.002).

Table 8 Regression output for ESG on EUA with control variables and fixed effects.

Number of obs.	373
F (8, 290)	12.83
Prob > F	0.0000
R-squared	0.9232
Adj. R-squared	0.9015
Within R-sq.	0.3038
Root MSE	6.1377

ESG	Coef.	Robust Std. Err.	t	P>t	[95% Conf. Interval]	
lnAGE	-2.929141	4.042186	-0.72	0.469	-10.88488	5.026601
lnSIZE	3.089628	1.437815	2.15	0.032	.2597529	5.919503
lnMKTCap	2.070687	1.413177	1.47	0.144	-.7106964	4.85207
lnREV	-3.107369	2.70129	-1.15	0.251	-8.423987	2.20925
lnRDEXP	1.468529	.7108567	2.07	0.040	.0694365	2.867621
LEV	.1238605	.0791904	1.56	0.119	-.0320003	.2797213
ROA	-.0682098	.0884095	-0.77	0.441	-.2422154	.1057959
EUA	.1473607	.0197655	7.46	0.000	.1084586	.1862628

_cons	34.20204	26.31132	1.30	0.195	-17.5833	85.98739

Table 9 Regression output for TOBINSQ on EUA with control variables and fixed effects.

Number of obs.	448
F (8, 360)	11.28
Prob > F	0.0000
R-squared	0.9316
Adj. R-squared	0.9151
Within R-sq.	0.4069
Root MSE	0.4045

TOBINSQ	Coef.	Robust Std. Err.	t	P>t	[95% Conf. Interval]	
lnAGE	.2350252	.1252809	1.88	0.061	-.0113492	.4813996
lnSIZE	-.1386453	.0943212	-1.47	0.142	-.3241351	.0468445
lnMKTCap	.9393017	.119662	7.85	0.000	.7039773	1.174626
lnREV	-.4202104	.1709142	-2.46	0.014	-.7563262	-.0840947
lnRDEXP	-.0259484	.0202448	-1.28	0.201	-.0657614	.0138647
LEV	-.0079011	.0051689	-1.53	0.127	-.018066	.0022639
ROA	-.0025616	.0051747	-0.50	0.621	-.0127381	.0076149
EUA	-.0029681	.0009457	-3.14	0.002	-.0048279	-.0011084
_cons	-1.989639	1.28202	-1.55	0.122	-4.510828	.5315493

4.4 Hypothesis testing

As stated in the previous section, the hypotheses will be tested using fixed-effects multiple regression analysis. Equations were formulated for each of the five hypotheses in the methodological chapter, which will now be tested in Stata. The regression outputs follow the same format as those presented in Chapter 4.3.3. and shown in Tables 7, 8, and 9. For clarity and simplicity, these regression results have been consolidated into a single table using the asdoc command in Stata. The outputs for each equation can be found in Table 10, which shows the regression coefficients for each independent variable (listed in the columns) in relation to the dependent variable (listed in the rows). The values in parentheses represent the p-values for each variable. Significance levels are indicated by stars, with * for 10%, ** for 5%, and *** for 1%. These stars are placed next to the regression coefficients to indicate whether any of the three significance levels are met.

Summary of regression results

Table 10 Regression results for equations 1-5.

	(1) ENV	(2) ESG	(3) TOBINSQ	(4) TOBINSQ	(5) TOBINSQ
lnAGE	-4.9012	-2.9291	0.2350*	0.3536*	0.3152
	(0.2856)	(0.4693)	(0.0615)	(0.0785)	(0.1058)
lnSIZE	4.3951**	3.0896**	-0.1386	-0.1216	-0.1184
	(0.0118)	(0.0325)	(0.1425)	(0.1270)	(0.1417)
lnMKTCap	2.5368*	2.0707	0.9393***	0.9172***	0.9193***
	(0.0961)	(0.1439)	(0.0000)	(0.0000)	(0.0000)
lnREV	-4.9167	-3.1074	-0.4202**	-0.8852***	-0.9182***
	(0.1336)	(0.2510)	(0.0144)	(0.0001)	(0.0001)
lnRDEXP	2.0620*	1.4685**	-0.0259	0.0094	0.0103
	(0.0720)	(0.0397)	(0.2008)	(0.6974)	(0.6621)
LEV	0.1403	0.1239	-0.0079	-0.0118*	-0.0119*
	(0.1280)	(0.1189)	(0.1272)	(0.0852)	(0.0875)
ROA	0.0322	-0.0682	-0.0026	-0.0029	-0.0021
	(0.7790)	(0.4410)	(0.6209)	(0.6042)	(0.7015)
EUA	0.1421***	0.1474***	-0.0030***		
	(0.0000)	(0.0000)	(0.0018)		
ESG				-0.0081***	
				(0.0026)	
ENV					-0.0058**
					(0.0112)
_cons	35.1927	34.2020	-1.9896	1.3931	1.6092
	(0.2705)	(0.1947)	(0.1216)	(0.3328)	(0.2601)
N	373	373	448	373	373
r2_a	0.9059	0.9015	0.9151	0.9233	0.9229

p-values in parentheses

*** 1% Significance, **5% Significance, *10% Significance.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

For a better overview of the study's equations and hypotheses, the key results have been highlighted using squared boxes within the table. Consequently, it is evident through the stars that all five equations have p-values, which are significant at either the 1% or 5% level. These results imply that the null hypothesis of each equation can therefore be rejected and that each independent variable does have a significant impact on the dependent variable. Furthermore, the value of R-squared is relatively similar in all five cases and lies in the range of 90.59% to 92.29% of explained variance in the models.

