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Mandatory Carbon Disclosure and its potential impact on firm-level emissions and financial performance: A Nordic Perspective

Master Thesis

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ABSTRACT

We study the impact of mandatory carbon disclosure regulations on the carbon emissions and firm value of Nordic firms. We focus on publicly listed companies in Norway, Sweden, Denmark, and Finland. We find no differential effect in the carbon emission levels and firm value of firms that only disclosed after the regulation compared to firms that voluntarily disclosed before the regulation. However, we observe a slight increase in emission intensity of firms that only disclosed after the regulation. We conclude that the mandatory disclosure rules have no impact on the firm value and total carbon emission levels of Nordic firms.

Keywords: Mandatory carbon disclosure regulation, greenhouse gas emissions, voluntary and mandatory disclosure, firm value, market capitalization.

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1.0 Introduction

Climate change and its risks have been a significant talking point in the news in recent years due to the havoc it is causing to lives, infrastructure, and economies around the globe. We hear of floods, droughts, forest fires, and other natural disasters in the news almost daily. As a result of this, governments around the world have taken the issue of climate change as a matter of grave concern that must be addressed. In an attempt to tackle climate change and its adverse effects, leaders worldwide reached a breakthrough in 2015 to substantially reduce global greenhouse emissions and limit the global temperature increase to 2°C this century (*The Paris Agreement / United Nations, 2015*). Over the years, some firms have also made efforts to contribute to the mitigation of climate change by pledging to reduce (with some already reducing) their carbon footprint and, in some cases, voluntarily disclosing their carbon emissions. This may be partially attributed to firms realizing that climate risk is not just a physical risk (droughts, floods, wildfires, etc.) that may affect their tangible assets, everyday operations, etc., but also a financial risk that may affect their cost of capital, profitability, employee retention, etc. In addition, retail investors, asset managers, and institutional investors are becoming more ESG conscious and, as a result, consider the effects of their investments on the environment. However, some climate activists and environmental commentators have raised the issue of greenwashing by firms, claiming some voluntarily report only metrics that make them look good publicly for reputational benefits (Priscila Azevedo Rocha et al., 2022). Others also claim that firms that voluntarily report and undertake CSR generally do so because they have the resources (good financial performance) to measure and report their disclosures. Some governments have therefore introduced mandatory carbon disclosure to mitigate climate risk. But do mandatory disclosures incentivize firms to reduce their carbon emissions? Do investors demand a higher cost of capital from high carbon emitting firms, and does this significantly impact the value of firms?

Opponents of ESG investing, including renowned academic Aswath Damodaran, have been vocal against ESG reporting and ESG investing itself, claiming ESG is not just a mistake that will cost companies and investors money, but it will also make the world worse off, creating more harm than good (Chakraborty, 2021).

However, researchers find that mandatory ESG disclosure increases the availability and quality of ESG reporting and provides informational and tangible benefits for firms in contrast to what antagonists of ESG claim. There is empirical evidence that adverse ESG incidents become less likely, and stock price crash risk declines after mandatory ESG disclosure is enacted (Krueger et al., 2021).

Nevertheless, (Krueger et al., 2021) find that despite the growing importance of firm-level greenhouse gas (GHG) emissions data, current disclosure schemes are primarily voluntary and nonprescriptive and remain largely non-standardized, inconsistent, and sparse. They argue that this could be why some governments, central banks, and international financial policy-makers are increasingly debating the issue of introducing mandatory climate-related disclosures.

In 2013, the United Kingdom, through the UK Companies Act, introduced a distinctive law that mandated UK-incorporated publicly listed firms to disclose their GHG emissions. Researchers found that firms reduced their GHG emissions by 16% by reducing their energy usage. They observed that the reason behind this emission reduction was that the regulation made disclosing high GHG costly and also created comparisons across firms (Jouvenot & Krueger, 2019).

The findings from the impact of mandatory disclosure regulation around the world could be a reason why countries in the Nordics, including Sweden (2017), Finland (2017), Norway (2018), and Denmark (2019), introduced and implemented mandatory non-financial disclosures, including carbon disclosures.

1.0.1 Background of mandatory disclosure in the Nordics

In Sweden, the law came into effect on January 1, 2017, and it mandates large public companies to report their environmental and social impact, including their GHG emissions, as part of their annual reports from 2017.

The legislation that introduced this reporting requirement is the Swedish Annual Accounts Act (Årsredovisningslagen), amended in 2016 to include these new reporting requirements. The amendments require large companies, defined as those with an average of more than 250 employees and net sales exceeding SEK 350 million per year, to report on their environmental and social impact in accordance with recognized

frameworks, such as the Global Reporting Initiative (GRI) Standards or the Sustainability Accounting Standards Board (SASB) Standards. The Act requires companies to report their Scope 1,2 and 3 emissions as defined by the Greenhouse Gas Protocol, which is the most widely used standard for greenhouse gas accounting (*Företagens Rapportering Om Hållbarhet Och Mångfaldspolicy* | *Lagen.nu*, 2015).

Scope 1 emissions are direct emissions from the operations of affiliates that are owned or controlled by a company. Scope 2 emissions come from the generation of purchased heat, steam, and electricity. Scope 3 emissions are indirect emissions caused by a company's operations and the use of its products. These include emissions from the production of purchased materials, product use, waste disposal, and outsourced activities (Bolton & Kacperczyk, 2020).

In Finland, the law came into effect on January 1, 2017, and mandates certain large companies (net annual turnover exceeds €40 million and more than 250 employees) to disclose non-financial information, including information on their environmental impact. The legislation that introduced this requirement is called the Corporate Social Responsibility (CSR) Directive, which is a European Union (EU) directive that aims to increase the transparency and accountability of large companies and groups. The Directive was transposed into Finnish law in 2016, and it requires companies that meet certain size and status criteria to report on their non-financial information, including environmental impact. However, the Directive does not specify the exact content and format of the non-financial statement, meaning companies have some flexibility on how they report their environmental impact (*EUR-Lex - 32014L0095 - EN - EUR-Lex*, 2014).

The law came into effect on January 1, 2018, in Norway. The Norwegian Accounting Act (Regnskapsloven) requires public companies to disclose information on environmental and social matters in their annual reports. Specifically, Section 3-3a of the Act mandates that such companies include a statement in their annual report that describes the company's impact on the environment, the measures taken to reduce the impact, and the company's policies and targets relating to environmental matters. The law provides specific guidelines on information that should be reported, including a description of a company's greenhouse gas emissions and other significant

environmental impacts, such as waste generation, water usage, and pollution (*Lov Om Årsregnskap M.v. (Regnskapsloven) - Lovdata, 2023*).

In Denmark, new legislation was enacted in Denmark in 2019 that requires certain large companies (net annual turnover of DKK 350 million and an average of 250 employees or more) to report on their climate-related financial risks and opportunities, including their greenhouse gas emissions. Under the Danish Financial Statements Act, these large companies must include a statement on their climate-related financial risks and opportunities in their management review as part of their annual report (Finanstilsynet, 2019).

It must also be noted that Sweden, Finland, and Denmark are part of the EU (European Union) and are, therefore, subject to the EU Taxonomy regulations. The EU, through the Non-Financial Reporting Directive (NFRD), requires large public interest entities with over 500 employees (listed companies, banks, and insurance companies) to disclose certain non-financial information (European Commission, 2023).

Our research objective is to test whether the introduction of mandatory carbon disclosure law in the Nordics caused firms that were not disclosing before (but were forced to disclose due to the law) to reduce their emissions compared to firms that voluntarily disclosed even before the introduction of the law. We also study if the law had any impact on the firm value of firms in the Nordics. We measure the impact of the regulations on Scopes 1 and 2 emissions individually, and the impact on the two combined. We anticipate that mandatory disclosures, if robustly established that it has financial implications on these firms, will provide incentives for other firms to work toward reducing carbon emissions by adopting innovative technologies and exploring ways to help reduce their carbon footprint. Moreover, we believe there will be an increase in demand for more disclosure among Nordic and other European firms if it is established that mandatory disclosures result in emission reduction among firms that fall under existing mandatory carbon disclosures, thereby helping alleviate climate risk.

Our paper contributes to the growing literature on mandatory carbon disclosure requirements by providing empirical evidence specific to the Nordic countries. By examining the impact of mandatory disclosure requirements on GHG emissions and value of firms in Nordic countries, this study adds to the body of knowledge by

providing insights into the Nordic context, which may have unique characteristics compared to other regions.

For instance (Ella Mae Matsumura et al., 2013) looks at the impact of carbon disclosure by mainly focusing on S&P 500 companies, (Jouvenot & Krueger, 2019) study mandatory carbon disclosure law in the U.K. (United Kingdom) with a strong focus on U.K. listed firms. Although, (Krueger et al., 2021) used a global sample in studying the effects of mandatory ESG (Environmental, Social, Governance) disclosure around the world, their focus was on unexplored informational and real outcome variables. Moreover, their data sample covered the period 2000-2017, a time at which mandatory disclosure had not been introduced in most Nordic countries. Likewise, (Gibbons, 2020) who did a similar study on the financially material effects of mandatory non-financial effects used global sample from the period 2000-2016.

We address our research question by taking advantage of the quasi-linear experiments, which are the introduction of mandatory carbon disclosure laws in the Nordic countries, including Sweden (2017), Finland (2017), Norway (2018), and Denmark (2019). Before the carbon disclosure was mandated some firms in the Nordics were already voluntarily disclosing their emissions. These firms can be thought of as a *control group*, given that these companies were already in compliance with the new regulations. The *treatment group* is composed of other firms that had not previously disclosed their emissions and that had began disclosing after the introduction of the mandatory carbon disclosure requirements. By looking at the differential effects of the new law between the two groups we can determine the effects of the mandatory carbon disclosure in the Nordics around the time the regulation was introduced.

We find that the mandatory carbon disclosure requirement has no impact on both changes in total emission levels across Scopes (1, 2, and 1+2) and firm value. However, we observe a slight increase of 0.0000399 tons of carbon dioxide equivalent (tCO₂e) of average (Scope 1+2) emissions per unit of sales (in euro) for our treatment group compared to our control group after the regulation when we use sector-fixed effects as one of our control variables. However, an additional striking finding is that we find no differential effect both on carbon emissions/emission intensity and firm value between

our treatment and control group when we replace sector-fixed effects with industry-fixed effects.

The rest of the paper is organized as follows. The next section provides background information and literature on mandatory carbon disclosures. Section 3 presents our hypothesis in relation to other theoretical frameworks. Section 4 describes our methodology. Section 5 describes our data. Section 6 presents our results and analysis (including robustness checks which explores potential alternative explanations). Section 7 concludes.

2.0 Background and Literature

People are progressively becoming aware of the effects of climate change and the mayhem it could wreak if nothing is done about it. As a result, governments, businesses, and organizations are taking steps to evaluate their contributions to running this heavy fossil fuel-reliant economy. It has been recognized that reducing carbon emissions is the best way to mitigate climate change risks. Nevertheless, it is asserted that many firms merely make statements about lowering their carbon emissions and operating sustainably without taking any concrete measures.

This has led to the EU introducing disclosure requirements for specific corporations through the EU taxonomy. Researchers, the investment community, climate activists, governments, and the general public will likely be interested in whether these mandatory disclosures can help mitigate climate risks. As previously mentioned, investors are likely to invest in firms with a low carbon footprint due to increased sustainability awareness. Suppose it is established that these mandatory disclosures help mitigate climate risk (through emission reduction) and improve firm value, asset managers will be encouraged to direct capital towards firms and projects that lower their carbon footprint. Additionally, it will assist in allocating funds to industries and regions where additional funding is required and in areas where doing so will be most advantageous from an economic, social, and environmental perspective.

Furthermore, as previously stated, if mandatory disclosures are found to be effective in reducing carbon emissions, key stakeholders will likely demand more disclosures on carbon emissions. This will help motivate researchers, scientists, and industry

participants to enhance their contribution toward the effectiveness of these disclosures. Moreover, if emission reduction is established to have favorable financial implications, firms will be incentivized to increase efforts to reduce their carbon footprint.

2.1 Literature on mandatory disclosures around the World

(Krueger et al., 2021), finds that mandatory ESG disclosure improves the availability and quality of ESG reporting, particularly among firms with low ESG performance. They observed a link between introducing these mandatory disclosures and some country-level variables. Using the paper (Liang & Renneboog, 2017) as a reference, they observed that mandatory ESG regulation is likely to be adopted in common law countries and countries with higher carbon emissions per capita. They cited the findings by (Jouvenot & Krueger, 2019; Tomar, 2019), which noted that countries with high carbon emissions per capita are more likely to implement mandatory ESG disclosures as a disciplinary tool to make firms reduce their carbon footprint. Although this study by (Krueger et al., 2021) is very insightful, we notice that this paper is mainly focused on the effects of mandatory disclosure on the quality and availability of ESG reporting, its effects on firm behavior, and the informational and tangible benefits to firms rather than their impact on emission reduction and financial performance of firms. Additionally, they focused on ESG as whole rather than carbon emission of firms. We believe carbon emissions can arguably be easily and better measured compared to a wholistic environmental characteristics firms.

There is also empirical evidence that the introduction of mandatory toxic release disclosure in the 1980s, which mandated firms in the US to disclose their (legal) toxic releases, led to a significant reduction in toxic releases. However, the authors discovered that in the short term, toxicity increased even though toxic emissions decreased. Thus, these firms substituted lower emissions with higher toxicity (Bae et al., 2010). One striking thing they found is that states that only focused on data dissemination without any interpretation significantly reduced toxic releases but did not affect toxic risk within the state. In contrast, states that focused on data dissemination and processing by providing well-structured and interpreted information that included risk and trend analysis, health effects, and ranking analysis did not affect

toxic release levels but reduced toxic risk. Based on this finding, they concluded that providing context matters for mandatory disclosure.

A further study by (Ella Mae Matsumura et al., 2013), as referenced by (Bolton & Kacperczyk, 2020), looks at carbon disclosure by S&P 500 companies from 2006 to 2008 based on a matched sample of disclosing and non-disclosing firms. They find that the median value of firms that disclose their carbon emissions is about \$2.3 billion higher than that of comparable non-disclosing firms. However, citing (Griffin et al., 2017) in a related study of the same CDP (Carbon Disclosure Project) carbon disclosure data, they find no differential effect on the firm value of disclosing and non-disclosing firms. This shows contradictory results on effects of mandatory disclosure on firm value. Unlike studies on effects of mandatory disclosure on emissions where most researchers find that mandatory disclosures lead to a reduction in emissions.

2.2 Literature on carbon disclosure signaling.

A study by (Bolton & Kacperczyk, 2020) on the Strategic Report and Directors Report Regulations 2013, which mandated publicly listed UK firms to disclose their GHG emissions, found that the regulation resulted in lower stock-level uncertainty and the effect of these mandatory disclosures was observed in other markets, particularly companies in the same industry and close economic and geographic proximity. They also noticed that voluntary disclosure of scope 1 emissions resulted in lower stock returns than non-disclosing companies. (Bolton & Kacperczyk, 2020) focused mainly on voluntary and mandatory disclosure of carbon emissions on stock returns, volatility, and turnover, while (Jouvenot & Krueger 2019) and (Krueger, 2015) focused on the real and financial effects of GHG disclosure regulation and the reasons behind firms' emission reduction after the introduction of mandatory carbon disclosure, with both using the UK mandatory carbon disclosure regulation as a case study.

One similarity between the papers by (Bolton & Kacperczyk, 2020) and (Jouvenot & Krueger, 2019) is that they all focus on emissions in levels. Unlike these papers, we focus on changes in emissions levels and changes in emission intensity. We believe there is high persistence in emission levels from year to year, and therefore we might

get a very high adjusted r-squared which does not give much information or explain any variation.

Additional research on firms' disclosures finds that emission abatement is highly influenced by firms' beliefs about climate regulation, and interactions across firms strengthen the impact of regulations (Ramadorai & Zeni, 2019). This paper observed that reputational externality generated an increased reaction across firms to changes in a carbon levy. In addition, they noticed that firms' profits from polluting decreased significantly when their competitors contemporaneously abated emissions.

From the papers we have studied so far, we observe a clear pattern that mandatory disclosures have implications for firms especially on their emissions. Most papers agree that mandatory disclosures cause firms to reduce their emissions, particularly their scope 1 emissions. Most researchers also find that mandatory disclosures have some financial repercussions for firms, with investors demanding a higher cost of capital for high-carbon emitting firms. There is also empirical evidence that firms consider the reputational effects of their emissions with the effect of these rules spilling over to other markets.

In conclusion, there is an increase in mandatory carbon disclosure across many countries, especially within the EU, with numerous sustainability reporting frameworks being developed, most of which involve carbon disclosure. In addition, the Nordic countries have, over the years, taken actions to deepen their cooperation in climate action, with Norway and Iceland joining the EU ETS (European Union Emission Trading System) in 2008 (*The European Union, Iceland and Norway Agree to Deepen Their Cooperation in Climate Action, 2019*). No prior research has been done on effect of mandatory carbon disclosure requirement on Nordic firms. We complement existing literature by focusing mainly on firms in the Nordics.