In addition, the table shows a positive significant relationship between the EUA price towards both the ESG and environmental pillar score. Further, their regression coefficients are nearly identical, with values of 0.1421 and 0.1474, respectively. This indicates that if the EUA price increases by one unit, both scores will rise by these specified amounts. By contrast, the relationship of Tobin's Q towards EUA price, ESG, and environmental pillar score appears to be negative based on the results shown in the table. For instance, a one-unit increase in the EUA price will lead to a decrease of Tobin's Q by 0.0030. Likewise, a one-unit increase of the ESG and environmental pillar score results in Tobin's Q reducing by 0.0081 and 0.0058, respectively.

Additionally, the regression output reveals several control variables, which are statistically significant. One of them is the variable for a firm's age, which shows a slightly (at a 10% level) significant positive relationship with Tobin's Q. As the independent variable for age is transformed with the natural logarithm, the regression coefficient needs to be divided by 100 to interpret the results (Ford, 2018; Fox, 2011). Therefore, a 1% increase in a firm's age corresponds to a $0.235/100 = 0.00235 \approx 0.02\%$ increase in Tobin's Q. In the same way, the variable for a company's size appears to be statistically significant at a 5% level for both ESG and the environmental pillar score. Thus, an increase of 1% in firm size would result in a $4.3951/100 = 0.043951 \approx 4.4\%$ increase in the environmental pillar score and $3.0896/100 = 0.030896 \approx 3.1\%$ increase in the ESG score. Similarly, a firm's market capitalization is marginally significant at a 10% level in relation to the environmental pillar score. Increasing it by 1% consequently results in a $2.5368/100 \approx 2.54\%$ growth of the score. Also, the market capitalization shows to be statistically different at the 1% level from Tobin's Q. Hence, a 1% increase leads to a rise of Tobin's Q by about 9%. Last but not least, the variable for R&D expenditures displays a positive and significant relationship with both the environmental pillar and ESG score at a 10% and 5% level. If R&D expenses go up by 1%, the environmental pillar score increases by $2.0620/100 \approx 2.1\%$, while the ESG score improves by $1.4685/100 \approx 1.5\%$.

4.5 Mediation analysis

As mentioned earlier in section 3.3.2, the environmental pillar and ESG score are hypothesized to mediate the relationship between carbon pricing policies and financial performance. To test this mediation, the analysis will follow the three steps of Baron and Kenny (1986). Table 11 displays the regression output for the mediation analysis. In all performed regressions, R-squared explains between 90-92% of the variance in the model, which implies that this model has high explanatory power.

The results for step 1, where the EUA price is regressed on Tobin's Q, can be seen in the first column. The findings indicate a negative relationship, with a p-value of 0.0018 that is statistically different at the 1% significance level. If there were no relationship at this stage, there would be no mediation, and the mediation analysis would conclude here (Baron & Kenny, 1986). Proceeding to the next stage, step 2 implies that there should be a relationship between the mediator(s) and the predictor variable, which is the EUA price in this research. As there are two potential mediators, columns (2) and (3) illustrate the results for step 2. Both regression outputs indicate a positive relationship with the EUA price, as both p-values are 0.00, which are statistically significant at the 1% level.

Moving on to the final step, each mediator and the EUA price are regressed on Tobin's Q, which is displayed in columns (4) and (5). When controlling for the environmental pillar score, the EUA price shows a p-value of 0.799 now, which implies no statistical significance with Tobin's Q. Nonetheless, the effect of the environmental pillar score towards Tobin's Q remains significant with a p-value of 0.02 at the 5% level. Likewise, the regression output in column (5) when accounting for the ESG score demonstrates that the EUA price is now non-significant (p-value = 0.564). In contrast, the ESG score is statistically different at the 1% level (p-value = 0.007). Thereafter, it is evident that in both cases (4 and 5) the EUA price does not have a significant relationship with Tobin's Q anymore, whereas both mediators seem to be statistically different from zero.

To conclude, Baron and Kenny (1986) stated that if the significant effect observed in the first step completely disappears in the last stage, full mediation is present. Since this is the case in this analysis, the results empirically support that the mediators fully mediate between the predictor and outcome variable. Accordingly, both the environmental pillar and ESG score mediate the relationship between carbon pricing policies and financial performance, which are represented by the EUA price and Tobin's Q.

Results of the mediation analysis

Table 11 Regression results for the mediation analysis.

	(1) TOBINSQ	(2) ENV	(3) ESG	(4) TOBINSQ	(5) TOBINSQ
lnAGE	0.2350*	-4.9012	-2.9291	0.2879*	0.2910*
	(0.0615)	(0.2856)	(0.4693)	(0.0967)	(0.0960)
lnSIZE	-0.1386	4.3951**	3.0896**	-0.1150	-0.1135
	(0.1425)	(0.0118)	(0.0325)	(0.1352)	(0.1248)
lnMKTCap	0.9393***	2.5368*	2.0707	0.9232***	0.9267***
	(0.0000)	(0.0961)	(0.1439)	(0.0000)	(0.0000)
lnREV	-0.4202**	-4.9167	-3.1074	-0.9424***	-0.9409***
	(0.0144)	(0.1336)	(0.2510)	(0.0009)	(0.0008)
lnRDEXP	-0.0259	2.0620*	1.4685**	0.0115	0.0124
	(0.2008)	(0.0720)	(0.0397)	(0.6365)	(0.6252)
LEV	-0.0079	0.1403	0.1239	-0.0119*	-0.0116*
	(0.1272)	(0.1280)	(0.1189)	(0.0826)	(0.0799)
ROA	-0.0026	0.0322	-0.0682	-0.0021	-0.0029
	(0.6209)	(0.7790)	(0.4410)	(0.7043)	(0.6005)
EUA	-0.0030***	0.1421***	0.1474***	0.0003	0.0008
	(0.0018)	(0.0000)	(0.0000)	(0.7989)	(0.5640)
ENV				-0.0061**	
				(0.0159)	
ESG					-0.0092***
					(0.0069)
_cons	-1.9896	35.1927	34.2020	1.8419	1.9402
	(0.1216)	(0.2705)	(0.1947)	(0.3372)	(0.3132)
N	448	373	373	373	373
r2_a	0.9151	0.9059	0.9015	0.9226	0.9231

p-values in parentheses

*** 1% Significance, **5% Significance, *10% Significance.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

To conclude the results chapter, the findings of the hypothesis testing are summarized in Table 12 below. It is apparent from this table that all five equations for each hypothesis are statistically different. Of the five hypotheses tested, H1 and H2 can be supported by empirical evidence. Although hypotheses H3, H4, and H5 show significant results, the correlations are negative rather than positive, as initially hypothesized.

Table 12 Summary of the hypothesis results.

No.	Hypothesis	Result
1	*Carbon pricing policies (i.e., EU ETS) can positively impact a firm's environmental performance.*	**Supported**
2	*Carbon pricing policies (i.e., EU ETS) can positively impact a firm's overall ESG performance.*	**Supported**
3	*Carbon pricing policies (i.e., EU ETS) can positively impact a firm's financial performance.*	**Significant, but negative**
4	*A firm's ESG performance can have a positive impact on its financial performance.*	**Significant, but negative**
5	*A firm's environmental performance can have a positive impact on its financial performance.*	**Significant, but negative**

Lastly, Table 13 presents an overview of the results for the mediation analysis. As can be seen from the table below, both steps 1 and 2 are statistically significant. In step 3, this effect disappeared for the EUA price, while it remained for both the ENV and ESG scores. As previously stated in Chapter 4.5, this signifies full mediation for both mediators in this study.

Table 13 Summary of mediation analysis results.

Step	Mediational tests		Significance
1	Effect of **X on Y**	Effect of **EUA on Tobin's Q**	**Yes**
2	Effect of **X on M1**	Effect of **EUA on ENV**	**Yes**
	Effect of **X on M2**	Effect of **EUA on ESG**	**Yes**
3	Effect of **X+M1 on Y**	Effect of **EUA + ENV on Tobin's Q**	**No for EUA Yes for ENV**
	Effect of **X+M2 on Y**	Effect of **EUA + ESG on Tobin's Q**	**No for EUA Yes for ESG**

5 DISCUSSION AND CONCLUSION

Climate change stands as an urgent global challenge, with recent studies indicating that the world is on track to exceed the 1.5°C warming threshold set by the Paris Agreement much sooner than anticipated (Fernández et al., 2018). In response, the EU has implemented the EU ETS, a market-based regulatory framework designed to cap and reduce GHG emissions across member states (Koch & Basse Mama, 2019). This system functions as a formal institution, providing economic incentives for companies to lower their carbon footprint through a structured allowance trading mechanism (Fernández et al., 2018). Unlike traditional command-and-control regulations, market-based approaches such as the EU ETS offer companies more flexibility in how they meet environmental goals (Colmer et al., 2024). As firms navigate these environmental regulations, understanding their impact on corporate sustainability and firm performance becomes increasingly important.

So far, much of the research on ESG performance has focused on broader institutional factors, such as legal systems and governance structures at a continental level (C. L. Lee & Liang, 2024). However, little research has been devoted to country-level analysis on formal institutions like carbon pricing policies in shaping corporate sustainability efforts. This is particularly important as regulations, even within the same framework, may affect companies differently depending on the national context. This study builds on existing knowledge by exploring how the EU's carbon pricing policy affects both companies' ESG and financial outcomes. Specifically, it assesses the role of the EU ETS as an institutional factor influencing sustainability efforts and economic performance within Germany's manufacturing sector. To investigate this impact, this work analyzes the effect of historical carbon allowance prices on firms' ESG scores and financial indicators.

In this study, the first research question sought to determine how carbon pricing policies influence companies' ESG performance, including the environmental dimension. This is addressed through hypotheses H1 and H2. The results of the analysis indicate a significant positive correlation between the EUA price (i.e., the EU carbon price) and firms' ESG performance. Likewise, the findings also demonstrate a significant positive relationship between the EUA price and companies' environmental performance. This implies that, as the EUA price increases, both ESG and environmental score also rise. Hence, these results can fully support hypotheses H1 and H2, which suggest that carbon pricing policies positively impact ESG and environmental performance.

These findings are consistent with previous studies, such as the research of Lim and Prakash (2023). The authors suggest that rising carbon prices drive environmental innovation by encouraging the development and adoption of low-carbon technologies (Lim & Prakash, 2023). As formal institutions, carbon pricing policies create regulatory pressures that push firms to invest in environmentally friendly solutions (Mandaroux et al., 2023; Rennings, 2000). As a result, firms that comply with these regulations see improvements in both their overall ESG and environmental performance, which aligns with the findings from this study (Berrone et al., 2013; C. L. Lee & Liang, 2024; Lu & Cheng, 2023; Markman et al., 2004; Zheng et al., 2023). From an institutional theory perspective, such policies act as normative and coercive institutional forces that influence corporate behavior (Scott, 1995). As reported by Scott (1995), these two forces are particularly influential in shaping environmental practices, which is also in line with the results of this present study. Consequently, carbon pricing policies may be able to enhance the ESG and environmental performance of German firms in the manufacturing sector.