3.0 Theoretical Framework and Hypothesis

The issue of firms not internalizing the entire social cost of their externalities has been a significant concern for most governments and authorities worldwide. Even though most firms have pledged to reduce their carbon emissions and to be carbon neutral by 2050, most of the time, such pledges are made by leaders nearing retirement and,

therefore, will not run the company in the long term. In addition, most climate activists and citizens have raised the issue of greenwashing by firms and sometimes doubt the credibility of these pledges. For this reason, countries worldwide have developed policies like carbon taxes, carbon trading schemes, and mandatory disclosures, among others, to mitigate climate risk. For example, the United Kingdom and most Nordic countries have introduced mandatory carbon disclosure and social reporting requirements, demanding firms to include non-financial reporting in their annual reports.

In this paper, we want to answer the question, does mandatory carbon disclosure have any impact on disclosing firms' GHG emissions and firm value?

3.1 Hypothesis

(Krueger et al., 2021) find that the will and commitment to introduce and implement mandatory ESG disclosures likely differ across countries because of economic development, environmental challenges, or political structure. However, if mandatory disclosure's impact is robust enough across countries and sectors to mitigate climate risk, most countries will be encouraged to adopt these measures. For this reason, we would like to test the null hypotheses that:

H1: Nordic firms subject to mandatory carbon disclosure requirements and forced to disclose their emissions as a result of the regulation do not reduce their emissions compared to firms that were voluntarily disclosing before the regulation.

H2: Nordic firms subject to mandatory carbon disclosure requirements and forced to disclose their emissions as a result of the regulation do not reduce their GHG emission intensity compared to firms that were voluntarily disclosing before the regulation.

H3: Nordic firms subject to mandatory carbon disclosure requirement and forced to disclose their emissions as a result of the regulation show no change in firm value compared to firms that were voluntarily disclosing before the regulation.

As previously stated, prior research (Jouvenot & Krueger, 2019) found that mandatory disclosure in the UK reduced firms' GHG emissions. They observed three reasons UK firms decreased their emissions and noted that UK firms with high emissions recorded

lower operating performance relative to their peers due to increased operating costs after the regulation was implemented. Also, they observed that institutional investors decreased their holdings in high-emitting firms. Finally, they noted that UK firms that disclosed lower emissions than their peers in the same industry experienced positive announcement returns. Hence, we notice that most reasons for UK firms' emission reduction seem to be financially motivated. They conducted this research using a difference-in-difference approach by comparing the change in GHG emissions between the UK (treatment group) and European firms (control group) before and after the regulation while controlling for country, industry, and firm-level characteristics.

The authors (Jouvenot & Krueger, 2019) gathered data from Worldscope Refinitiv GHG emissions data. Firms with annual sales growth larger than 500% and those with negative assets or sales were excluded. Furthermore, they restricted their sample to firms that reported GHG emissions in 2010 to address the concerns that their results might be driven by firms that started disclosing their emissions only after the regulation was implemented. Another reason for the restriction was to address the concern that UK firms that started disclosing their GHG emissions did so because they anticipated the regulation.

Another paper (Bolton & Kacperczyk, 2020) noticed that UK's mandatory carbon disclosure resulted in lower stock-level uncertainty. However, they observed that there is no disciplining effect of disclosure on firms, at least for the first year a company discloses its emissions, concluding that the reduced cost of capital following carbon disclosure is not likely to be driven by moral hazard. They also found evidence that disclosures have the most substantial effect in North America and Asia, with the weakest effect observed in Europe. The author's primary source of data in this experiment was Trucost, where they obtained information on estimated and disclosed-firm level GHG emissions. They used this data in addition to data on stock returns and corporate balance sheets provided by FactSet. Their full data set contained 14,468 firms across 77 countries. Using ESG data collated by MSCI, they controlled for the other variables correlated with carbon emissions to isolate the impact of carbon emission disclosures. (Bolton et al.) observed that growth in emissions is lower for disclosing firms compared to non-disclosing firms when it comes to yearly changes in emissions. Nevertheless, they noticed that mean $\log(\text{size})$, book-to-market ratios, leverage,

business segment diversification, and volatility are almost identical for disclosing and non-disclosing firms. They observed that firms that disclose their emissions had slightly higher fixed assets (log (PPE)) and ROE relative to non-disclosing firms, indicating that disclosing firms are, to some extent, less risky.

In this paper, we use the above-mentioned theory as our foundation to examine the effect of mandatory carbon disclosure on carbon emissions, emission intensity, and firm value of Nordic firms.

4.0 Methodology

In this section, we present the methods used to test the hypothesis we derived in the previous section. We split the section into several parts, where we first briefly discuss our research objectives, statistical methods, data collection process, and finally, the limitations of our methodology.

Our main research objective is to test if the introduction of mandatory carbon disclosure requirements in the Nordics has an impact on the GHG emissions of these firms. We also want to test if the introduction of these requirements has any effect on firm value.

We did this by using the standard difference-in-differences approach. Difference-in-differences is a widely used statistical method for evaluating the impact of a policy or treatment. In our analysis, it helped us compare the change in emissions and firm value before and after the implementation of mandatory carbon disclosure for Nordic firms subject to the policy and had to disclose (treatment group) relative to firms that were already voluntarily disclosing even before the introduction of the mandatory disclosure regulations (control group).

Our main data source for carbon emission disclosure is Refinitiv ESG. Refinitiv gives information on disclosed carbon and other greenhouse gas emissions. They report emissions in tons of carbon dioxide equivalent (tCO_{2e}). From this data, we were able to determine companies in the Nordics that disclose information about their scope 1 and 2 emissions, and when they began to disclose it.

As mentioned earlier, to test the effect of these mandatory disclosures on carbon emissions and firm value, we created a control and treatment group. As a quick

reminder, our treatment group consists of Nordic firms that were not disclosing their carbon emissions but were forced to disclose because of the introduction of mandatory carbon disclosure requirements. On the other hand, our control group (voluntarily disclosing from 2013) consists of Nordic firms that were voluntarily disclosing even before the introduction of the mandatory carbon disclosure requirements. The main reason for using this approach is to distinguish between firms that voluntarily disclosed from those that only disclosed because they were forced to disclose. We would normally expect a different impact. This is because those that have disclosed earlier are likely to have already taken actions to reduce their emissions, and therefore, we might not see much action after it becomes compulsory. In contrast, firms in our treatment group are likely to take more action.

We considered firms in Sweden, Denmark, Norway, and Finland in our treatment and control groups. We only considered firms in the top 30% in terms of market capitalization in these countries. To avoid the issue of survival bias in our data, we did not use current market capitalization, but rather the market capitalization at the beginning of each year for each observation. We did not consider small firms and other firms that have not been disclosing consistently before and after the regulation; this is because they have different characteristics related to their size that may negatively affect our inferences. They are also not attractive because there is less data available on them.

Additionally, we only considered data from 2013 to 2021. This is because data on scope 1 and 2 emissions, even for the voluntarily disclosing companies in our control group, were not readily available before 2010. However, the time horizon is enough to measure the impact of the disclosure requirement.

Data on Scope 1 and 2 emissions for our control group were available on Refinitiv ESG for our time horizon from 2013 to 2021. However, for our treatment group, we did not have data on their pre-regulation emissions, because these firms were not disclosing and only started disclosing after the regulation. We, therefore, estimated the pre-regulation Scope 1 and 2 emissions for firms in our treatment group for the period between 2013-2018 (depending on when the law was introduced in each country) using carbon emission data for comparable firms on the Euro Stoxx 600.

4.1 Pre-regulation estimation (Treatment group)

To estimate the pre-regulation Scope 1 and 2 emissions for our treatment group, we used carbon emissions data on firms in Euro Stoxx 600 (from Bloomberg) that consistently disclosed their emissions from 2013 to 2018 to estimate the following panel regression equation:

$$y_{it} = \alpha_0 t + \alpha_1, it \text{ Size} + \alpha_2, it \text{ Sector} + \alpha_3, it \text{ Leverage} + \alpha_4, it \left(\frac{B}{M} \right) + \alpha_5, it \text{ ROE} + \alpha_6, i(\text{Country FEs}) + \alpha_7, t (\text{Time FEs}) + \varepsilon_{it}$$

(Equation 1)

In this equation, t and i index event years, and a particular firm in our sample, respectively, and the dependent variable is either the natural logarithm of Scope 1 or 2 emissions of comparable firms (in particular sector) on the Euro Stoxx 600 measured in tCO_{2e} (denoted by *ln Scope 1 or 2 emissions*). We also control for firm size (using a natural log of total revenue as a proxy), sector, leverage (using a firm's debt-to-equity ratio as a proxy), book-to-market ratio (B/M), return on equity (ROE), country and time fixed effects respectively, with ε_{it} denoting the error term.

From this regression, we obtained sector and firm characteristic matched coefficients of similar disclosing firms on the Euro Stoxx 600. We then used the coefficients of each of our control variables and multiplied them by the company-specific characteristics of our control variables, like size, leverage, etc., of the firms in our treatment group; we then added them together, including the constant (intercept) as in the equation above to come up with the pre-regulation estimates of Scope 1 and 2 emissions. Sector is a dummy variable that equals 1 if a firm is in a particular sector and zero otherwise. We initially decided to use sector instead of industries in calculating our estimates because Euro stock 600 has so many industries, and we wanted to reduce the number of dummies to avoid any bias and overfitting issues. We used 11 sector dummies in total. However, in our robustness checking, we used industries to calculate the estimated emissions. Likewise, CountryFEs is a dummy variable that equals 1 for a specific country in our treatment group and 0 otherwise. For example, when estimating the emissions of a Norwegian firm, this equals 1 if a firm in

our treatment group is a Norwegian firm and zero otherwise. We used 21 country dummies in total. The coefficients from the four Nordic country-fixed effects as estimated from the Euro Stoxx 600 regression were used in calculating the estimated pre-regulation GHG emissions of our treatment group. TimeFEs is a dummy variable that equals 1 for a particular year we are looking at and zero otherwise. We used six-time dummies (2013-18) in our estimation. In total, we used 36 dummies in estimating Scope 1 and 2 emissions for our treatment group.

In calculating the estimates of Scope 1 and 2 emissions (levels), we used the full specification (plus the intercept) of the equation above, including coefficients of all the sector categories and control variables, even for those that were not statistically significant. However, for country categories, we only used the coefficients of the Nordic countries in our treatment group. The regression above helped us obtain the estimated pre-regulation Scope 1 and 2 emissions for our treatment group.

4.2 Panel Regression (Impact of Regulation on GHG Emissions)

Under our null hypothesis that mandatory carbon disclosure requirement has no impact on Nordic firms, the change in GHG emissions levels (emission intensity) and firm value between our treatment group and control group would not be significantly different from zero. On the other hand, if the introduction of the disclosure requirements leads firms in our treatment group to reduce their GHG emissions, the change in emissions between our treatment and control group should be negative. Similar to the regression used by (Jouvenot & Krueger 2019) to study the real and financial effects of mandatory carbon disclosure in the United Kingdom, to test this hypothesis, we estimate the following difference-in-differences (DID) regression equation:

$$\begin{aligned}
 y_{it} = & \beta_0 t + \beta_1 Treat_i + \beta_2 Aftert + \beta_3 Treat_i * Aftert \\
 & + \beta_4, it (\Delta \text{ in size}) + \beta_5, it (Leverage) + \beta_6, it \left(\frac{B}{M} \right) \\
 & + \beta_7, it (ROE) + + \beta_8, i Sector + \beta_9, i (Country FEs) + \epsilon_{it}
 \end{aligned}$$

(Equation 2)

In this equation, t indexes event years, and i indexes a particular firm, and the dependent variable is either a change in a firm's Scope 1 emissions (emission intensity), Scope 2 emissions (emission intensity), or a combination of the two as measured in tCO_{2e} . We decided to use (changes) in GHG emissions instead of levels of GHG emissions as our dependent variable, unlike emission levels used by (Jouvenot & Krueger 2019) to study the impact of mandatory disclosure in the United Kingdom. This is because we believe there is high persistence in emission levels which may result in a very high adjusted r -squared which does not mean anything (explain any variation). We measured GHG emission intensity as the ratio between GHG emissions and total revenues. *Treat* is a dummy variable that equals 1 if a firm is part of our treatment group (and only started disclosing after the implementation of the mandatory disclosure requirement) and zero otherwise. *After* is a dummy variable that equals one in the event years where Nordic firms in both our treatment and control group had to be in compliance with the disclosure requirement and zero otherwise. We also include firm-level controls that include changes in size (using total revenue as a proxy), leverage (using debt-to-equity ratio as a proxy), book-to-market ratio, and return on equity. We also control for sector and country-fixed effects. This adds robustness to our analysis. We did not include time-fixed effects in this regression because we believe if revenues grow with time, then the revenues will take into account the time component, and therefore the two will be highly correlated.

What ultimately matters in our analysis is the coefficient estimate for the interaction between the *Treat* and *After* dummies, that is, β_3 , which measures the change in average GHG emissions between our treatment and control group following the introduction of the regulation. If the law has no impact on firm-level GHG emissions, β_3 should not be statistically significantly different from zero. In contrast, if the law leads to a reduction in firm-level GHG emissions, β_3 should be negative and significant.

4.3 Panel Regression (Impact of Regulation on firm value)

We test our third null hypothesis that Nordic firms subject to mandatory carbon disclosure requirements (and forced to disclose) show no change in firm value compared to firms that were voluntarily disclosing even before the regulation. To

examine this hypothesis, we estimate the following difference-in-differences (DID) regression equation:

$$\begin{aligned}
 y_{it} = & \gamma_0 t + \gamma_1 Treat_i + \gamma_2 Aftert + \gamma_3 Treat_i * Aftert \\
 & + \gamma_{4,it} (\Delta \text{ in size}) + \gamma_{5,it} (Leverage) + \gamma_{6,it} \left(\frac{B}{M} \right) \\
 & + \gamma_{7,it} (ROE) + \gamma_{8,i} Sector + \gamma_{9,i} (Country FEs) + \epsilon_{it}
 \end{aligned}$$

(Equation 3)

Similar to the previous equations, i and t index firms and event years, respectively, and the dependent variable (y_{it}) is either firm value or change in firm value (using market capitalization measured in millions of Euros as a proxy for firm value). Market capitalization is a measure used to determine the total value or size of a publicly traded company. It is calculated by multiplying the market price of a single share by the total number of outstanding shares. To avoid the issue of survival bias, we used market capitalization at the beginning of the year for each observation. Like the previous equation, $Treat$ is a dummy variable indicating if a firm is part of our treatment group (and only started disclosing after the implementation of the mandatory disclosure requirement) and 0 otherwise. $After$ is a dummy variable that equals one in the event years where Nordic firms in both our treatment and control group had to be in compliance with the disclosure requirement and 0 otherwise. We also include firm-level controls that include changes in size (using total revenue as a proxy), leverage (using debt-to-equity ratio as a proxy), book-to-market ratio, and return on equity. We also control for sector and country-fixed effects.

There are some limitations and challenges we faced in our estimation process. Some of them include the assumption that the pre-regulation emission estimate of a company in our treatment group is equal to the average sector emission of a comparable firm on the Euro Stoxx 600 given size, return on equity, and other firm characteristics. It could be the case that companies within the same sector with the same characteristics have different emissions, but we do not have enough information, so we use our best guess. Additionally, the small sample size may limit the statistical power and generalizability of our findings. To address this, we could increase our sample by including firms from

other regions. However, our main objective is to measure the impact of the regulation specifically on Nordic firms.

5.0 Main Data

In this section, we present our data set by describing the sources and data collection process. We also take a closer look at the emissions and firm-level control variables. Finally, we present tables with summary statistics for all variables and briefly discuss the summary statistics.

Our data set combines WorldScope Refinitiv and the Bloomberg Terminal. Our combined data set contains 20,296 observations. We had 67 firms in our control group and 51 firms in our treatment group. Our treatment and control groups contained 118 unique companies from 4 countries across 11 sectors. However, data from Euro Stoxx 600 that we used in the estimation of undisclosed pre-regulation GHG emissions of our treatment group covers 21 countries, 206 unique companies, 11 sectors, and 59 industries between the period 2013-2018. We collected carbon emissions data (Scopes 1 and 2) measured in tons of carbon dioxide equivalent (tCO_2e) from Worldscope Refinitiv for our treatment and control group covering the period 2013 to 2021. From this data, we were able to determine which companies disclosed their GHG emissions and when they began to disclose them. Reporting of emissions data by firms is largely confined to Scope 1 and 2 emissions. Therefore, we focused mainly on these emissions in our analysis. Given that the definition, measurements, and methods of computation for Scope 3 emissions have been changing over the last decade, we found the data on Scope 3 emissions not reliable enough, and therefore, we did not include Scope 3 emissions in our analysis, unlike (Bolton & Kacperczyk, 2020) that used Scope 3 emissions as part of their analysis.

In addition, we only included companies that consistently disclosed their Scope 1 and 2 emissions from 2013 to 2021 in our control group, and for our treatment group, we only included companies that consistently disclosed their carbon emissions from the year the regulation was implemented in that particular country in the Nordics, up to 2021. This allowed us to get rid of firms with numerous unavailable data from our sample.

Additionally, we collected financial data (as control variables) in Euros (€) on both our control and treatment group from Bloomberg, with the exception of the market capitalization of firms in both groups, which were collected from World Refinitiv. Also, the accounting/ financial data from Euro Stoxx 600 that we used to estimate Scope 1 and 2 emissions of our treatment group before the regulations were implemented was collected from Bloomberg. Our financial and accounting data, especially for our control variables for both treatment and control groups, were measured in Euros (€) using the average daily exchange rate for each year. This is to ensure that everything is measured in a single currency (which ensures consistency in our data). We also collected data on market capitalization for both our control and treatment groups from Refinitiv. As previously stated, we only considered firms in the top 30% in terms of market capitalization in Finland, Sweden, Norway, and Denmark for our treatment and control group. To avoid the issue of survival bias in our data, we did not use current market capitalization, but we used market capitalization at the beginning of each year for each observation.

5.1 Definition of Variables

From the Bloomberg terminal, we obtained our control variables. These variables helped us control for the potential firm-level characteristics that could influence GHG emissions of firms and firm value, other than the impact from the implementation of the mandatory carbon disclosure requirements. Our control variables include changes in revenue (used as a proxy for firm size), sector/industry, leverage (debt-to-equity ratio of a firm (D/E)), book-to-market ratio (B/M), return on equity (ROE), and country and time fixed effects.

Revenue refers to the total amount of income or sales generated by a business or organization through its primary activities, typically from the sale of goods or the provision of services. In our analysis, we used the change in revenue year-on-year as a proxy for firm size. Sector/industry refers to the sector or industry a firm belongs to. We used them as a dummy variable which equals 1 if a firm belongs to a particular sector/industry or 0 otherwise. Debt-to-equity ratio is a financial ratio that measures the proportion of a company's total debt to its total equity. It provides insights into the company's capital structure and the extent to which it relies on debt financing relative

to its own shareholders' equity. We used the D/E as a proxy for the leverage of a firm. The book-to-market ratio, also known as the B/M ratio or the value factor, is a financial metric used to assess the investment attractiveness of a company by comparing its book value of equity to its market value of equity. It is calculated by dividing the book value of equity (or net assets) per share by the market price per share.

Also, Return on Equity (ROE) is a financial ratio that measures the profitability and efficiency of a company in generating profits from the shareholders' equity invested in the firm. It indicates the return earned by the company for each dollar of equity invested by shareholders. All these are firm-level characteristics that could influence the GHG emissions of firms and firm value that we controlled for to ensure any impact on firm value and GHG emissions is as a result of the mandatory carbon disclosure. Additionally, we included country (CountryFE_s), which is a dummy that equals 1 if a firm belongs to a particular country and 0 otherwise. (TimeFE_s), is also a dummy that equals 1 in the year the mandatory disclosure requirement came into effect in a particular country and 0 otherwise. The dependent variables in our main regression denoted by (*yit*) denotes changes in Scope 1 and 2 emissions/emission intensity year-on-year. As mentioned earlier, Scope 1 emissions are direct emissions from the operations of affiliates that are owned or controlled by a company. Scope 2 emissions are those that come from the generation of purchased heat, steam, and electricity. In the case of measuring the impact of the regulation on firm value, our dependent variable becomes firm value/changes in firm value year on year (YoY). Like Matsumura, Prakash, and Vera-Muñoz (2014), we used market capitalization as a proxy for firm value. As previously mentioned, to avoid the issue of survival bias, we used market capitalization at the beginning of the year for each observation. Apart from our control variables, we also have the *Treat and After* dummies. *Treat* is a dummy variable that equals 1 if a firm is part of our treatment group and 0 otherwise. *After* is a dummy variable that equals one in the event years where Nordic firms in both our treatment and control group had to be in compliance with the disclosure requirement and 0 otherwise. The $Treat_i * After_i$ interaction term measures the difference in the average GHG emission/emission intensity of our treatment and control group after the introduction of the mandatory disclosure rule.

5.2 Description of Variables in Tables

Tables 1 and 2 show the results from the regression that we used to estimate the undisclosed pre-regulation Scope 1 and 2 emissions, respectively, of our treatment group. As previously stated, in calculating the estimates of Scope 1 and 2 emissions (levels), we used the full specification (plus the intercept) of the equation above, including coefficients of all the sector categories and control variables, even for those that were not statistically significant. From the tables, we find that the Adjusted R squared for Scope 1 and 2 emission levels are 0.84 and 0.75, respectively, meaning most of the variation in Scope 1 and 2 emission levels (84% for Scope 1 and 75% for Scope 2) is explained by our independent variables. Tables 8 and 9 show results from the regression (using data from Euro Stoxx 600) used in the estimation of our pre-regulation Scope 1 and 2 emissions, respectively. However, in this regression, we replaced sector-fixed effects with industry-fixed effects as part of our robustness checks to test if there will be any difference in results in terms of the impact of mandatory carbon disclosure requirement on GHG emissions of firms and firm value.

Table 3 shows the impact of mandatory carbon disclosure on changes in GHG emissions/emission intensity of firms in our treatment and control group. We find that the coefficient estimates for the interaction term between the After and Treat dummies, which measure how different the average changes in GHG emissions year-on-year (Scope 1, Scope 2, and Scope 1+2) for our treatment group differs from our control group after the introduction of the mandatory disclosure law are all not statistically significantly different from zero. This means that the introduction of the law had no impact in terms of changes in average firm-level GHG emissions between our treatment and control group. Table 3 shows the same results for changes in emission intensity year-on-year (YoY) for Scope 1 and Scope 2. However, for changes in emission intensity Scope 1+2, we find that the coefficient of our interaction term is statistically significant at the 5% significance level. We observe that the coefficient of the ($Treat_t * After_t$) is positive although quite small (3,99E-05), indicating that the introduction of the law led to a slight increase in the average emission intensity (Scope 1+2) for our treatment group compared to our control group after the introduction of the law. Our results on changes in emission levels is contrary to the results from previous study like

(Jouvenot & Krueger 2019) which finds that the introduction of mandatory carbon disclosure requirements cause firms to reduce their GHG emissions levels. Our Adjusted R squared, which shows how well our model explains the data range between 4%-48%, which is relatively high. Table 10 shows the results from our Robustness test when we use industry-fixed effects instead of sector-fixed effects in our regression. We find that none of ($Treat_i * After_t$) interaction terms are significantly different from zero, with both changes in emissions and changes in emission intensity as the dependent variable. This means that the introduction of the mandatory disclosure law had no impact in terms of firm-level changes in average GHG emissions and emission intensity between our treatment and control group after the introduction of the law. From both Tables 3 and 10, we observe that the changes in firm size (using YoY changes in revenues as a proxy) are positive and statistically significant for changes in emission for Scope 1 and Scope 1+2. This means an increase in firm size results in an increase in Scope 1 and Scope 1+2 emissions of firms in the Nordics, keeping everything else constant, although this increase is relatively small. Similarly, the coefficients of changes in emission intensity for Scope 1 and Scope 1+2 are negative and statistically significant. This indicates that as firms in the Nordics become larger, they become efficient with their emissions, resulting in a slight decrease in their carbon emissions (Scope 1 and Scope 1+2) per unit of activity level (as measured by total revenue), keeping everything else constant.

Table 1: Regression on Scope 1 emissions for Euro STOXX 600 companies

Below are results from a regression on Scope 1 emissions (in tCO₂e) for the Euro STOXX 600 companies from 2013 to 2018. The estimates obtained for the variables were used to estimate our treatment companies' unreported Scope 1 emissions. The variables in *italic* text are all dummy variables (Sector, Country, and Year). The relevant country dummies have been marked in bold italic text to highlight our focus group (Denmark, Finland, Norway, Sweden). The asterisk and dot next to the t-value shows the significance levels at which the corresponding coefficients are significant. “.”, *, and *** indicate 10%, 5%, and 0,1% levels, respectively.

Coefficients	Estimate (1)	t-value (2)	
<i>(Intercept)</i>	-12,79	-13,99	***
Log(Revenue)	1,18	38,33	***
<i>Sector 15 (Materials)</i>	0,25	1,07	
<i>Sector 20 (Industrials)</i>	-2,09	-9,16	***
<i>Sector 25 (Consumer Discretionary)</i>	-3,52	-15,00	***
<i>Sector 30 (Consumer Staples)</i>	-2,23	-9,36	***
<i>Sector 35 (Health Care)</i>	-2,36	-9,32	***
<i>Sector 40 (Financials)</i>	-6,22	-26,95	***
<i>Sector 45 (Information Technology)</i>	-3,74	-13,79	***
<i>Sector 50 (Communication Services)</i>	-4,27	-16,69	***
<i>Sector 55 (Utilities)</i>	0,91	3,84	***
<i>Sector 60 (Real Estate)</i>	-2,83	-9,53	***
Leverage	0,03	1,01	
B/M	0,64	5,60	***
ROE	0,03	0,88	
<i>Belgium</i>	1,13	1,49	
<i>Bermuda</i>	-0,17	-0,23	
<i>Chile</i>	-0,30	-0,39	
<i>Denmark</i>	-0,55	-0,95	
<i>Finland</i>	-0,87	-1,53	
<i>France</i>	-0,47	-0,86	
<i>Germany</i>	0,26	0,47	
<i>Ireland</i>	-1,34	-1,77	.
<i>Italy</i>	0,16	0,28	
<i>Jordan</i>	0,33	0,44	
<i>Luxembourg</i>	0,98	1,58	
<i>Netherlands</i>	-0,82	-1,40	
<i>Norway</i>	0,56	0,95	
<i>Poland</i>	0,07	0,09	
<i>Portugal</i>	0,21	0,33	
<i>South Africa</i>	0,08	0,10	
<i>Spain</i>	-0,82	-1,50	
<i>Sweden</i>	-0,97	-1,72	.
<i>Switzerland</i>	-0,50	-0,90	
<i>United Kingdom</i>	-0,09	-0,17	
2014	-0,09	-0,75	
2015	-0,16	-1,32	

2016	-0,16	-1,25
2017	-0,18	-1,44
2018	-0,28	-2,25 *

RSE: 1,265 on 1196 degrees of freedom

Multiple R-Sq.: 0,8477

F-stat: 170,6 on 39 and 1196 DF, p-value: < 2,2e-16

Number of observations: 1236

Adj. R-Sq.: 0,8427

Table 2: Regression on Scope 2 emissions for Euro STOXX 600 companies

Below are results from a regression on Scope 2 emissions (in tCO₂e) for the Euro STOXX 600 companies from 2013 to 2018. The estimates obtained for the variables were used to estimate our treatment companies' unreported Scope 2 emissions. The variables in *italic* text are all dummy variables (Sector, Country, and Year). The relevant country dummies have been marked in bold italic text to highlight our focus group (Denmark, Finland, Norway, Sweden). The asterisk and dot next to the t-value shows the significance levels at which the corresponding coefficients are significant. “.”, **, and *** indicate 10%, 1%, and 0,1% levels, respectively.

Coefficients	Estimate (1)	t-value (2)	
<i>(Intercept)</i>	-10,85	-13,72	***
Log(Revenue)	1,06	39,66	***
<i>Sector 15 (Materials)</i>	2,75	13,59	***
<i>Sector 20 (Industrials)</i>	0,21	1,09	
<i>Sector 25 (Consumer Discretionary)</i>	0,23	1,13	
<i>Sector 30 (Consumer Staples)</i>	0,72	3,47	***
<i>Sector 35 (Health Care)</i>	0,92	4,19	***
<i>Sector 40 (Financials)</i>	-1,34	-6,72	***
<i>Sector 45 (Information Technology)</i>	0,71	3,04	**
<i>Sector 50 (Communication Services)</i>	0,40	1,83	.
<i>Sector 55 (Utilities)</i>	1,38	6,73	***
<i>Sector 60 (Real Estate)</i>	1,73	6,74	***
Leverage	0,09	3,10	**
B/M	0,08	0,78	
ROE	-0,12	-4,10	***
<i>Belgium</i>	-1,15	-1,76	.
<i>Bermuda</i>	-2,89	-4,42	***
<i>Chile</i>	-0,83	-1,28	
<i>Denmark</i>	-2,35	-4,66	***
<i>Finland</i>	-2,11	-4,29	***
<i>France</i>	-2,12	-4,49	***
<i>Germany</i>	-1,81	-3,77	***
<i>Ireland</i>	-4,03	-6,18	***
<i>Italy</i>	-2,35	-4,86	***
<i>Jordan</i>	-1,07	-1,63	
<i>Luxembourg</i>	-1,61	-2,99	**
<i>Netherlands</i>	-2,18	-4,29	***
<i>Norway</i>	-2,00	-3,93	***
<i>Poland</i>	-0,90	-1,38	
<i>Portugal</i>	-1,60	-2,88	**
<i>South Africa</i>	-0,77	-1,19	
<i>Spain</i>	-1,73	-3,65	***
<i>Sweden</i>	-1,96	-4,01	***
<i>Switzerland</i>	-2,31	-4,76	***
<i>United Kingdom</i>	-2,11	-4,53	***
2014	-0,07	-0,61	
2015	-0,10	-0,97	

2016	-0,15	-1,35
2017	-0,21	-1,96 .
2018	-0,31	-2,90 **

RSE: 1,095 on 1196 degrees of freedom

Multiple R-Sq.: 0,7664

Adj. R-Sq.: 0,7588

F-stat: 100,6 on 39 and 1196 DF, p-value: < 2,2e-16

Number of observations: 1236

Table 3: Regressions on Changes in emissions and Changes in emission intensity of our Nordic sample

The table contains results from six regressions (see columns). The first three are on changes in GHG emissions. Column (1) has changes in Scope 1 emissions as the dependent variable, (2) has changes in Scope 2 emissions as the dependent variable, and (3) has changes in Scope 1+2 as the dependent variable. The last 3 are on changes in emission intensity (Emissions/Revenue) of the companies. Column (4) has changes in Scope 1 emissions intensity as the dependent variable, (5) has changes in Scope 2 emissions intensity as the dependent variable, and (6) has changes in Scope 1+2 emissions intensity as the dependent variable. The dataset on which these regressions were run contains companies from all four of our focus countries i.e., Denmark, Finland, Norway, and Sweden. The currencies have been converted to EUR at the average exchange rates for the currencies in each specific year. The results are the coefficient estimates and their respective t-stats in parentheses under those estimates. All dummy variables (Sector, Country, and Regulation) are in *italic* text and the most important control variable is a regulation dummy variable called *Treat x After* which captures the effect of the introduction of mandatory emissions reporting regulation on our sample. *Treat* is a dummy which equals 1 if a company belongs to our treatment group and 0 otherwise. *After* is a dummy which equals 1 in regulation years (e.g., from 2018 onwards for Norway) and 0 otherwise (before 2018 for Norway). The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

	Change in emissions (YoY)			Change in emission intensity (YoY)		
	Scope 1 (1)	Scope 2 (2)	Scope 1+2 (3)	Scope 1 (4)	Scope 2 (5)	Scope 1+2 (6)
<i>Treat</i>	- 19 290,00 (-0,199)	16 560,00 (1,873)	- 2 730,00 (-0,028)	-1,23E-05 (-0,800)	-2,73E-06 (-0,843)	-1,51E-05 (-0,949)
<i>After</i>	- 72 730,00 (-0,907)	6 231,00 (0,853)	- 66 500,00 (-0,811)	-1,61E-05 (-1,260)	-2,48E-06 (-0,925)	-1,85E-05 (-1,413)
<i>Treat x After</i>	- 94 170,00 (0,794)	- 4 856,00 (-0,450)	89 310,00 (0,737)	3,39E-05 (1,797)	6,00E-06 (1,518)	3,99E-05 (2,056)*
Change in Revenue (YoY)	0,00024 (22,603)***	0,0000012 (1,266)	0,00024 (22,227)***	-1,97E-14 (-11,877)***	-4,28E-16 (-1,232)	-2,01E-14 (-11,793)***
<i>Sector 15 (Materials)</i>	59 850,00 (0,354)	-55 650,00 (-3,608)***	4 202,00 (0,024)	-1,14E-05 (-0,422)	-9,08E-06 (-1,608)	-2,04E-05 (-0,738)
<i>Sector 20 (Industrials)</i>	114 900,00 (0,720)	-13 260,00 (-0,912)	101 600,00 (0,623)	2,65E-05 (1,045)	-5,13E-08 (-0,010)	2,65E-05 (1,014)