The next hypothesis, H3, studied the link between carbon pricing policies and the overall financial outcomes of a company. Contrary to expectations, this study revealed a significant but negative relationship between the EU carbon price and a firm's economic performance. Specifically, an increase in the EUA price was associated with a decline in Tobin's Q, indicating that higher carbon prices are linked with weaker financial performance. This contrasts with the initial hypothesis H3, which anticipated a significant positive correlation.

This finding does not support the previous research of Brower and Dacin (2020) as well as Porter and Van Der Linde (1995), who have suggested that environmental regulations can provide firms with a competitive advantage through early adoption of sustainable measures. Several factors could explain this observation. A possible explanation for this might be the narrower scope of this study. While many studies investigate multiple sectors across an entire continent, this research focuses on a single country and sector, which could lead to different results. Another factor may be the relatively short time frame of this study, which may not be long enough to capture the full financial impact of carbon pricing. It often takes time for the benefits of sustainability efforts to be reflected in financial indicators, as companies initially face high costs from innovation and compliance (Xie et al., 2022). Rising carbon prices can add to this pressure, especially for firms that have not yet invested in low-carbon technologies, as they face higher costs for carbon allowances. Consequently, if firms do not promptly reduce their emissions, they must purchase these increasingly expensive allowances, which can negatively affect their economic performance in the short run. These expenses may help explain the observed significant negative relationship between carbon pricing policies and firm performance during this period. Thus, hypothesis H3 is not supported, as, surprisingly, the relationship is negative rather than the anticipated positive one.

Turning to the second research question, the focus is on how firms' ESG performance, including the environmental aspect, relates to their financial outcomes. In the study, hypotheses H4 and H5 were designed to address this research question. The research results indicate a significant negative relationship in both cases. It is somewhat surprising that no significant positive correlation was found between ESG performance and financial outcomes. Similarly, no positive relation was found between environmental performance and economic performance. Previous studies provided empirical evidence that strong ESG performance is linked to improved financial efficiency (Abdi et al., 2022; Dkhili, 2023; N. Xu et al., 2023). In addition, other research has demonstrated that enhanced environmental performance contributes to a firm's profitability and competitiveness (Makridou et al., 2019; Molina-Azorín et al., 2009; Orlitzky et al., 2003).

This contradictory finding can be attributed to factors similar to those discussed earlier. First, the timeframe of the study may play a role, as previously mentioned, as it might not fully capture the period when innovations and other sustainability efforts begin to yield financial benefits for the firm (Xie et al., 2022). Another reason why stronger ESG performance appears to reduce economic performance is the upfront costs associated with investing in ESG initiatives. These expenses can initially strain a company's financial performance before translating into a competitive advantage. Similarly, higher environmental performance often requires significant investments in eco-friendly alternatives, which, like broader ESG efforts, can lead to short-term financial setbacks before delivering long-term profits.

Other studies have noted that ESG inputs and environmental protection costs may increase the short-term expenses of a firm, but improve medium- and long-term corporate financial performance (Chen et al., 2023; K. Q. Zhang & Chen, 2017). Since this study covers a period of merely six years, it may only reflect the short-term costs companies experience when complying with environmental regulations. Consequently, hypotheses H4 and H5 are not supported. However, both yield significant results, which are negative instead of positive correlations. ESG and environmental performance are therefore negatively associated with economic outcomes.

To account for external influencing factors, this study utilized several firm characteristics as control variables. In the analysis, four characteristics were found to be statistically significant. First, the age of a company positively correlated with Tobin's Q, suggesting that older firms tend to exhibit stronger financial performance. Studies in the literature have demonstrated mixed results for this relationship, with findings indicating both negative and positive effects (Ilaboya & Ohiokha, 2016; Loderer & Waelchli, 2011). Given the study's focus on firms in the manufacturing sector under the EU carbon pricing policy, the positive relationship could be related to several factors. One explanation might be that older firms have had more time to adapt to evolving environmental regulations, such as the EU ETS in this case, which allows them to implement more cost-effectively than younger firms (Kalantzis et al., 2024). Furthermore, established firms may also have a better market position and, thus, tend to have more stable financial structures, which contribute towards better financial outcomes (Kücher et al., 2020).

Secondly, the analysis identified a positive relationship between a firm's size and both ESG and environmental performance. Subsequently, bigger companies in the manufacturing sector tend to have a higher ESG and environmental pillar score in Germany. These results are in agreement with previous studies, which suggest that larger firms typically have more financial resources to invest in sustainability initiatives, resulting in higher ESG performance (Abdi et al., 2022; Younis & Sundarakani, 2020). Moreover, these findings further support the idea of bigger firms implementing sustainable practices to a greater extent, which is directly reflected in their overall ESG performance (Younis & Sundarakani, 2020).

Thirdly, another positive correlation was revealed between R&D expenditures and ESG and environmental scores. This result implies that the more a firm invests in R&D, the stronger its ESG and environmental performance. It also supports previous studies in the literature, which underlines that higher R&D spending often leads to the development of more sustainable alternatives (Y. Zhang et al., 2023). By allocating more financial resources to R&D, companies may innovate more and create environmentally friendly technologies, which ultimately improve their ESG and environmental outcomes.