<i>Sector 25 (Consumer Discretionary)</i>	76 110,00	-26 600,00	49 510,00	1,03E-05	-8,86E-08	1,02E-05
	(0,411)	(-1,576)	(0,262)	(0,349)	(-0,014)	(0,337)
<i>Sector 30 (Consumer Staples)</i>	83 860,00	- 6 292,00	77 570,00	1,08E-05	-4,07E-07	1,04E-05
	(0,465)	(-0,382)	(0,420)	(0,378)	(-0,068)	(0,353)
<i>Sector 35 (Health Care)</i>	81 540,00	-32 620,00	48 930,00	5,46E-06	-4,99E-07	4,97E-06
	(0,391)	(-1,718) .	(0,230)	(0,165)	(-0,072)	(0,146)
<i>Sector 40 (Financials)</i>	102 700,00	- 2 603,00	100 100,00	4,05E-06	-5,08E-06	-1,04E-06
	(0,604)	(-0,168)	(0,576)	(0,150)	(-0,896)	(-0,037)
<i>Sector 45 (Information Technology)</i>	94 650,00	-13 880,00	80 770,00	7,62E-06	8,75E-06	1,64E-05
	(0,506)	(-0,814)	(0,422)	(0,256)	(1,403)	(0,535)
<i>Sector 50 (Communication Services)</i>	153 400,00	-11 530,00	141 900,00	7,64E-06	-6,27E-07	7,01E-06
	(0,815)	(-0,672)	(0,738)	(0,255)	(-0,100)	(0,228)
<i>Sector 55 (Utilities)</i>	3 763 000,00	28 160,00	3 791 000,00	-1,06E-04	-8,50E-07	-1,07E-04
	(10,292)***	(0,845)	(10,144)***	(-1,818) .	(-0,070)	(-1,781) .
<i>Sector 60 (Real Estate)</i>	74 870,00	- 8 242,00	66 630,00	7,49E-06	-3,40E-06	4,08E-06
	(0,385)	(-0,465)	(0,335)	(0,242)	(-0,524)	(0,128)
Leverage	- 2 316,00	- 254,00	- 2 570,00	-7,84E-07	8,72E-07	8,87E-08
	(-0,522)	(-0,628)	(-0,566)	(-1,110)	(5,887)***	(0,122)
B/M	- 21 780,00	-29 390,00	- 51 170,00	7,70E-06	3,48E-06	1,12E-05
	(-0,287)	(-4,251)***	(-0,660)	(0,639)	(1,373)	(0,901)
ROE	- 285 400,00	-18 540,00	- 304 000,00	-7,77E-06	2,32E-06	-5,44E-06
	(-1,287)	(-0,918)	(-1,341)	(-0,220)	(0,314)	(-0,150)
<i>Denmark</i>	- 766,60	30 300,00	29 540,00	9,96E-06	-2,11E-06	7,85E-06
	(-0,004)	(1,738) .	(0,151)	(0,327)	(-0,330)	(0,251)
<i>Finland</i>	- 15 700,00	21 700,00	6 005,00	1,48E-06	-1,73E-06	-2,52E-07
	(-0,087)	(1,315)	(0,032)	(0,051)	(-0,287)	(-0,008)
<i>Norway</i>	- 30 320,00	11 670,00	- 18 650,00	-6,09E-07	-3,39E-07	-9,49E-07
	(-0,184)	(0,779)	(-0,111)	(-0,023)	(-0,062)	(-0,035)

<i>Sweden</i>	-	26 660,00	20 710,00	-	5 951,00	-1,14E-05	-2,15E-06	-1,35E-05
		(-0,146)	(1,242)		(-0,032)	(-0,390)	(-0,353)	(-0,451)
Adj. R-Sq.		0,4804	0,06128		0,4727	0,1602	0,04943	0,16
Observations		944	944		944	944	944	944

Table 4-a shows the correlation between Scope 1 and Scope 2 emissions, and their intensities are positive and high (except for Scope 1 emission and Scope 1 emission intensity) but not perfectly correlated, as firms with different emission levels can have similar emission intensity due to size. Table 4-b shows the correlation between the change in emissions levels of Scope 1 and 2 and changes in emission intensity. We notice a relatively large and negative correlation (-0.363) between changes in Scope 1 emission levels and changes in Scope 1 emission intensity. Table 4-c shows the correlation between our dependent and independent variables. We notice size is positively correlated with changes in emission levels but negatively correlated changes in emission intensity. This is not surprising because size is inversely correlated with emission intensity. Thus, for the same emission levels, emission per unit of activity level (size) decreases with an increasing size all other variables remaining constant.

Table 4-a: Cross-Correlations

This table reports the cross-correlation between levels of emission and emission intensity variables in our sample for our focus group (Nordic region).

	Scope 1 (1)	Scope 2 (2)	Scope 1 Intensity (3)	Scope 2 Intensity (4)
Scope 1	1,00			
Scope 2	0,24	1,00		
Scope 1 Intensity	0,54	0,22	1,00	
Scope 2 Intensity	0,03	0,41	0,14	1,00

Table 4-b: Cross-Correlations

This table reports the cross-correlation between changes in emission levels and changes in emission intensity in our sample for our focus group (Nordic region).

	Δ emission levels Scope1 (1)	Δ emission intensity Scope1 (2)	Δ emission levels Scope2 (3)	Δ emission intensity Scope2 (4)
Δ emission levels Scope1	1,00			
Δ emission intensity Scope1	-0,363	1,00		
Δ emission levels Scope2	0,189	-0,080	1,00	
Δ emission intensity Scope2	-0,009	0,050	0,323	1,00

Table 4-c: Correlations for the dependent and explanatory variables

This table reports the correlations between our dependent variable (rows) and explanatory variables (columns). Column (5) only has one correlation as Log(Revenue) is only used in 1 out of the 8 regressions that were used (on Market Cap). All the NAs signify the variables that were not a part of the regression on that specific dependent variable.

	Δ in Revenue (1)	ROE (2)	Leverage (D/E) (3)	B/M (4)	Log(Revenue) (5)
Δ in emissions levels Scope1	0,648	0,010	-0,003	0,006	NA
Δ in emissions levels Scope2	0,059	0,020	0,002	-0,144	NA
Δ in emissions levels Scope1+2	0,642	0,011	-0,003	-0,004	NA
Δ in Emission Intensity Scope1	-0,402	-0,027	-0,035	0,014	NA
Δ in Emission Intensity Scope2	-0,045	-0,110	0,217	0,021	NA
Δ in Emission Intensity Scope1+2	-0,399	-0,047	0,008	0,017	NA
Market Cap EUR	NA	0,337	0,008	-0,146	0,487
Δ in Market Cap	0,232	0,164	-0,018	-0,128	NA

From Table 5, we find that the coefficient of our interaction term ($Treat_i * After_t$), which tells us how the average firm value for our treatment group differs from our control group after the introduction of the mandatory disclosure law, is not statistically significantly different from zero. Hence, similar to the results by Griffin, Lont, and Sun (2017), we find no differential effect on the firm value of firms in our treatment and control group after the introduction of the law. However, we find that most of our control variables, including size, B/M, and leverage, are statistically significant, meaning they explain variation in firm value. We had an Adjusted R-squared of 0.57. This means our model explains approximately 57% of the variation in our data.

Table 5: Regression on Market Cap of firms in our Nordic sample

This table represents the regression on Market Cap (in EUR) for all companies in our sample. We use this to judge the financial performance of the firms after the introduction of mandatory disclosure regulation in each of our Nordic countries (Denmark, Finland, Norway, and Sweden). All dummy variables are in *italic* text and our most important variable is the *Treat x After* dummy. It captures the effect of the introduction of mandatory emissions reporting regulation on our sample. *Treat* is a dummy which equals 1 if a company belongs to our treatment group and 0 otherwise. *After* is a dummy which equals 1 in regulation years (e.g., from 2018 onwards for Norway) and 0 otherwise (before 2018 for Norway). The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

Coefficients	Estimate t-value	
	(1)	(2)
<i>Treat</i>	- 1 070 000 000	-0,969
<i>After</i>	1 656 000 000	1,898 .
<i>Treat x After</i>	- 1 467 000 000	-1,126
Log(Revenue)	3 477 000 000	15,289 ***
<i>Denmark</i>	- 59 180 000 000	-10,797 ***
<i>Finland</i>	- 63 290 000 000	-11,618 ***
<i>Norway</i>	- 59 800 000 000	-11,383 ***
<i>Sweden</i>	- 61 450 000 000	-11,357 ***
Leverage	188 200 000	3,604 ***
B/M	- 1 755 000 000	-2,051 *
ROE	21 900 000 000	8,415 ***
<i>Sector 15 (Materials)</i>	- 10 220 000 000	-5,373 ***
<i>Sector 20 (Industrials)</i>	- 9 393 000 000	-5,255 ***
<i>Sector 25 (Consumer Discretionary)</i>	- 8 968 000 000	-4,324 ***
<i>Sector 30 (Consumer Staples)</i>	- 12 880 000 000	-6,392 ***
<i>Sector 35 (Health Care)</i>	247 900 000	0,106
<i>Sector 40 (Financials)</i>	- 1 586 000 000	-0,832
<i>Sector 45 (Information Technology)</i>	- 5 603 000 000	-2,678 **
<i>Sector 50 (Communication Services)</i>	- 8 546 000 000	-4,055 ***
<i>Sector 55 (Utilities)</i>	- 1 576 000 000	-0,404
<i>Sector 60 (Real Estate)</i>	- 2 555 000 000	-1,15

RSE: 1,045E+10 on 1041 degrees of freedom

Multiple R-sq.: 0,5766

Adj. R-sq.: 0,5681

F-stat: 67,52 on 21 and 1041 DF, p-value: < 2,2e-16

From Table 6, we make the change in market capitalization (YoY) our dependent variable, unlike in Table 5, where market capitalization is our dependent variable. We find similar results that the interaction term ($Treat_i * After_t$) is not statistically significant. This means we had no differential effect in terms of changes in the firm value of firms in our treatment and control group after the introduction of the law.

Table 6: Regression on Change in Market Cap of firms in our Nordic sample

This table represents the regression on Change in Market Cap (in EUR) for all companies in our sample. We also use this to judge the financial performance of the firms after the introduction of mandatory disclosure regulation in each of our Nordic countries (Denmark, Finland, Norway, and Sweden). All dummy variables are in *italic* text and our most important variable is the *Treat x After* dummy. It captures the effect of the introduction of mandatory emissions reporting regulation on our sample. *Treat* is a dummy which equals 1 if a company belongs to our treatment group and 0 otherwise. *After* is a dummy which equals 1 in regulation years (e.g., from 2018 onwards for Norway) and 0 otherwise (before 2018 for Norway). The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

Coefficients	Estimate t-value	
	(1)	(2)
<i>Treat</i>	- 165 400 000	-0,355
<i>After</i>	379 400 000	0,985
<i>Treat x After</i>	170 200 000	0,299
Δ in Revenue	0,35	7,021 ***
<i>Denmark</i>	1 840 000 000	2,002 *
<i>Finland</i>	1 097 000 000	1,262
<i>Norway</i>	1 209 000 000	1,532
<i>Sweden</i>	947 100 000	1,077
Leverage	25 210 000	1,182
B/M	- 763 800 000	-2,096 *
ROE	3 517 000 000	3,303 ***
<i>Sector 15 (Materials)</i>	- 820 200 000	-1,009
<i>Sector 20 (Industrials)</i>	- 830 000 000	-1,083
<i>Sector 25 (Consumer Discretionary)</i>	- 1 807 000 000	-2,032 *
<i>Sector 30 (Consumer Staples)</i>	- 1 075 000 000	-1,239
<i>Sector 35 (Health Care)</i>	- 27 680 000	-0,028
<i>Sector 40 (Financials)</i>	- 1 128 000 000	-1,381
<i>Sector 45 (Information Technology)</i>	- 854 600 000	-0,951
<i>Sector 50 (Communication Services)</i>	- 1 638 000 000	-1,813 .
<i>Sector 55 (Utilities)</i>	- 3 545 000 000	-2,018 *
<i>Sector 60 (Real Estate)</i>	- 375 300 000	-0,402

RSE: 4,232e+09 on 923 degrees of freedom.

Multiple R-sq.: 0,1186

Adj. R-sq.: 0,09852

F-stat: 5,913 on 21 and 923 DF, p-value: < 1,9e-15

Table 7 reports the summary statistics on firm characteristics in the full sample, firms in our control group, and firms in our treatment group respectively. A first notable observation is that the control group has higher total average emission levels compared to the treatment group (the log total Scope 1, Scope 2, and Scope 1+2 emissions of the average firm in our control group are 10.76, 11.04, 12.07 respectively, compared to 7.35, 8.50 and 9.28 respectively for our treatment group). The per-firm mean carbon

emissions are reported in tons of carbon dioxide equivalent (tCO_{2e}). There is also higher variability (as measured by the standard deviation) in levels of emissions across all Scopes for the treatment group relative to the control group. The standard deviation for Log (Scope 1, 2, 1+2) for our treatment group are 4.57, 2.35, and 2.73, respectively. Whilst the standard deviation of our control group are 3.21, 1.88, and 2.22 for Log (Scope 1, 2, and 1+2), respectively. Additionally, a difference can be observed in the Scope (1, 2, and 1+2) emission intensity. The average emission intensity is higher for our control group compared to our treatment group.

Table 7: Descriptive Statistics

This table contains the descriptive statistics of our dataset that was used for all the regressions for our focus group (Denmark, Finland, Norway, and Sweden). It contains the mean, standard deviation, minimum, and maximum of all variables used to conduct this study. The table has been separated into 3 separate parts/columns. The column called “Full” contains information from the combined dataset with our treatment companies and control companies merged into a single set (118 companies). The column called “Control” contains information from only the companies in our control group (67 companies). Lastly, the column called “Treatment” contains information from only the companies in our treatment group (51 companies).

Variables	Full (1)				Control (2)				Treatment (3)			
	Mean	Stdev.	Min.	Max.	Mean	Stdev.	Min.	Max.	Mean	Stdev.	Min.	Max.
Log(Scope 1)	9,26	4,16	-26,81	18,05	10,76	3,21	-9,21	18,05	7,35	4,57	-26,81	17,31
Log(Scope 2)	9,94	2,44	-23,89	15,02	11,04	1,88	5,30	15,02	8,50	2,35	-23,89	12,97
Log(Scope 1+2)	10,83	2,78	-23,84	18,06	12,07	2,22	6,42	18,06	9,28	2,73	-23,84	17,31
Δ Scope 1	54 080	1 221 796	-3 364 000	29 700 000	83 979	1 595 454	-3 364 000	29 700 000	14 800	1 735 271	-18 564 247	25 964 099
Δ Scope 2	-7 740	82 563	-1 357 000	497 900	-13 162	108 553	-1 357 000	497 900	-617	12 602	-70 907	111 359
Δ Scope 1+2	46 340	1 240 025	-3 585 000	30 197 900	70 818	1 620 125	-3 585 000	30 197 900	14 183	1 736 009	-18 576 225	25 978 238
Scope 1 Intensity	1,25E-04	4,45E-04	8,63E-20	5,31E-03	1,78E-04	5,59E-04	6,93E-14	5,31E-03	1,53E-04	1,01E-03	8,63E-20	1,55E-02
Scope 2 Intensity	4,31E-05	1,15E-04	4,06E-08	1,49E-03	5,80E-05	1,45E-04	8,43E-08	1,49E-03	2,54E-05	5,05E-05	4,06E-08	4,68E-04
Scope 1+2 Intensity	1,68E-04	4,75E-04	1,08E-07	5,34E-03	2,36E-04	5,95E-04	2,57E-07	5,34E-03	1,78E-04	1,02E-03	1,08E-07	1,55E-02
Δ Emission intensity 1	-4,34E-07	1,53E-04	-2,56E-03	2,29E-03	-5,90E-06	1,83E-04	-2,56E-03	2,29E-03	6,75E-06	7,36E-04	-7,43E-03	1,09E-02
Δ Emission intensity 2	-9,28E-07	3,02E-05	-2,03E-04	6,20E-04	-1,58E-06	3,71E-05	-2,03E-04	6,20E-04	-6,57E-08	1,83E-05	-7,85E-05	1,75E-04
Δ Emission intensity 1+2	-1,36E-06	1,57E-04	-2,57E-03	2,29E-03	-7,49E-06	1,89E-04	-2,57E-03	2,29E-03	6,69E-06	7,37E-04	-7,43E-03	1,09E-02
Revenue (EUR)	5,05E+09	8,74E+09	1,28E-05	8,79E+10	7,85E+09	1,06E+10	9,16E+07	8,79E+10	1,38E+09	2,44E+09	1,28E-05	1,88E+10
Δ in Revenue(EUR)	1,49E+08	2,94E+09	-2,59E+10	4,71E+10	2,29E+08	3,89E+09	-2,59E+10	4,71E+10	4,40E+07	2,80E+08	-2,27E+09	2,56E+09
Log(Revenue)	21,33	1,82	-11,27	25,20	22,20	1,13	18,33	25,20	20,18	1,93	-11,27	23,66
ROE	0,14	0,16	-1,98	0,82	0,14	0,17	-1,98	0,76	0,13	0,15	-0,76	0,82
Leverage (D/E)	1,36	7,10	0,00	225,00	1,46	9,29	0,00	225	1,23	1,84	0,00	11,64
B/M	0,59	0,45	0,01	4,76	0,56	0,45	0,01	4,76	0,63	0,45	0,04	3,44
Market Cap (EUR)	8,30E+09	1,36E+10	2,30E+06	1,75E+11	1,14E+10	1,18E+10	7,58E+07	7,56E+10	4,22E+09	1,46E+10	2,30E+06	1,75E+11

Total firms	118
Control Group	67
Treatment Group	51
Total years (2013-2021)	9

Additionally, we observe a higher positive increase average in Scope 1 emissions YoY for firms in the control group compared to firms in the treatment group which is consistent with our earlier observation with regard to emission level. This suggests that firms in the control group, on average, have a higher increase in terms of changes in Scope 1 emissions YoY compared to our treatment group. Also, for changes in Scope 1+2, firms in our control group had a higher reduction compared to the treatment group. Interestingly, when it comes to changes in emissions (YoY), firms in the control group, on average, experienced a decrease in their emission intensity across all Scopes, including Scope 1+2, unlike firms in our treatment group that had inconsistent results across Scopes, recording an increase in Scope (1 and 1+2) but a decrease in Scope 2 emission intensity. This implies that the firm's emissions per unit of activity have decreased over time (year-on-year), for firms in our control group reflecting an improvement in their environmental performance. This could be because firms in the control group had taken measures with regard to their emission efficiency because they have been voluntarily disclosing for a long time and, therefore, have adopted improved technology and other measures that help them decrease their emission intensity on average YoY.