Lastly, the study found a positive and significant relationship between market capitalization and Tobin's Q. As a firm's market capitalization increases, its overall financial performance tends to improve. This finding is expected, as companies with a higher stock market value also have greater overall market value (Butt et al., 2023; Nimtrakoon, 2015). Moreover, as illustrated in the methodology chapter, market capitalization is a component of Tobin's Q, which naturally explains the strong and significant relationship between these two.

The final section of the analysis focused on testing mediation effects in the study. Interestingly, the results revealed that both ESG and environmental performance fully mediate the relationship between carbon pricing policies and financial outcomes. This signifies that instead of the EU ETS directly impacting a firm's financial performance, it does so indirectly by influencing its ESG and environmental performance. Subsequently, companies respond to carbon pricing policies by focusing on better ESG and environmental practices, which eventually leads to stronger financial results. These findings broadly support the works of other studies in this area, linking ESG and other sustainable practices with economic performance. For instance, previous studies demonstrate that environmental collaboration mediates the link between environmental commitment and financial performance (Vu & Dang, 2021). Other research, particularly focusing on the UK and Germany, has found that green innovation fully mediates between ESG performance and financial outcomes (Chouaibi et al., 2022). The research results also reflect those of Ali and Chouaibi (2024), which revealed the significant mediating effect of ESG practices on banks' financial performance.

Overall, the findings reported here suggest that all five hypotheses were supported by empirical evidence, though to varying degrees. Specifically, the last three hypotheses revealed a significant negative correlation, rather than the expected positive one. In contrast, the first two hypotheses demonstrated a significant positive effect, fully supporting the initial hypothesis. As a result, carbon pricing policies, such as the EU ETS, can positively impact a firm's ESG performance. Likewise, the EU ETS can have a positive effect on companies' environmental performance. Nonetheless, the research has found that the EU carbon pricing policy is negatively linked to a firm's financial outcome. Similarly, higher ESG and environmental performance are seemingly associated with weaker economic results, under certain conditions. Finally, the study identified that both ESG and environmental performance act as full mediators in the relationship between the EU ETS and a company's financial outcomes.

Thus, these findings address the study's research questions by showing the varied effects (both positive and negative) of carbon pricing policies, as well as the complex interplay between ESG performance and financial outcomes.

In addition, the study found that older and larger companies tend to demonstrate better economic results, along with higher ESG and environmental performance, compared to younger and smaller firms. Moreover, businesses that allocate more resources to their R&D departments also appear to exhibit stronger ESG performance and a greater focus on environmental sustainability. In summary, this research contributes to the existing literature by analyzing the effects of carbon pricing policies like the EU ETS on financial performance, with a particular focus on the mediation role of ESG and environmental performance.

5.1 Contributions to the literature

This work contributes to existing knowledge on carbon pricing policies by providing a focused analysis of Germany's manufacturing, utilities, and materials sectors under the EU ETS. Previous research has explored the impact of the EU ETS on the economic performance and energy efficiency of German manufacturing firms (Löschel et al., 2019; Wagner et al., 2014). This study adds to the growing body of research by analyzing the impact of the EU ETS on two critical dimensions: ESG and financial performance. By combining both impacts, it expands and enhances the understanding of the broader institutional effects of carbon pricing policies on German companies. Given the limited research on the combined effect of financial and ESG performance within the context of the EU ETS, this study makes a significant contribution by providing valuable new insights into this research area.

First of all, the present study confirms the findings of Lim and Prakash (2023), Berrone et al. (2013) and C. L. Lee and Liang (2024), showing that carbon regulation initiatives, such as the EU ETS, can improve ESG performance, strengthen environmental commitment, and ultimately reduce GHG emissions by encouraging firms to innovate in low-carbon technologies. Nonetheless, while these studies have primarily focused on a continental scale or developing countries, this study examines a developed country, contributing to the literature by demonstrating and confirming these effects specifically within the German context.

A novel insight from this study is the negative relationship between the EU ETS and financial performance, which challenges previous research suggesting that the EU ETS enhances the economic performance of German firms (Löschel et al., 2019). Nevertheless, it should be recognized that these studies have analyzed the period between 2005 and 2012, covering the trial and second phase of the EU ETS, which are not part of this current study (Löschel et al., 2019). As discussed earlier, this finding likely reflects the short-term financial impact of carbon pricing, whereas studies with a longer time horizon may have captured both medium- and long-term effects. This study sheds new light and contributes to the literature by examining the EU ETS from the years 2018 to 2023, covering its third and part of its fourth phases. By focusing on this period, it emphasizes the short-term financial effects of carbon pricing, particularly the immediate costs that negatively affect the financial performance of German firms in the manufacturing sector. This perspective adds to the understanding of how carbon pricing policies influence businesses in the short run, before potential long-term benefits materialize.

While there has been little research on how both ESG and environmental performance mediate the relationship between carbon pricing policies and financial outcomes, this study adds insights by exploring these specific mediators in the context of German firms. It reveals that both factors play a significant role in mediating the link between carbon pricing policies and financial results, which offers a deeper understanding of how regulations affect financial performance through corporate sustainability practices.