It is important to note that the descriptive statistics in Table 7 do not take into account the direct impact of the regulation. It only measures the average emission levels and changes in emission levels of the control and treatment group without measuring the impact of the regulation. It is not uncommon that any changes observed could be due to something completely unrelated to the regulation. In other respects, the firms in our treatment and control groups are quite similar. Their mean log(revenue/size), return on equity (ROE), debt-to-equity (D/E), and book-to-market(B/M) ratios are nearly identical with relatively small differences. On average, firms in our control group have a higher market capitalization than firms in our treatment group.

6.0 Results and Analysis

In this section, we discuss the results from our findings/tests in relation to our main research objective of evaluating the impact of mandatory carbon emissions disclosure requirements on Nordic firms. We have organized our discussions into three

subsections. The first explores the impact of mandatory disclosure requirements on changes in emission levels and changes in emission intensity (Scope 1, 2, and 1+2) of Nordic firms subject to this requirement. The second subsection explores the impact of mandatory disclosure requirements on the firm value of Nordic firms. Finally, we discuss the results of our robustness checks on the impact of the disclosure on Nordic firms.

6.1 Impact of mandatory disclosure on GHG Emissions of Nordic Firms

We report the findings on the impact of mandatory carbon disclosure requirements on changes in firm-level Scope 1, Scope 2, and Scope 1+2 emissions in Table 3. We test the null hypothesis that Nordic firms subject to mandatory carbon disclosure requirements and forced to disclose as a result of the regulation do not reduce their emissions compared to firms that were voluntarily disclosing before the regulation. To examine this hypothesis, we estimated a difference-in-differences equation below:

$$\begin{aligned}
 y_{it} = & \beta_0 t + \beta_1 Treat_i + \beta_2 Aftert + \beta_3 Treat_i * Aftert \\
 & + \beta_4, it (\Delta \text{ in size}) + \beta_5, it (\text{leverage}) + \beta_6, it \left(\frac{B}{M} \right) \\
 & + \beta_7, it (ROE) + \beta_8, i Sector + \beta_9, i (Country FEs) + \epsilon_{it}
 \end{aligned}$$

(Equation 4)

In this equation, t indexes event years, and i indexes a particular firm, and the dependent variable (y_{it}) is either a change in a firm's Scope 1 emissions/emission intensity, Scope 2 emissions/emission intensity, or a combination of the two as measured in tCO_{2e} . We used GHG emissions of comparable firms on Euro Stoxx 600 to estimate the pre-regulation GHG emissions of our treatment group. *Treat* is a dummy variable that equals 1 if a firm is part of our treatment group (and only started disclosing after the implementation of the mandatory disclosure requirement) and 0 otherwise. The coefficient of this dummy shows the difference between the average carbon emissions of the treatment group and the control group before the regulation. For example, there could be a difference in emission levels or changes in emission intensity between the two groups that are completely unrelated to the regulation. The coefficient of the *Treat* dummy captures this effect. *After* is a dummy variable that equals 1 in the event years

where Nordic firms in both our treatment and control group had to be in compliance with the disclosure requirement and 0 otherwise. We also include firm-level controls that include changes in size (using total revenue as a proxy), leverage (using debt-to-equity ratio as a proxy), book-to-market ratio (B/M) and return on equity (ROE). We also control for sector and country-fixed effects.

The constant term (β_{0t}) measures the average GHG emissions (Scopes 1, 2, and 1+2) for our control group before the introduction of the mandatory disclosure requirements. The coefficient (β_1) of the Treat dummy measures the difference between the average GHG emissions of the treatment group and the control group before the rule. Thus, it tells us whether the average GHG emissions of the treatment group were higher or lower (depending on the sign) compared to the control group before the rule. The coefficient (β_2) measures the difference between the average GHG emissions of our control group after the introduction of the mandatory requirement and before the mandatory disclosure requirement. Our coefficient of interest in each regression is the coefficient (β_3) of the interaction term. It measures the difference between the average GHG emissions of the treatment group and the control group after the introduction of the mandatory disclosure requirement. It tells us how different the average emissions of the treatment group are from the control group after the introduction of the rule.

6.1.1 Interpretation of Results on Impact on Emissions

From Table 3, columns 1, 2, and 3, respectively, we find that none of our coefficient of interest, which is the coefficient of the interaction term $Treat_i * After_t$, is statistically significantly different from zero for changes in Scope 1 emissions levels (YoY), changes in Scope 2 emissions levels (YoY) and changes in (Scope 1+2) emissions levels. These variable measures the difference between the average GHG emissions of our treatment group and our control group after the introduction of mandatory disclosure requirements. For example, in column 1, the coefficient of interaction term $Treat_i * After_t$ is (-94,170.00), meaning the introduction of the mandatory disclosure requirement resulted in an additional reduction of 94,170.00 ((tons of carbon dioxide equivalent (tCO_{2e})) of average Scope 1 emission for the treatment group compared to the control group keeping other variables constant. However, the reported coefficients for Scope (1, 2, and 1+2) regarding changes in GHG emission levels are all not

statistically significant judging by their t-statistic and using any of the standard p-values as a threshold.

We, therefore, find no evidence to reject our first null hypothesis that Nordic firms subject to mandatory carbon disclosure requirements and forced to disclose (treatment group) as a result of the regulation do not reduce their emissions compared to firms that were voluntarily disclosing even before the regulation (control group). This suggests that the law had no impact on the total GHG emissions levels of firms in the Nordics, and therefore, there was no difference between the average GHG emissions of firms in our treatment group compared to our control group after the introduction of the mandatory disclosure requirements. This indicates that no extra or significant measures/actions were taken by firms in our treatment group (that were forced to disclose as a result of the regulation) to reduce their GHG emissions compared to firms that were already voluntarily disclosing, as one would expect. This is in contrast to the studies by (Jouvenot & Krueger, 2019), who found that firms in the United Kingdom (UK) reduced their GHG emissions due to the introduction of mandatory carbon disclosure requirements.

However, we find an impact when it comes to changes in emission intensity (Scope 1 and Scope 1+2). Columns 4 and 6 in Table 3 show that the coefficient of the interaction term $Treat_i * After_t$ is statistically significant at the 10% and 5% significance level for changes in Scope 1 emission intensity and changes in Scope 1+2 emission intensity, respectively. This result is similar to the study on carbon intensity (see Harris, 2015), where they found different results across Scopes (1,2, and 3) when measuring the impact of carbon intensity on returns.

Nevertheless, the sign of both coefficients is positive. This suggests that there were higher increases in average (Scope 1 and Scope 1+2) emissions per unit of sales (in euro) for firms in the treatment group compared to firms in the control group after the mandatory carbon disclosure law, although the difference is not large. For example, the coefficient of changes in emission intensity (Scope 1+2) is 3.99E-05. This implies that the treatment group, on average, had an additional increase of 0.0000399 tons of carbon dioxide equivalent (tCO₂e) of average (Scope 1+2) emissions per unit of sales (in euro) compared to the control group after the rule, keeping other variables constant. This

suggests that firms, especially those in our control group, possibly took some measures to improve their emission efficiency slightly relative to our treatment group. A reason could be that because firms in our control group have been disclosing even before the law, they might have already taken measures to improve their operational efficiency. Though not at the total emission level changes but emission levels (Scope 1+2) per unit of sales. Emission efficiency, to some extent, adjusts for activity level. For example, if the activity level of a firm is relatively constant, that firm typically emits less per unit of activity level. However, as stated earlier, the result could also mean that firms in our treatment group did very little to improve their emission intensity rather than firms in our control group making more efforts to improve their emission intensity.

We find that change in revenues (YoY) which we used as a proxy for firm size, is the control variable that is statistically significant across most Scopes. From columns 1, 3, 4, and 6 in Table 3, we find that size has an impact on changes in Scope (1 and 1+2) and changes in emission intensity Scope (1 and 1+2) of Nordic firms. The signs of changes in emission levels are positive, although very small. This shows that high activity levels result in a slightly higher increase in emission levels Scope (1 and 1+2).

However, the signs of changes in emission intensity are all negative. This means an increase in activity level (size) as measured by changes in revenues results in a decrease in total emission levels (Scope 1 and 1+2) per unit of sales. This is not surprising because large firms or firms with high activity levels are likely to have more emissions compared to small firms. However, they also have the resources and leverage (for example, negotiating for more sustainable power from power suppliers, which affects Scope 2 emissions) to invest in technology or improve operational efficiency to reduce their GHG emissions and emission intensity. Most of our control variables are not statistically significant except for B/M and leverage (D/E), which has an impact on changes in Scope 2 emission levels/emissions intensity, as seen from columns 2 and 5, respectively, in Table 3. B/M and D/E are financial performance indicators that provide insights into a company's profitability and financial health, and risk profile. Companies with good financials generally have more resources available to invest in emission-reduction technologies, energy-efficient and other sustainable processes. From Table 3, we find that most of our sector and country variables are not statistically significant at the especially at the 5% significance level and therefore have no impact on changes

in firm-level emissions/emission intensity, except for the materials sector, which has an impact on changes in Scope 2 emissions, and the utility sector that has a positive impact on changes in Scope 1 and Scope 1+2 emissions, suggesting firms in this sector on average have a higher increase in GHG emission (Scope1 and 1+2) compared to firms in other sectors keeping other variables constant.

6.2 Impact of mandatory carbon disclosure on firm value

Do mandatory carbon disclosure requirements have an impact on firm value? We explore this question by using the same difference-in-differences approach to estimate a similar regression equation as before, but in this case, our dependent variable is firm value or changes in firm value using the market capitalization of firms as a proxy for firm value.

$$\begin{aligned}
 y_{it} = & \gamma_0 t + \gamma_1 Treat_i + \gamma_2 Aftert + \gamma_3 Treat_i * Aftert \\
 & + \gamma_4, it (\Delta \text{ in size}) + \gamma_5, it (\text{leverage}) + \gamma_6, it \left(\frac{B}{M} \right) \\
 & + \gamma_7, it (ROE) + \gamma_8, i \text{ sector} + \gamma_9, i (\text{Country FEs}) + \epsilon_{it}
 \end{aligned}$$

(Equation 5)

Our coefficient of interest is γ_3 which is the coefficient of the interaction term ($Treat_i * Aftert_i$). This coefficient tells us how different the average firm value of our treatment group is from our control group after the introduction of the mandatory requirement. Thus, it helps us test our third null hypothesis that Nordic firms subject to mandatory carbon disclosure requirements that only disclosed after the regulation show no change in firm value compared to firms that were voluntarily disclosing even before the regulation.

6.2.1 Interpretation of Results on Impact on firm value

We report the results on the impact of the regulation on firm value in Table 5 and the impact on changes in firm value in Table 6. From column 2 on both Tables, we find that the coefficients of our interaction term are not statistically significant (based on their t-values). This suggests that the regulation had no impact on the firm value or changes in the firm value of Nordic firms. This is in line with the findings by Griffin,

Lont, and Sun (2017), where they found no differential effect on the firm value of disclosing and non-disclosing firms by looking at the carbon disclosure of S&P 500 companies from 2006 to 2008 based on a matched sample of disclosing and non-disclosing firms. However, our result is contrary to the findings by Matsumura, Prakash, and Vera-Muñoz (2014), who did a similar study on carbon disclosure by S&P 500 companies. They found that the median value of firms that disclose their carbon emissions is about \$2.3 billion higher than that of comparable non-disclosing firms. Additionally, (Krueger et al., 2021), in a related study, find that stock price crash risk declines after mandatory ESG disclosure is enacted. This suggests mandatory disclosure has some impact on firm value which is contrary to our findings.

One possible reason why the law had no impact on firms in the Nordics could be that investors and stakeholders may have already been aware of (and did not expect the regulation to cause an immediate change in the emissions of firms in our treatment group) the environmental practices and carbon emissions of the firms in our treatment group, despite the lack of voluntary disclosure before the regulation. This information could have been inferred through other channels or industry knowledge. Therefore, when the mandatory disclosure requirements were introduced, the new information provided may not have significantly altered the market's perception of these firms' environmental performance, resulting in a non-significant interaction term. Probably because they expect them (treatment group) to take more time to adapt. From Table 5, we find that revenue (a proxy for size), B/M, ROE, and leverage are all statistically significant, although at different significance levels. This is not surprising because these are financial, value, profitability, and risk metrics that have an impact on firm value. A relatively similar result is found in Table 6.

6.3 Robustness Tests

Our results have, so far, provided no significant indication of a relationship between carbon disclosure requirements and changes in GHG emissions levels of Nordic firms in our sample and their firm value except for changes in Scope 1+2 emissions, where we have had some impact. We conduct further robustness tests presented in this subsection to confidently conclude that the law had no impact on changes in GHG

emissions and firm value within the sample of Nordic firms we examined from 2013-2021.