Drawing on institutional theory, this research underlines the role of environmental regulations, especially the EU ETS, in enhancing both ESG and environmental performance. The EU ETS serves as a regulatory mechanism that signals the price of carbon and influences corporate behavior (Kalantzis et al., 2024). As carbon prices increase, companies are more likely to adopt cleaner technologies and improve their ESG scores (Dai & He, 2025). Firms do so by integrating these into their long-term business strategies rather than short-term compliance measures (Lei & Yu, 2024; Scott, 2008). Over time, these changes become institutionalized within firms, which reflects deeper structural shifts driven by external institutional pressures (Scott, 2008, p. 432). Therefore, institutional factors play a crucial role in steering corporate actions (Hoskisson et al., 2000).

Taken together, this research contributes to the understanding of institutional mechanisms in influencing firm behavior. It shows how the EU ETS strengthens the EU’s environmental commitments and supports the Paris Agreement goals by reducing GHG emissions. Utilizing fixed-effects multiple regression, this study controls for time-invariant factors specific to industries and firms. This offers a different angle compared to other methods used in previous studies, such as difference-in-differences (DiD) or generalized method of moments (GMM) (Lei & Yu, 2024; Lim & Prakash, 2023; Löschel et al., 2019; Wagner et al., 2014). By focusing on the latest phases of the EU ETS and its impact on German manufacturing companies, this present study provides new empirical insights into the evolving effect of carbon pricing policies.

5.2 Practical implications

The objective of this research is to examine the impact of the EU ETS on German manufacturing firms between 2018 and 2023. These findings can offer practical insights and suggest several courses of action for corporate managers, investors, and policymakers. For corporate managers, this study emphasizes the importance of integrating sustainability practices into business strategies. The EU ETS functions as a regulatory framework that encourages firms to improve their environmental and ESG performance (Martin et al., 2016). Through the lens of institutional theory, companies respond to external pressures to maintain legitimacy and align with broader societal expectations (Berrone et al., 2013; Dimaggio & Powell, 1983; North, 1990b). While the short-term financial impact of complying with the EU ETS may seem negative due to initial costs, these are likely transitional and can be offset by long-term gains.

Compliance with regulations can push companies to adopt more sustainable practices, which can strengthen their overall reputation. As a result, this can increase their attractiveness to stakeholders and investors. In the long run, embedding sustainability into core business strategies can support long-term growth and improve market competitiveness. Therefore, corporate managers should view higher carbon prices not as a burden, but rather as an incentive for innovation. One area managers may also consider strengthening is R&D, as investments can lead to valuable innovations that improve ESG performance and help meet regulatory requirements. Investment efforts in R&D not only support compliance with environmental policies but also contribute to product or process innovation that aligns with broader sustainability goals.

ESG performance has become a core part of investment decision-making (Halid et al., 2023). ESG scores are used to evaluate companies, compare peers, and assess both risks and growth potential (Halid et al., 2023; Putzer & Posza, 2024). The findings of the study suggest a positive relationship between higher carbon prices and improved ESG and environmental performance. Therefore, for investors and stakeholders, this indicates that incorporating carbon pricing signals, such as a firm's exposure to the EU ETS, into investment analysis could be useful. Firms that respond actively to carbon pricing may be better positioned to manage environmental risks and adapt to evolving regulatory expectations.

In addition, investors should also be aware that firms engaging in ESG improvements, e.g., environmental policies such as the EU ETS, may face increased short-term costs and weaker financial outcomes. Nonetheless, these should not be viewed solely as drawbacks. In the long term, such investments can support regulatory compliance, reduce exposure to climate-related risks, and overall strengthen the company's competitive position.

Lastly, policymakers can leverage carbon pricing policies, like the EU ETS, to drive progress toward international climate goals, such as the targets in the Paris Agreement. When environmental regulations are clearly defined and involve financial consequences for non-compliance, firms are more likely to invest in sustainable innovation to remain legitimate and meet expectations. These regulations can lead to reduced GHG emissions, support the transition to a low-carbon economy, and contribute to positive environmental and economic outcomes. Ultimately, well-designed carbon pricing policies can serve as both a tool for achieving climate goals and a mechanism to drive innovation and long-term sustainability in business.

5.3 Limitations of the study

The generalizability of the study's findings is subject to certain methodological limitations. One of the main weaknesses is that the research focuses solely on one country, namely Germany, and one main industry, which may have introduced potential biases. Therefore, other countries and industries were excluded from the analysis, which may have provided a more comprehensive perspective.

The scope of the study was constrained by limited data access, as only certain databases were available, and more comprehensive datasets could not be accessed. As a result, the sample size is relatively small compared to traditional, more extensive studies. It is crucial to note that caution is necessary when interpreting the findings of this study. Consequently, the results may not fully reflect the relationships between the observed factors on a broader scale. The data of the study covers the years from 2018 to 2023, and some data points might be missing in between. As a consequence, this could have affected the regression results to some extent. For instance, the significant negative correlations found in hypotheses H3, H4, and H5 are only marginally negative. A longer timespan might have produced different outcomes.

Moreover, the ESG data used in this research is obtained from LSEG/Refinitiv Workspace, which has its specific approach to ESG reporting, as mentioned in the methodology chapter. Other data providers, such as Bloomberg or S&P, also have their own ESG scores, which could differ from the ones used in this study and may have influenced the findings.

5.4 Future research

The analysis of this study has several limitations that could be examined further in subsequent research studies. Future research could build on this study by expanding the dataset to include more countries and industries. Since this study focuses on the EU ETS, an extension could involve examining all participating countries and the industries regulated by the system. A longer panel data analysis would likely yield more comprehensive insights. As a result, future studies could investigate the full effects of all phases of the EU ETS from 2005 through to the most recent data in 2025, to provide a broader understanding of how carbon pricing impacts businesses over the course of a decade.

Regarding this specific study, the timeframe of the study may be too short to fully capture long-term financial benefits for firms. Therefore, future research focusing solely on Germany could extend the period to 2005-2025 and incorporate lagged analysis, which would allow for a better understanding of the delayed effects of carbon pricing. A longer timeframe could reveal medium- and long-term financial performance that might not be evident in this short-term study.

Another possible extension of this study would be to explore other independent, dependent, and control variables, as altering these could lead to different insights and results. The study could also be replicated using alternative econometric approaches, such as difference-in-differences, or by employing other statistical software like SPSS, R, or Python. Finally, the research could benefit from incorporating mixed methods or qualitative research to gain deeper insights into how businesses or corporate managers perceive carbon pricing and whether it does influence their strategies to improve their ESG or environmental performance.

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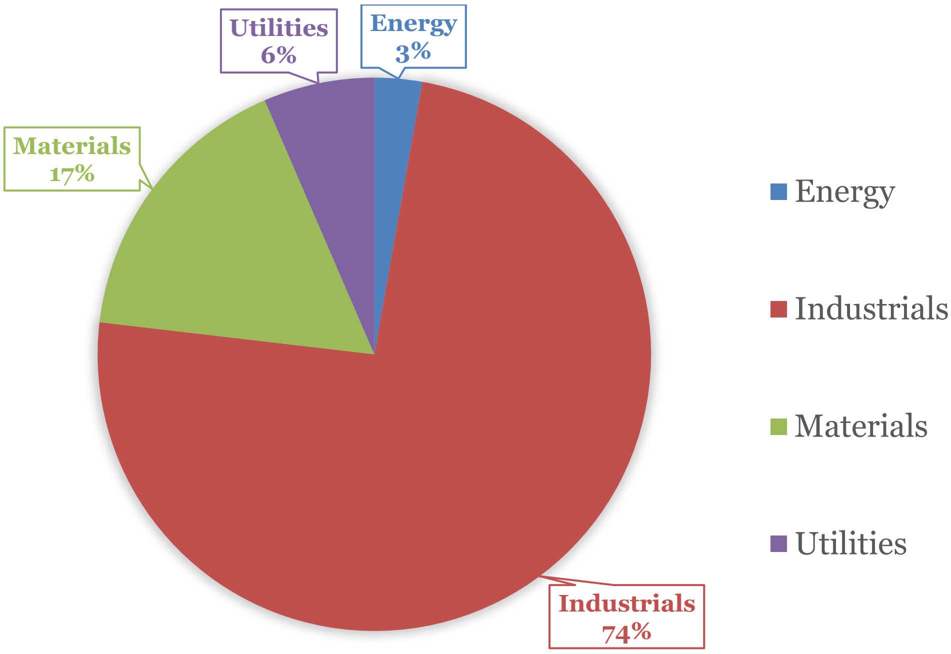
APPENDIX 1 LIST OF ALL FIRMS INCLUDED IN THE STUDY

No.	Company Name	GICS Sector Name	GICS Industry Name
1	11 88 0 Solutions AG	Industrials	Commercial Services & Supplies
2	2G Energy AG	Industrials	Electrical Equipment
3	ABO Energy GmbH & Co KgaA	Utilities	Independent Power and Renewable Electricity Producers
4	Allane SE	Industrials	Ground Transportation
5	Alzchem Group AG	Materials	Chemicals
6	Amadeus Fire AG	Industrials	Professional Services
7	Aumann AG	Industrials	Machinery
8	Aurubis AG	Materials	Metals & Mining
9	BASF SE	Materials	Chemicals
10	Bauer AG	Industrials	Construction & Engineering
11	BayWa AG	Industrials	Trading Companies & Distributors
12	Befesa SA	Industrials	Commercial Services & Supplies
13	Bertrandt AG	Industrials	Professional Services
14	Bilfinger SE	Industrials	Commercial Services & Supplies
15	BREMER LAGERHAUS-GESELLSCHAFT AG Von 1877	Industrials	Transportation Infrastructure
16	Brenntag SE	Industrials	Trading Companies & Distributors
17	Cewe Stiftung & Co KGaA	Industrials	Commercial Services & Supplies
18	Covestro AG	Materials	Chemicals
19	CropEnergies AG	Energy	Oil, Gas & Consumable Fuels
20	Daimler Truck Holding AG	Industrials	Machinery
21	Deufol SE	Industrials	Air Freight & Logistics
22	Deutsche Lufthansa AG	Industrials	Passenger Airlines
23	Deutsche Post AG	Industrials	Air Freight & Logistics
24	DEUTZ AG	Industrials	Machinery
25	Dmg Mori AG	Industrials	Machinery
26	Dr Hoenle AG	Industrials	Electrical Equipment
27	Duerr AG	Industrials	Machinery
28	E On Se	Utilities	Multi-Utilities
29	Edding AG	Industrials	Commercial Services & Supplies
30	EnBW Energie Baden Wuerttemberg AG	Utilities	Electric Utilities
31	Encavis AG	Utilities	Independent Power and Renewable Electricity Producers