6.3.1 Replacing Sector fixed-effects with Industry fixed-effects.

In our previous regression, we used sector-fixed effects as a set of dummy variables that capture the unobserved heterogeneity or differences across different sectors. We used sector-fixed effects in estimating the pre-regulation GHG emissions of our treatment group using comparable firms on the Euro Stoxx 600. Likewise, we used sector-fixed effects in estimating the impact of mandatory disclosure requirements on changes in the total carbon emission level of firms and changes in firm value. However, in our robustness tests, we replace sector-fixed effects with industry-fixed effects both in estimating the pre-regulation carbon emissions of our treatment group and examining the impact of the regulation on changes in GHG emission of Nordic firms and their firm value. Industry fixed effects allow for a more detailed analysis by capturing the unique characteristics of specific industries. Industries can have distinct dynamics, competitive structures, and regulatory environments that affect firm value and emissions. By replacing sector-fixed effects with industry-fixed effects, we account for these industry-specific factors at a more granular level, which may provide more precise estimates. Under our null hypothesis that the mandatory disclosure regulation has no impact on changes in GHG emissions and firm value of Nordic firms, we estimate the following differences-in differences regression:

$$\begin{aligned}
 y_{it} = & \theta_0 + \theta_1 Treat_i + \theta_2 Aftert + \theta_3 Treat_i * Aftert \\
 & + \theta_4, it (\Delta \text{ in size}) + \theta_5, it (\text{leverage}) + \theta_6, it (B/M) \\
 & + \theta_7, it (ROE) + \theta_8, i \text{ industry} + \theta_9, i (\text{Country FEs}) \\
 & + \epsilon_{it}
 \end{aligned}$$

(Equation 6)

Table 8: Running IndustryFE instead of SectorFE on Scope 1 emissions for Euro STOXX 600 companies

Below are results from a regression on Scope 1 emissions (in tCO₂e) for the Euro STOXX 600 companies from 2013 to 2018. The estimates obtained for the variables were used to estimate our treatment companies' unreported Scope 1 emissions. The variables in *italic* text are all dummy variables (Industry, Country, and Year). An important point to note here is that sector-fixed effects have been replaced with industry-fixed effects for estimating Scope 1 emissions for our treatment group which will be used for a robustness check. The relevant country dummies have been marked in bold italic text to highlight our focus group (Denmark, Finland, Norway, Sweden). After the coefficient estimates from this regression have been used to estimate unreported emissions for our treatment group, that new dataset will be used to run a robustness check of our initial model with sector-fixed effects. The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

Coefficients	Estimate (1)	t-value (2)	
<i>(Intercept)</i>	-13,43	-17,89	***
Log(Revenue)	1,07	37,07	***
<i>Automobile Components</i>	-0,07	-0,16	
<i>Automobiles</i>	-0,91	-2,68	**
<i>Banks</i>	-2,68	-9,51	***
<i>Beverages</i>	0,74	2,77	**
<i>Biotechnology</i>	1,98	6,35	***
<i>Broadline Retail</i>	0,06	0,14	
<i>Building Products</i>	2,87	6,67	***
<i>Capital Markets</i>	-3,15	-11,96	***
<i>Chemicals</i>	2,71	12,07	***
<i>Communications Equipment</i>	-1,01	-2,77	**
<i>Construction & Engineering</i>	2,29	7,88	***
<i>Consumer Staples Distribution & Retail</i>	0,19	0,67	
<i>Containers & Packaging</i>	2,57	8,20	***
<i>Distributors</i>	-1,84	-4,23	***
<i>Diversified Consumer Services</i>	-1,42	-3,25	**
<i>Diversified REITs</i>	-0,22	-0,61	
<i>Diversified Telecommunication Services</i>	-0,85	-3,01	**
<i>Electric Utilities</i>	4,31	15,54	***
<i>Electrical Equipment</i>	-0,39	-1,13	
<i>Electrical Equipment, Instruments & Components</i>	-0,84	-1,94	.
<i>Financial Services</i>	-6,06	-14,03	***
<i>Food Products</i>	0,73	2,49	*
<i>Gas Utilities</i>	4,54	14,12	***
<i>Health Care Equipment & Supplies</i>	-0,38	-1,45	
<i>Hotels, Restaurants & Leisure</i>	0,77	2,59	**
<i>Household Durables</i>	-1,05	-3,82	***
<i>Household Products</i>	-0,62	-1,44	
<i>IT Services</i>	-3,37	-11,11	***
<i>Independent Power and Renewable Electricity Producers</i>	2,94	9,65	***
<i>Industrial Conglomerates</i>	0,08	0,13	
<i>Industrial REITs</i>	-0,18	-0,40	
<i>Insurance</i>	-3,77	-14,84	***
<i>Interactive Media & Services</i>	-0,52	-0,48	
<i>Life Sciences Tools & Services</i>	-0,67	-1,55	

<i>Machinery</i>	0,27	1,08	
<i>Marine Transportation</i>	5,66	11,70	***
<i>Media</i>	-2,32	-9,16	***
<i>Metals & Mining</i>	3,29	12,28	***
<i>Multi-Utilities</i>	3,71	12,14	***
<i>Office REITs</i>	-0,14	-0,39	
<i>Oil, Gas & Consumable Fuels</i>	3,09	11,66	***
<i>Paper & Forest Products</i>	3,58	10,13	***
<i>Passenger Airlines</i>	4,47	10,19	***
<i>Personal Care Products</i>	0,21	0,47	
<i>Pharmaceuticals</i>	0,18	0,76	
<i>Professional Services</i>	-1,34	-4,96	***
<i>Real Estate Management & Development</i>	-2,12	-4,52	***
<i>Residential REITs</i>	1,01	2,23	*
<i>Retail REITs</i>	0,14	0,32	
<i>Semiconductors & Semiconductor Equipment</i>	1,32	3,94	***
<i>Software</i>	-1,56	-4,67	***
<i>Specialized REITs</i>	-1,41	-3,88	***
<i>Specialty Retail</i>	-1,25	-4,02	***
<i>Textiles, Apparel & Luxury Goods</i>	-2,01	-7,46	***
<i>Tobacco</i>	-0,06	-0,18	
<i>Trading Companies & Distributors</i>	-0,18	-0,68	
<i>Water Utilities</i>	2,98	8,48	***
<i>Wireless Telecommunication Services</i>	-0,78	-2,09	*
<i>Leverage</i>	-0,07	-2,30	*
<i>B/M</i>	0,36	3,79	***
<i>ROE</i>	-0,07	-1,06	
<i>Belgium</i>	1,81	3,01	**
<i>Bermuda</i>	0,64	1,11	
<i>Chile</i>	0,03	0,05	
<i>Denmark</i>	-0,85	-1,84	.
<i>Finland</i>	0,10	0,24	
<i>France</i>	0,51	1,20	
<i>Germany</i>	1,30	2,93	**
<i>Ireland</i>	NA	NA	
<i>Italy</i>	0,94	2,16	*
<i>Jordan</i>	0,97	1,66	.
<i>Luxembourg</i>	1,72	3,49	***
<i>Netherlands</i>	0,45	0,97	
<i>Norway</i>	1,13	2,45	*
<i>Poland</i>	0,50	0,85	
<i>Portugal</i>	0,57	1,20	
<i>South Africa</i>	0,59	1,01	
<i>Spain</i>	-0,66	-1,55	
<i>Sweden</i>	-0,16	-0,36	
<i>Switzerland</i>	0,50	1,14	

<i>United Kingdom</i>	0,76	1,81 .
<i>2014</i>	-0,09	-1,02
<i>2015</i>	-0,15	-1,69 .
<i>2016</i>	-0,15	-1,66 .
<i>2017</i>	-0,19	-2,08 *
<i>2018</i>	-0,26	-2,78 **

RSE: 0,924 on 1149 degrees of freedom

Multiple R-Sq.: 0,9219

Adj. R-Sq.: 0,9161

F-stat: 157,7 on 86 and 1149 DF, p-value: < 2,2e-16

Number of observations: 1236

Table 9: Running IndustryFE instead of SectorFE on Scope 2 emissions for Euro STOXX 600 companies

Below are results from a regression on Scope 2 emissions (in tCO₂e) for the Euro STOXX 600 companies from 2013 to 2018. The estimates obtained for the variables were used to estimate our treatment companies' unreported Scope 2 emissions. The variables in *italic* text are all dummy variables (Industry, Country, and Year). An important point to note here is that sector-fixed effects have been replaced with industry-fixed effects for estimating Scope 2 emissions for our treatment group which will be used for a robustness check. The relevant country dummies have been marked in bold italic text to highlight our focus group (Denmark, Finland, Norway, Sweden). After the coefficient estimates from this regression have been used to estimate unreported emissions for our treatment group, that new dataset will be used to run a robustness check of our initial model with sector-fixed effects. The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

Coefficients	Estimate	t-value	
	(1)	(2)	
<i>(Intercept)</i>	-10,18	-14,37	***
<i>Log(Revenue)</i>	1,02	37,56	***
<i>Automobile Components</i>	1,54	3,82	***
<i>Automobiles</i>	0,23	0,71	
<i>Banks</i>	-0,52	-1,95	.
<i>Beverages</i>	0,11	0,45	
<i>Biotechnology</i>	1,10	3,73	***
<i>Broadline Retail</i>	1,21	2,83	**
<i>Building Products</i>	2,18	5,37	***
<i>Capital Markets</i>	-0,30	-1,22	
<i>Chemicals</i>	2,84	13,41	***
<i>Communications Equipment</i>	0,14	0,40	
<i>Construction & Engineering</i>	-0,36	-1,33	
<i>Consumer Staples Distribution & Retail</i>	1,00	3,80	***
<i>Containers & Packaging</i>	2,22	7,49	***
<i>Distributors</i>	-0,42	-1,01	
<i>Diversified Consumer Services</i>	0,51	1,23	
<i>Diversified REITs</i>	1,88	5,49	***
<i>Diversified Telecommunication Services</i>	1,12	4,21	***
<i>Electric Utilities</i>	1,58	6,02	***

<i>Electrical Equipment</i>	1,33	4,14	***
<i>Electrical Equipment, Instruments & Components</i>	0,98	2,40	*
<i>Financial Services</i>	-5,76	-14,11	***
<i>Food Products</i>	1,42	5,13	***
<i>Gas Utilities</i>	0,92	3,03	**
<i>Health Care Equipment & Supplies</i>	1,03	4,16	***
<i>Hotels, Restaurants & Leisure</i>	1,08	3,82	***
<i>Household Durables</i>	-1,02	-3,93	***
<i>Household Products</i>	0,77	1,88	.
<i>IT Services</i>	0,06	0,19	
<i>Independent Power and Renewable Electricity Producers</i>	1,13	3,91	***
<i>Industrial Conglomerates</i>	-3,48	-6,09	***
<i>Industrial REITs</i>	1,24	2,94	**
<i>Insurance</i>	-2,03	-8,46	***
<i>Interactive Media & Services</i>	-1,69	-1,64	
<i>Life Sciences Tools & Services</i>	0,68	1,65	.
<i>Machinery</i>	0,53	2,30	*
<i>Marine Transportation</i>	0,74	1,63	
<i>Media</i>	-0,21	-0,89	
<i>Metals & Mining</i>	3,04	12,00	***
<i>Multi-Utilities</i>	1,19	4,11	***
<i>Office REITs</i>	0,49	1,47	
<i>Oil, Gas & Consumable Fuels</i>	0,11	0,43	
<i>Paper & Forest Products</i>	2,82	8,45	***
<i>Passenger Airlines</i>	-0,53	-1,29	
<i>Personal Care Products</i>	0,95	2,27	*
<i>Pharmaceuticals</i>	0,77	3,36	***
<i>Professional Services</i>	-0,21	-0,82	
<i>Real Estate Management & Development</i>	0,22	0,50	
<i>Residential REITs</i>	3,59	8,41	***
<i>Retail REITs</i>	2,07	5,06	***
<i>Semiconductors & Semiconductor Equipment</i>	2,65	8,36	***
<i>Software</i>	-0,37	-1,18	
<i>Specialized REITs</i>	1,71	5,01	***
<i>Specialty Retail</i>	0,75	2,55	*
<i>Textiles, Apparel & Luxury Goods</i>	-0,13	-0,52	
<i>Tobacco</i>	0,55	1,67	.
<i>Trading Companies & Distributors</i>	-0,41	-1,63	
<i>Water Utilities</i>	2,72	8,19	***
<i>Wireless Telecommunication Services</i>	1,17	3,35	***
<i>Leverage</i>	-0,05	-1,88	.
<i>B/M</i>	0,10	1,09	
<i>ROE</i>	-0,01	-0,20	
<i>Belgium</i>	-0,16	-0,28	
<i>Bermuda</i>	-2,07	-3,78	***
<i>Chile</i>	-0,95	-1,71	.

Denmark	-2,38	-5,44	***
Finland	-1,78	-4,28	***
<i>France</i>	-1,71	-4,21	***
<i>Germany</i>	-1,61	-3,85	***
<i>Ireland</i>	NA	NA	
<i>Italy</i>	-2,12	-5,16	***
<i>Jordan</i>	-0,74	-1,35	
<i>Luxembourg</i>	-1,48	-3,17	**
<i>Netherlands</i>	-1,82	-4,17	***
Norway	-2,16	-4,94	***
<i>Poland</i>	-0,99	-1,79	.
<i>Portugal</i>	-1,43	-3,18	**
<i>South Africa</i>	-1,41	-2,56	*
<i>Spain</i>	-1,38	-3,44	***
Sweden	-1,52	-3,63	***
<i>Switzerland</i>	-2,25	-5,35	***
<i>United Kingdom</i>	-1,83	-4,59	***
<i>2014</i>	-0,08	-0,93	
<i>2015</i>	-0,12	-1,41	
<i>2016</i>	-0,17	-1,92	.
<i>2017</i>	-0,23	-2,68	**
<i>2018</i>	-0,34	-3,88	***

RSE: 0,924 on 1149 degrees of freedom

Multiple R-Sq.: 0,8527

Adj. R-Sq.: 0,8467

F-stat: 80,3 on 86 and 1149 DF, p-value: < 2,2e-16

Number of observations: 1236

Table 10: Robustness check for emissions-related regressions

This table contains the results from our robustness testing using industry-fixed effects instead of sector-fixed effects to observe for any significant changes to our original model in Table 3 with sector-fixed effects. We have results from six regressions (see columns). The first three are on changes in GHG emissions. Column (1) has changes in Scope 1 emissions as the dependent variable, (2) has changes in Scope 2 emissions as the dependent variable, and (3) has changes in Scope 1+2 as the dependent variable. The last 3 are on changes in emission intensity (Emissions/Revenue) of the companies. Column (4) has changes in Scope 1 emissions intensity as the dependent variable, (5) has changes in Scope 2 emissions intensity as the dependent variable, and (6) has changes in Scope 1+2 emissions intensity as the dependent variable. The dataset on which these regressions were run contains companies from all four of our focus countries i.e., Denmark, Finland, Norway, and Sweden. The currencies have been converted to EUR at the average exchange rates for the currencies in each specific year. The results are the coefficient estimates and their respective t-stats in parentheses under those estimates. All dummy variables (Industry, Country, and Regulation) are in *italic* text and the most important control variable is a regulation dummy variable called *Treat x After* which captures the effect of the introduction of mandatory emissions reporting regulation on our sample. *Treat* is a dummy which equals 1 if a company belongs to our treatment group and 0 otherwise. *After* is a dummy which equals 1 in regulation years (e.g., from 2018 onwards for Norway) and 0 otherwise (before 2018 for Norway). The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

	Change in emissions (YoY)			Change in emission intensity (YoY)		
	Scope 1 (1)	Scope 2 (2)	Scope 1+2 (3)	Scope 1 (4)	Scope 2 (5)	Scope 1+2 (6)
<i>Treat</i>	-1,22E+05 (-0,713)	2,84E+04 (2,421)*	-9,38E+04 (-0,541)	-7,78E-05 (-1,489)	-4,60E-06 (-1,077)	-8,24E-05 (-1,573)
<i>After</i>	-1,22E+05 (-0,956)	1,02E+04 (1,162)	-1,12E+05 (-0,866)	-2,39E-05 (-0,613)	-4,16E-06 (-1,307)	-2,80E-05 (-0,718)
<i>Treat x After</i>	1,33E+05 (0,711)	-9,92E+03 (-0,773)	1,23E+05 (0,650)	4,86E-05 (0,851)	5,82E-06 (1,244)	5,45E-05 (0,949)
Change in Revenue (YoY)	2,37E-04 (15,967)***	1,05E-06 (1,031)	2,38E-04 (15,852)***	-1,75E-14 (-3,864)***	-3,65E-16 (-0,986)	-1,79E-14 (-3,933)***
<i>Denmark</i>	4,99E+05 (0,969)	1,28E+04 (0,364)	5,12E+05 (0,983)	1,65E-04 (1,052)	-4,35E-06 (-0,339)	1,61E-04 (1,021)
<i>Finland</i>	2,73E+05 (0,532)	1,24E+04 (0,352)	2,85E+05 (0,550)	6,19E-05 (0,396)	-4,09E-06 (-0,320)	5,78E-05 (0,368)
<i>Norway</i>	1,27E+05 (0,258)	-1,01E+04 (-0,300)	1,7E+05 (0,235)	1,95E-05 (+0,131)	-3,46E-06 (-0,283)	1,61E-05 (+0,107)
<i>Sweden</i>	3,14E+05 (+0,613)	1,54E+04 (+0,438)	3,29E+05 (+0,635)	6,86E-05 (+0,439)	-3,31E-06 (-0,259)	6,53E-05 (+0,417)
Leverage	-2,91E+03 (-0,459)	-2,26E+02 (-0,521)	-3,13E+03 (-0,489)	-1,03E-06 (-0,535)	8,74E-07 (+5,543)***	-1,58E-07 (-0,082)
B/M	-1,34E+04	-2,62E+04	-3,96E+04	9,13E-05	1,41E-05	1,05E-04