32	Envitec Biogas AG	Energy	Oil, Gas & Consumable Fuels
33	EUROKAI GmbH & Co KgaA	Industrials	Transportation Infrastructure
34	Evonik Industries AG	Materials	Chemicals
35	Francotyp Postalia Holding AG	Industrials	Commercial Services & Supplies
36	Fraport Frankfurt Airport Services Worldwide AG	Industrials	Transportation Infrastructure
37	Frequentis AG	Industrials	Aerospace & Defense
38	Fuchs Se	Materials	Chemicals
39	GEA Group AG	Industrials	Machinery
40	Gesco SE	Industrials	Machinery
41	Give AG	Industrials	Construction & Engineering
42	H&R GmbH & Co KgaA	Materials	Chemicals
43	Hamburger Hafen und Logistik AG	Industrials	Transportation Infrastructure
44	Hapag-Lloyd AG	Industrials	Marine Transportation
45	Heidelberg Materials AG	Materials	Construction Materials
46	Heidelberger Druckmaschinen AG	Industrials	Machinery
47	Hensoldt AG	Industrials	Aerospace & Defense
48	Hochtief AG	Industrials	Construction & Engineering
49	Indus Holding AG	Industrials	Industrial Conglomerates
50	Jost Werke SE	Industrials	Machinery
51	Jungheinrich AG	Industrials	Machinery
52	K+S AG	Materials	Chemicals
53	Kap AG	Industrials	Industrial Conglomerates
54	KHD Humboldt Wedag International AG	Industrials	Machinery
55	Kion Group AG	Industrials	Machinery
56	Kloeckner & Co SE	Industrials	Trading Companies & Distributors
57	Knorr Bremse AG	Industrials	Machinery
58	Koenig & Bauer AG	Industrials	Machinery
59	Krones AG	Industrials	Machinery
60	KSB SE & Co KGaA	Industrials	Machinery
61	Lanxess AG	Materials	Chemicals
62	Logwin AG SA	Industrials	Air Freight & Logistics
63	Maschinenfabrik Berthold Hermle AG	Industrials	Machinery
64	Masterflex SE	Industrials	Machinery
65	MAX Automation SE	Industrials	Machinery
66	MBB SE	Industrials	Industrial Conglomerates
67	MTU Aero Engines AG	Industrials	Aerospace & Defense
68	MVV Energie AG	Utilities	Multi-Utilities
69	Nabaltec AG	Materials	Chemicals
70	Nordex SE	Industrials	Electrical Equipment

71	Norma Group SE	Industrials	Machinery
72	OHB SE	Industrials	Aerospace & Defense
73	Osram Licht AG	Industrials	Electrical Equipment
74	Pfeiffer Vacuum Technology AG	Industrials	Machinery
75	PNE AG	Industrials	Electrical Equipment
76	R Stahl AG	Industrials	Machinery
77	Rational AG	Industrials	Machinery
78	Rheinmetall AG	Industrials	Aerospace & Defense
79	Ringmetall SE	Industrials	Machinery
80	RWE AG	Utilities	Independent Power and Renewable Electricity Producers
81	Salzgitter AG	Materials	Metals & Mining
82	Schaltbau Holding AG	Industrials	Machinery
83	SFC Energy AG	Industrials	Electrical Equipment
84	SGL Carbon SE	Industrials	Electrical Equipment
85	Siemens AG	Industrials	Industrial Conglomerates
86	Siemens Energy AG	Industrials	Electrical Equipment
87	Simona AG	Materials	Chemicals
88	Sixt SE	Industrials	Ground Transportation
89	Stabilus SE	Industrials	Machinery
90	Steico SE	Industrials	Building Products
91	Sto SE & Co KgaA	Materials	Construction Materials
92	STS Group AG	Industrials	Machinery
93	Symrise AG	Materials	Chemicals
94	Takkt AG	Industrials	Commercial Services & Supplies
95	technotrans SE	Industrials	Machinery
96	thyssenkrupp AG	Materials	Metals & Mining
97	thyssenkrupp nucera AG & Co KgaA	Industrials	Construction & Engineering
98	Traton SE	Industrials	Machinery
99	Uniper SE	Utilities	Independent Power and Renewable Electricity Producers
100	Uzin Utz SE	Materials	Chemicals
101	va Q tec AG	Industrials	Machinery
102	Varta AG	Industrials	Electrical Equipment
103	Verbio SE	Energy	Oil, Gas & Consumable Fuels
104	Villeroy & Boch AG	Industrials	Building Products
105	Vossloh AG	Industrials	Machinery
106	Wacker Chemie AG	Materials	Chemicals
107	Wacker Neuson SE	Industrials	Machinery
108	Washtec AG	Industrials	Machinery

APPENDIX 2 DISTRIBUTION OF FIRMS BY GICS SECTOR



APPENDIX 3 USE OF AI-BASED TOOLS IN THIS THESIS

In this thesis, I have used an artificial intelligence language model called ChatGPT (OpenAI, 2023) to improve the structure and wording of my text. It has not been used to generate new ideas or build completely new sentences. I have solely used it to find synonyms for words or phrases I use frequently and to improve the flow and clarity of some paragraphs.

My process with ChatGPT went as follows: I wrote the text based on my own thoughts, notes, and content-wise, with the help of academic journals. If I were not content with how a sentence flows, I refined it through a couple of back-and-forth interactions with ChatGPT. For that, I gave specific prompts about how I wanted it improved, e.g., I asked for a clearer structure or asked for alternative wordings to make the text sound smoother within the paragraph. In some cases, ChatGPT provided a useful version of my original text, while other times, the suggestions did not fit the purpose of my writing, so I carefully decided which ones to use and which to dismiss. Due to the security concerns of such AI models, I did not copy-paste any content from my data or findings. Its use was mostly concentrated around the theoretical framework, where most of the academic journals and their content are accessible online.