ROE	(-0,095)	(-2,698)**	(-0,276)	(+2,113)*	(+3,983)***	(+2,431)*
	-3,43E+05	-1,60E+04	-3,59E+05	-1,27E-05	1,39E-05	1,23E-06
	(-0,963)	(-0,657)	(-0,997)	(-0,117)	(+1,571)	(+0,011)
<i>Automobile Components</i>	-4,29E+04	-3,66E+03	-4,66E+04	-4,76E-05	-3,59E-06	-5,12E-05
	(-0,075)	(-0,093)	(-0,080)	(-0,272)	(-0,252)	(-0,292)
<i>Banks</i>	-1,26E+05	2,65E+03	-1,23E+05	-1,13E-04	-1,30E-05	-1,26E-04
	(-0,254)	(+0,078)	(-0,245)	(-0,748)	(-1,052)	(-0,832)
<i>Biotechnology</i>	-1,10E+05	-3,70E+04	-1,47E+05	-1,88E-05	-3,03E-06	-2,18E-05
	(-0,185)	(-0,911)	(-0,245)	(-0,104)	(-0,205)	(-0,120)
<i>Building Products</i>	-2,35E+05	-1,66E+04	-2,51E+05	-9,48E-05	-6,42E-06	-1,01E-04
	(-0,437)	(-0,451)	(-0,463)	(-0,579)	(-0,480)	(-0,617)
<i>Chemicals</i>	-1,97E+05	-1,57E+04	-2,12E+05	-9,15E-05	-8,77E-06	-1,00E-04
	(-0,369)	(-0,430)	(-0,394)	(-0,564)	(-0,660)	(-0,616)
<i>Commercial Services & Supplies</i>	-2,01E+05	-2,21E+04	-2,23E+05	-7,13E-05	-2,09E-06	-7,34E-05
	(-0,383)	(-0,615)	(-0,420)	(-0,446)	(-0,160)	(-0,458)
<i>Communications Equipment</i>	-2,59E+05	-5,84E+02	-2,60E+05	-8,79E-05	-3,20E-06	-9,11E-05
	(-0,440)	(-0,014)	(-0,436)	(-0,490)	(-0,218)	(-0,506)
<i>Construction & Engineering</i>	-1,29E+05	-1,34E+04	-1,42E+05	-8,41E-05	-2,30E-06	-8,64E-05
	(-0,217)	(-0,330)	(-0,237)	(-0,466)	(-0,156)	(-0,477)
<i>Consumer Staples Distribution & Retail</i>	-1,66E+05	-1,37E+04	-1,79E+05	-6,00E-05	-1,18E-06	-6,12E-05
	(-0,280)	(-0,338)	(-0,300)	(-0,334)	(-0,080)	(-0,339)
<i>Containers & Packaging</i>	-1,63E+05	1,43E+02	-1,63E+05	-8,39E-05	-3,25E-06	-8,71E-05
	(-0,277)	(+0,004)	(-0,274)	(-0,468)	(-0,221)	(-0,484)
<i>Diversified Telecommunication Services</i>	-3,08E+04	-1,09E+04	-4,17E+04	-6,20E-05	-2,50E-06	-6,45E-05
	(-0,056)	(-0,289)	(-0,075)	(-0,370)	(-0,182)	(-0,384)
<i>Electrical Utilities</i>	4,00E+06	6,24E+04	4,07E+06	-3,98E-04	-3,96E-06	-4,02E-04
	(+5,719)***	(+1,302)	(+5,741)***	(-1,863) .	(-0,227)	(-1,876) .
<i>Electrical Equipment</i>	-3,47E+05	-1,26E+04	-3,59E+05	-6,59E-05	1,95E-06	-6,39E-05
	(-0,602)	(-0,321)	(-0,617)	(-0,375)	(+0,136)	(-0,363)
<i>Electronic Equipment, Instruments & Components</i>	-8,31E+04	-3,40E+04	-1,17E+05	-1,91E-05	-4,72E-06	-2,38E-05

	(-0,123)	(-0,733)	(-0,171)	(-0,092)	(-0,279)	(-0,115)
<i>Energy Equipment & Services</i>	-5,80E+04	1,88E+04	-3,92E+04	-8,27E-05	-1,87E-06	-8,46E-05
	(-0,101)	(+0,475)	(-0,067)	(-0,471)	(-0,130)	(-0,480)
<i>Entertainment</i>	-1,35E+05	3,38E+03	-1,32E+05	-1,38E-04	-9,29E-06	-1,48E-04
	(-0,199)	(+0,072)	(-0,191)	(-0,667)	(-0,547)	(-0,710)
<i>Food Products</i>	-4,80E+04	-2,04E+02	-4,82E+04	-3,71E-05	-5,12E-06	-4,22E-05
	(-0,096)	(-0,006)	(-0,095)	(-0,242)	(-0,409)	(-0,275)
<i>Health Care Equipment & Supplies</i>	-3,30E+05	-6,93E+03	-3,37E+05	-1,55E-04	-2,37E-06	-1,58E-04
	(-0,541)	(-0,166)	(-0,546)	(-0,835)	(-0,156)	(-0,845)
<i>Health Care Providers & Services</i>	-8,88E+04	-3,53E+04	-1,24E+05	-4,23E-05	-4,74E-06	-4,70E-05
	(-0,132)	(-0,768)	(-0,183)	(-0,206)	(-0,283)	(-0,229)
<i>Hotels, Restaurants & Leisure</i>	-1,34E+05	-3,04E+04	-1,65E+05	-4,60E-05	-7,24E-06	-5,32E-05
	(-0,228)	(-0,754)	(-0,276)	(-0,256)	(-0,492)	(-0,295)
<i>Household Durables</i>	-2,57E+05	-3,37E+04	-2,91E+05	-9,61E-05	-2,22E-07	-9,64E-05
	(-0,478)	(-0,914)	(-0,534)	(-0,586)	(-0,017)	(-0,586)
<i>IT Services</i>	-5,83E+04	-9,91E+03	-6,82E+04	-2,38E-05	-1,71E-06	-2,55E-05
	(-0,102)	(-0,253)	(-0,118)	(-0,136)	(-0,120)	(-0,146)
<i>Insurance</i>	-2,90E+04	-5,74E+03	-3,48E+04	-3,55E-05	-1,39E-06	-3,69E-05
	(-0,051)	(-0,147)	(-0,060)	(-0,203)	(-0,097)	(-0,211)
<i>Machinery</i>	-1,64E+05	-7,18E+03	-1,72E+05	-7,42E-05	-1,35E-06	-7,55E-05
	(-0,330)	(-0,211)	(-0,341)	(-0,489)	(-0,109)	(-0,496)
<i>Marine Transportation</i>	-1,04E+06	1,55E+04	-1,02E+06	-5,82E-04	-1,53E-05	-5,97E-04
	(-1,832)	(+0,401)	(-1,783)	(-3,369)***	(-1,082)	(-3,447)***
<i>Media</i>	-3,77E+04	-6,70E+03	-4,44E+04	-3,96E-05	-1,51E-06	-4,11E-05
	(-0,066)	(-0,171)	(-0,077)	(-0,227)	(-0,106)	(-0,235)
<i>Metals & Mining</i>	-1,95E+05	-8,32E+04	-2,78E+05	-1,70E-04	-2,97E-05	-2,00E-04
	(-0,357)	(-2,222)*	(-0,503)	(-1,018)	(-2,181)*	(-1,193)
<i>Oil, Gas & Consumable Fuels</i>	-2,97E+05	6,37E+02	-2,97E+05	-4,63E-05	-3,81E-06	-5,01E-05
	(-0,549)	(+0,017)	(-0,542)	(-0,281)	(-0,282)	(-0,303)
<i>Paper & Forest Products</i>	-1,54E+05	-8,60E+04	-2,40E+05	-1,22E-04	-6,80E-06	-1,29E-04

	(-0,292)	(-2,377)*	(-0,449)	(-0,759)	(-0,516)	(-0,799)
<i>Passenger Airlines</i>	-2,41E+05	-2,32E+04	-2,64E+05	1,66E-05	-3,64E-06	1,30E-05
	(-0,356)	(-0,499)	(-0,385)	-0,08	(-0,216)	(+0,063)
<i>Pharmaceuticals</i>	-3,57E+05	-3,93E+04	-3,96E+05	-9,92E-05	-1,09E-06	-1,00E-04
	(-0,589)	(-0,946)	(-0,646)	(-0,536)	(-0,072)	(-0,541)
<i>Professional Services</i>	-1,77E+05	-3,26E+04	-2,10E+05	-3,82E-05	-2,21E-06	-4,04E-05
	(-0,263)	(-0,707)	(-0,308)	(-0,186)	(-0,131)	(-0,196)
<i>Real Estate Management & Development</i>	-1,70E+05	-1,37E+04	-1,84E+05	-9,63E-05	-5,68E-06	-1,02E-04
	(-0,330)	(-0,388)	(-0,353)	(-0,614)	(-0,443)	(-0,648)
<i>Semiconductors & Semiconductor Equipment</i>	-1,10E+05	-3,18E+03	-1,13E+05	-3,05E-05	3,60E-05	5,53E-06
	(-0,187)	(-0,079)	(-0,190)	(-0,171)	(+2,465)*	(+0,031)
<i>Specialty Retail</i>	-1,75E+05	-3,97E+04	-2,15E+05	-4,93E-05	-4,69E-06	-5,39E-05
	(-0,314)	(-1,040)	(-0,381)	(-0,290)	(-0,337)	(-0,317)
<i>Wireless Telecommunication Services</i>	-1,65E+05	-1,20E+04	-1,77E+05	-9,47E-05	-4,78E-06	-9,95E-05
	(-0,243)	(-0,258)	(-0,258)	(-0,459)	(-0,283)	(-0,481)
Adj. R-Sq.	0,3513	0,06038	0,3496	0,02316	0,05592	0,02586
Observations	826	826	826	826	826	826

Like in our previous equation, the dependent variable is either changes in GHG emissions/emission intensity or changes in firm value. Industry is a dummy variable that equals 1 if a firm belongs to a particular industry and 0 otherwise. From Table 10, we find that none of the coefficients of the interaction term $Treat_i * After_i$ is statistically significantly different from 0 across both Scope 1 and 2 and a combination of the two. Therefore, the overall result that emerges is that the introduction of the mandatory disclosure law had no impact on changes in total carbon emission levels/changes in emissions intensity for (Scope 1, 2 and 1+2) for Nordic firms that were forced to disclose as a result of the regulation and those that were voluntarily disclosing before the regulation even after replacing sector-fixed effects with industry-fixed effects. Similar results are found in Columns 2 (reports t-value) of Tables 11 and 12. We find that none of the coefficients of our interaction term is statistically significant. We can therefore conclude that the introduction of the mandatory disclosure law had no differential effect on the average firm value of Nordic firms that were forced to disclose as a result of the regulation and those that voluntarily disclosed before the regulation. This is in line with the studies by Griffin, Lont, and Sun (2017).

Table 11: Robustness check for Market Cap regression

This table contains the results from our robustness testing for the regression on Market Cap of our sample firms using industry-fixed effects instead of sector-fixed effects to observe for any significant changes to our original model in Table 5 with sector-fixed effects. All dummy variables are in *italic* text and our most important variable is the *Treat x After* dummy. It captures the effect of the introduction of mandatory emissions reporting regulation on our sample. *Treat* is a dummy which equals 1 if a company belongs to our treatment group and 0 otherwise. *After* is a dummy which equals 1 in regulation years (e.g., from 2018 onwards for Norway) and 0 otherwise (before 2018 for Norway). The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

Coefficients	Estimate (1)	t-value (2)
<i>Treat</i>	-4,45E+09	-4,159 ***
<i>After</i>	1,13E+09	1,491
<i>Treat x After</i>	-6,21E+07	-0,055
Log(Revenue)	2,86E+09	12,403 ***
<i>Denmark</i>	-5,90E+10	-9,298 ***
<i>Finland</i>	-5,84E+10	-9,276 ***
<i>Norway</i>	-5,64E+10	-9,154 ***
<i>Sweden</i>	-5,60E+10	-8,872 ***
Leverage	1,80E+08	3,922 ***
B/M	-2,98E+09	-3,369 ***
ROE	2,33E+10	9,592 ***
<i>Automobile Components</i>	5,94E+07	0,016
<i>Banks</i>	1,11E+10	3,42 ***
<i>Biotechnology</i>	3,76E+09	0,951
<i>Building Products</i>	4,73E+08	0,134
<i>Chemicals</i>	6,68E+08	0,191
<i>Commercial Services & Supplies</i>	-2,91E+09	-0,852
<i>Communications Equipment</i>	1,31E+10	3,43 ***
<i>Construction & Engineering</i>	-9,02E+09	-2,341 *
<i>Consumer Staples Distribution & Retail</i>	-8,72E+09	-2,271 *
<i>Containers & Packaging</i>	-4,17E+09	-1,083
<i>Diversified Telecommunication Services</i>	4,11E+09	1,148
<i>Electrical Utilities</i>	8,78E+09	1,993 *
<i>Electrical Equipment</i>	1,49E+10	3,865 ***
<i>Electronic Equipment, Instruments & Components</i>	-6,06E+08	-0,136
<i>Energy Equipment & Services</i>	5,32E+09	1,415
<i>Entertainment</i>	-2,90E+09	-0,649
<i>Food Products</i>	6,80E+08	0,208
<i>Health Care Equipment & Supplies</i>	-2,09E+08	-0,052
<i>Health Care Providers & Services</i>	-6,93E+07	-0,016
<i>Hotels, Restaurants & Leisure</i>	1,42E+09	0,365
<i>Household Durables</i>	1,58E+09	0,45
<i>IT Services</i>	-4,50E+09	-1,207
<i>Insurance</i>	9,02E+09	2,424 *
<i>Machinery</i>	7,52E+08	0,231
<i>Marine Transportation</i>	9,95E+09	2,713 **

<i>Media</i>	7,41E+08	0,198	
<i>Metals & Mining</i>	-1,10E+09	-0,31	
<i>Oil, Gas & Consumable Fuels</i>	1,62E+10	4,605	***
<i>Paper & Forest Products</i>	3,83E+09	1,108	
<i>Passenger Airlines</i>	6,59E+09	1,498	
<i>Pharmaceuticals</i>	4,06E+10	10,33	***
<i>Professional Services</i>	-8,89E+08	-0,203	
<i>Real Estate Management & Development</i>	7,34E+09	2,157	*
<i>Semiconductors & Semiconductor Equipment</i>	9,41E+09	2,457	*
<i>Specialty Retail</i>	4,97E+09	1,368	
<i>Wireless Telecommunication Services</i>	-2,43E+09	-0,55	

RSE: 9,003e+09 on 1015 degrees of freedom.

Multiple R-sq.: 0,6936

Adj. R-sq.: 0,6794

F-stat: 48,89 on 47 and 1015 DF, p-value: < 2,2e-16

Table 12: Robustness check for Change in Market Cap regression

This table contains the results from our robustness testing for the regression on Change in Market Cap of our sample firms using industry-fixed effects instead of sector-fixed effects to observe for any significant changes to our original model in Table 6 with sector-fixed effects. All dummy variables are in *italic* text and our most important variable is the *Treat x After* dummy. It captures the effect of the introduction of mandatory emissions reporting regulation on our sample. *Treat* is a dummy which equals 1 if a company belongs to our treatment group and 0 otherwise. *After* is a dummy which equals 1 in regulation years (e.g., from 2018 onwards for Norway) and 0 otherwise (before 2018 for Norway). The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

Coefficients	Estimate	t-value	
	(1)	(2)	
<i>Treat</i>	-3,98E+08	-0,788	
<i>After</i>	2,22E+08	0,576	
<i>Treat x After</i>	5,03E+08	0,88	
Δ in Revenue	3,42E-01	6,864	***
<i>Denmark</i>	8,52E+08	0,515	
<i>Finland</i>	8,01E+08	0,488	
<i>Norway</i>	5,93E+08	0,377	
<i>Sweden</i>	7,43E+08	0,453	
Leverage	2,37E+07	1,099	
B/M	-1,43E+09	-3,235	**
ROE	3,86E+09	3,306	***
<i>Automobile Components</i>	-4,64E+08	-0,252	
<i>Banks</i>	1,39E+08	0,087	
<i>Biotechnology</i>	-1,16E+09	-0,607	
<i>Building Products</i>	-5,16E+08	-0,299	
<i>Chemicals</i>	-6,71E+08	-0,391	
<i>Commercial Services & Supplies</i>	-1,07E+09	-0,633	

<i>Communications Equipment</i>	2,62E+08	0,138
<i>Construction & Engineering</i>	-9,31E+08	-0,488
<i>Consumer Staples Distribution & Retail</i>	-8,30E+08	-0,437
<i>Containers & Packaging</i>	-6,08E+08	-0,321
<i>Diversified Telecommunication Services</i>	-1,81E+09	-1,02
<i>Electrical Utilities</i>	-2,55E+09	-1,139
<i>Electrical Equipment</i>	6,84E+08	0,369
<i>Electronic Equipment, Instruments & Components</i>	-1,60E+09	-0,734
<i>Energy Equipment & Services</i>	8,86E+08	0,478
<i>Entertainment</i>	-1,14E+08	-0,052
<i>Food Products</i>	-1,93E+07	-0,012
<i>Health Care Equipment & Supplies</i>	-8,94E+08	-0,456
<i>Health Care Providers & Services</i>	-8,93E+08	-0,413
<i>Hotels, Restaurants & Leisure</i>	-8,89E+08	-0,468
<i>Household Durables</i>	-5,79E+08	-0,334
<i>IT Services</i>	-8,74E+08	-0,474
<i>Insurance</i>	-3,18E+08	-0,173
<i>Machinery</i>	4,50E+07	0,028
<i>Marine Transportation</i>	1,91E+09	1,049
<i>Media</i>	-4,95E+08	-0,268
<i>Metals & Mining</i>	1,05E+09	0,598
<i>Oil, Gas & Consumable Fuels</i>	1,29E+09	0,741
<i>Paper & Forest Products</i>	4,02E+08	0,236
<i>Passenger Airlines</i>	7,91E+08	0,363
<i>Pharmaceuticals</i>	5,15E+09	2,64 **
<i>Professional Services</i>	-6,48E+08	-0,298
<i>Real Estate Management & Development</i>	5,14E+08	0,31
<i>Semiconductors & Semiconductor Equipment</i>	1,26E+09	0,671
<i>Specialty Retail</i>	-2,23E+09	-1,241
<i>Wireless Telecommunication Services</i>	-3,97E+07	-0,018

RSE: 4,206e+09 on 897 degrees of freedom.

Multiple R-sq.: 0,1539

Adj. R-sq.: 0,1096

F-stat: 3,472 on 47 and 897 DF, p-value: < 3,043e-13

One surprising difference between our results was when we replaced sector-fixed effects with industry-fixed effects, none of our interaction terms $Treat_i * After_t$ was significantly different from zero, as can be observed in Table 10. However, in Table 3, changes in emission intensity (Scope 1+2) are statistically significant at the 5% level. A possible reason could be that within a sector, there can still be significant variation among individual firms in terms of their emission intensity changes. For example, certain firms within a sector may have proactively implemented emission reduction

measures before the mandatory disclosure requirements were introduced, while others may have been slower to take action. By using sector-fixed effects, the model may be able to capture this within-sector variation and find a significant relationship between the interaction term and emission intensity changes. There are also variations among firms in the same industry, and therefore industries can still encompass a wide range of firms with differing emission intensity changes. However, if there is limited variation in emission intensity changes within industries, the industry-fixed effects may not effectively capture this variation, which could result in a loss of significance for the interaction term. Hence, the level of variation and the specific characteristics of the sectors and industries in the dataset can influence the significance of the interaction term in each case.

7.0 Summary and Conclusion

In this paper, we exploit the introduction of mandatory carbon disclosure laws in four Nordic countries (Sweden, Denmark, Finland, and Norway) to estimate whether mandatory carbon disclosure requirements affect corporate GHG emissions and firm value.

We focus on Nordic firms that already voluntarily disclosed their GHG emissions prior to the introduction of the regulation (control group) and firms that were forced to disclose their emissions as a result of the regulation (treatment group). Our sample covers the period from 2013-2021. We find that the disclosure regulation had no impact on changes in total GHG emissions and firm value of Nordic firms. However, in terms of changes in emission intensity (Scope 1+2), the regulation led to an additional increase in the average GHG emissions (Scope 1+2) for our treatment group compared to our control group (using sector-fixed effects as one of our control variables in our regression). This suggests that firms in our control group have better emission efficiency compared to our treatment group, probably because they had already taken measures and adopted technology to improve their total emissions per unit of sales/activity level. However, when we replace sector-fixed effects with industry-fixed effects, we find no impact of the regulation on both GHG emissions and firm value which is quite surprising.

The findings of this study contribute to the existing literature on mandatory carbon disclosure requirements by providing empirical evidence specific to the Nordic countries. The literature on this topic has been growing in recent years as policymakers and researchers have sought to understand the effectiveness of mandatory disclosure regulations in driving emission reductions and promoting corporate transparency. By examining the impact of mandatory disclosure requirements on GHG emissions and firm value in Nordic countries, this study adds to the body of knowledge by providing insights into the Nordic context, which may have unique characteristics compared to other regions, thereby expanding the geographical scope of research on carbon disclosure requirement.

Moreover, our findings that the mandatory disclosure requirements did not lead to a reduction in emissions or an increase in firm value contribute to the ongoing debate on the effectiveness of such regulations. While some studies (Jouvenot & Krueger, 2019) have shown positive outcomes in terms of emission reductions associated with mandatory disclosure, our findings suggest that the relationship between disclosure requirements and emission reductions may vary across jurisdictions. The lack of a significant effect on emissions levels and firm value in the Nordic countries adds nuance to the existing literature and highlights the importance of considering contextual factors, such as existing voluntary initiatives, prescriptiveness of the law (what kind of information needs to be disclosed), standardization of the law, and other concurrent policies when analyzing the impact of mandatory disclosure requirements.

The study's findings also emphasize the need for further research and analysis to better understand the conditions under which mandatory carbon disclosure requirements are most effective and identify potential barriers or limitations to their success. It opens avenues for exploring alternative policy approaches and complementary instruments that can enhance the effectiveness of disclosure requirements in achieving emission reduction goals.

7.0.1 Limitations of our study

Firstly, our study only includes firms in the top 30% market capitalization in Sweden, Denmark, Norway, and Finland. This selection criterion may introduce bias and limit the generalizability of the findings to smaller or mid-sized firms outside of the Nordic

region. The findings may not be applicable to the entire population of firms in these countries or to firms in other regions. Secondly, our study focuses only on Scope 1 and Scope 2 emissions and excludes Scope 3 emissions due to concerns about their reliability and consistency in reporting. However, Scope 3 emissions are an important/significant component of a company's overall carbon footprint. Excluding them may result in an incomplete assessment of the impact of mandatory disclosure requirements on GHG emissions and firm value.

Thirdly, our methodology relies on assumptions in estimating the pre-regulation Scope 1 and Scope 2 emissions for the treatment group. These assumptions include using emissions of comparable firms on Euro Stoxx 600 within the same sector/industry with other similar firm-level characteristics as a proxy for the average pre-regulation emissions of our treatment group. The accuracy of these estimates relies on the validity of these assumptions, which may introduce uncertainties and potential biases in the analysis. Also, our study only considers data from 2013 to 2021, which may not capture the long-term effects of mandatory carbon disclosure requirements. The impact of such regulations on GHG emissions and firm value may evolve over time, and a longer time frame would provide a more comprehensive understanding of the effects.

Finally, the sample size used in the study, consisting of 67 firms in the control group and 51 firms in the treatment group, may be considered relatively small. This could affect the statistical power of the analysis and limit the generalizability of the findings. A larger sample size would provide more robust results and improve the representativeness of the study.

It is important to acknowledge these limitations and shortcomings when interpreting the results of this study and considering its implications. Future research could address these limitations by considering a broader range of firms as the number of disclosing companies and data increases, including Scope 3 emissions in their analysis, and conducting longer-term analysis (expanding time horizon).

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Appendix

Table 13: Exchange rates

Exchange rates used to convert from each country's base currency to EUR. The rates used are average daily exchange rates for each year. Units are domestic currency units per unit of Euro.

	EURSEK	EURNOK	EURDKK
2013	8,65	7,81	7,46
2014	9,10	8,35	7,45
2015	9,36	8,95	7,46
2016	9,47	9,29	7,45
2017	9,63	9,33	7,44
2018	10,26	9,60	7,45
2019	10,59	9,85	7,47
2020	10,49	10,72	7,45
2021	10,14	10,16	7,44

Table 14-a: Regression excluding Tax Havens and non-European countries (Scope 1)

This table contains results for the regression equation [$\text{LogScope1} = \beta_0 + \beta_1\text{Log(Revenue)} + \beta_2\text{Sector} + \beta_3\text{Leverage} + \beta_4\text{B/M} + \beta_5\text{ROE} + \beta_6\text{CountryFE} + \beta_7\text{TimeFE} + u$] but without 7 countries labelled as potential tax havens or non-European i.e. Bermuda, Chile, Ireland, Jordan, Luxembourg, South Africa, and Switzerland. This helps in reducing noise in our model due to unnecessary dummies. The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

	Estimate	t-value	
<i>(Intercept)</i>	-12,66	-16,23	***
Log(Revenue)	1,16	38,30	***
<i>Austria</i>	0,21	0,37	
<i>Belgium</i>	1,41	2,57	*
<i>Denmark</i>	-0,33	-1,31	
<i>Finland</i>	-0,63	-2,68	**
<i>France</i>	-0,23	-1,54	
<i>Germany</i>	0,50	2,90	**
<i>Italy</i>	0,38	1,66	.
<i>Netherlands</i>	-0,57	-2,18	*
<i>Norway</i>	0,78	2,85	**
<i>Poland</i>	0,24	0,44	
<i>Portugal</i>	0,45	1,11	
<i>Spain</i>	-0,58	-2,89	**
<i>Sweden</i>	-0,72	-3,59	***

<i>United Kingdom</i>	0,15	1,10	
<i>Sector 15 (Materials)</i>	0,27	1,14	
<i>Sector 20 (Industrials)</i>	-2,15	-9,42	***
<i>Sector 25 (Consumer Discretionary)</i>	-3,54	-15,02	***
<i>Sector 30 (Consumer Staples)</i>	-2,24	-9,33	***
<i>Sector 35 (Health Care)</i>	-2,37	-9,35	***
<i>Sector 40 (Financials)</i>	-6,26	-27,13	***
<i>Sector 45 (Information Technology)</i>	-3,79	-13,90	***
<i>Sector 50 (Communication Services)</i>	-4,10	-16,20	***
<i>Sector 55 (Utilities)</i>	0,89	3,76	***
<i>Sector 60 (Real Estate)</i>	-2,92	-9,83	***
Leverage	0,03	0,89	
B/M	0,70	6,17	***
ROE	0,02	0,56	
2014	-0,09	-0,74	
2015	-0,16	-1,31	
2016	-0,16	-1,24	
2017	-0,18	-1,40	
2018	-0,29	-2,27	*

RSE: 1,274 on 1202 degrees of freedom
Multiple R-Sq.: 0,8447 Adj. R-Sq.: 0,8404
F-stat: 198,1 on 33 and 1202 DF, p-value: < 2,2e-16

Table 14-b: Regression excluding Tax Havens and non-European countries (Scope 2)

This table contains results for the regression equation [$\text{LogScope2} = \beta_0 + \beta_1 \text{Log(Revenue)} + \beta_2 \text{Sector} + \beta_3 \text{Leverage} + \beta_4 \text{B/M} + \beta_5 \text{ROE} + \beta_6 \text{CountryFE} + \beta_7 \text{TimeFE} + u$] but without 7 countries labelled as potential tax havens or non-European i.e. Bermuda, Chile, Ireland, Jordan, Luxembourg, South Africa, and Switzerland. This helps in reducing noise in our model due to unnecessary dummies. The asterisk and dot next to the t-values show the significance levels at which the corresponding coefficients are significant. “.”, *, **, and *** indicate 10%, 5%, 1%, and 0,1% levels, respectively.

Coefficients	Estimate	t-value	
<i>(Intercept)</i>	-12,48	-18,32	***
Log(Revenue)	1,04	39,00	***
<i>Austria</i>	2,09	4,31	***
<i>Belgium</i>	1,00	2,09	*
<i>Denmark</i>	-0,29	-1,29	
<i>Finland</i>	0,00	-0,02	
<i>France</i>	0,01	0,08	
<i>Germany</i>	0,31	2,02	*
<i>Italy</i>	-0,23	-1,14	
<i>Netherlands</i>	-0,06	-0,27	
<i>Norway</i>	0,08	0,33	
<i>Poland</i>	1,11	2,34	*

<i>Portugal</i>	0,52	1,45	
<i>Spain</i>	0,40	2,29	*
<i>Sweden</i>	0,19	1,08	
<i>United Kingdom</i>	0,00	0,03	
<i>Sector 15 (Materials)</i>	2,80	13,69	***
<i>Sector 20 (Industrials)</i>	0,12	0,62	
<i>Sector 25 (Consumer Discretionary)</i>	0,20	0,98	
<i>Sector 30 (Consumer Staples)</i>	0,71	3,38	***
<i>Sector 35 (Health Care)</i>	0,95	4,29	***
<i>Sector 40 (Financials)</i>	-1,38	-6,84	***
<i>Sector 45 (Information Technology)</i>	0,67	2,81	**
<i>Sector 50 (Communication Services)</i>	0,45	2,05	*
<i>Sector 55 (Utilities)</i>	1,35	6,48	***
<i>Sector 60 (Real Estate)</i>	1,61	6,22	***
Leverage	0,08	3,01	**
B/M	0,13	1,36	
ROE	-0,13	-4,23	***
2014	-0,07	-0,59	
2015	-0,10	-0,95	
2016	-0,15	-1,33	
2017	-0,21	-1,88	.
2018	-0,32	-2,88	**

RSE: 1,113 on 1202 degrees of freedom

Multiple R-Sq.: 0,7571

Adj. R-Sq.: 0,7505

F-stat: 113,5 on 33 and 1202 DF, p-value: < 2,2e-16

Table 15: Description of variables

Variable Name	Description
GHG emissions	Greenhouse gas emissions in tons of carbon dioxide equivalent.
Scope 1	These emissions are direct emissions from the operations of affiliates that are owned or controlled by a company.
Scope 2	These emissions come from the generation of purchased heat, steam, and electricity.
Scope 3	These emissions are indirect emissions caused by a company's operations and the use of its products. These include emissions from the production of purchased materials,

	product use, waste disposal, and outsourced activities.
Market Capitalization	Market capitalization is equal to the market price per common share multiplied by the number of common shares outstanding.
Return on Equity (ROE)	ROE measures a company's profitability by assessing how effectively it generates returns for its shareholders based on their equity investment.
Leverage (D/E)	It compares a company's total debt to its shareholders' equity, providing insight into its financial leverage and risk profile.
Book-to-Market (B/M)	It compares a company's book value to its market value, providing insights into its valuation and potential investment opportunities.
Size	It is the natural logarithm of the total revenue of a firm.
D in Size	It is the year-on-year change in the total revenue of a firm.
Treat	It is a dummy variable that equals 1 if a corresponding firm is part of our treatment group and 0 otherwise.
After	It is a dummy variable that equals 1 if an observation is in a year post-regulation in that specific country and 0 otherwise.

Data collection and handling process:

We identified WorldScope Refinitiv and Bloomberg as the primary sources of our data extraction process. All the financial and emissions data for our control and treatment group i.e., Denmark, Finland, Norway, and Sweden, was used from Refinitiv. We picked the top 30% of the companies in terms of market cap from each country because small companies may have characteristics related to their size that may muddy our inference. Small companies also do not have enough or an adequate amount of data. We do not include data on emissions before 2010. This is because data on Scope 1 and 2 emissions were not readily available, especially for Nordic firms. We looked at data from 2013 to 2021 and when we extracted the data on top 30% in terms of market cap from each country, then we had to filter out all the companies that had not reported their emissions in the sample period. This left us with only companies that were regularly disclosing emissions information from 2013 to 2018 and some companies that started disclosing after regulations were in place. We had 67 companies from our 4 countries that voluntarily and consistently disclosed emissions information throughout the period (control group) and 51 companies that only started reporting after the regulation (treatment group).

From the regression equation 1 in the methodology section of the paper, we obtained sector and firm characteristic matched coefficients of similar disclosing firms on the Euro Stoxx 600. We then used the coefficients of each of our control variables and multiplied them by the company-specific characteristics of our control variables, like size, leverage, etc., of the firms in our treatment group; we then added them together, including the constant (intercept) as in the equation above to come up with the pre-regulation estimates of Scope 1 and 2 emissions. Sector is a dummy variable that equals 1 if a firm is in a particular sector and zero otherwise. We initially decided to use sector instead of industries in calculating our estimates because Euro stock 600 has so many industries, and we wanted to reduce the number of dummies to avoid any bias and overfitting issues. We used 11 sector dummies in total. However, in our robustness checking, we used industries to calculate the estimated emissions. Likewise, CountryFEs is a dummy variable that equals 1 for a specific country in our treatment group and 0 otherwise. For example, when estimating the emissions of a Norwegian firm, this equals 1 if a firm in our treatment group is a Norwegian firm and zero

otherwise. We used 21 country dummies in total. The coefficients from the four Nordic country-fixed effects as estimated from the Euro Stoxx 600 regression were used in calculating the estimated pre-regulation GHG emissions of our treatment group. To avoid having too many dummy variables in our regressions, we grouped country dummies into categories. These categories consist of countries in the EU that are tax-havens e.g., Switzerland, and countries outside the EU that are also tax havens e.g., Bermuda. TimeFEs is a dummy variable that equals 1 for a particular year we are looking at and zero otherwise. We used six-time dummies (2013-18) in our estimation. In total, we used 36 dummies in estimating Scope 1 and 2 emissions for our treatment group.

In calculating the estimates of Scope 1 and 2 emissions (levels), we used the full specification (plus the intercept) of the equation above, including coefficients of all the sector categories and control variables, even for those that were not statistically significant. However, for country categories, we only used the coefficients of the Nordic countries in our treatment group. The regression above helped us obtain the estimated pre-regulation Scope 1 and 2 emissions for our treatment group.