The impact of carbon emissions on firm profitability and firm risk in Europe

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ABSTRACT

This thesis aims to assess the connection between firm profitability and firm risk in the European area for 568 companies between 2010 and 2020, incorporating times of higher investor awareness. Stock returns, return on assets, stock return volatility and operating-income volatility serve as proxies when computing panel regressions while differentiating between three scopes of emissions and three emission variables. The results suggest a negative relationship between the level and intensities of carbon emissions and firm profitability, while there is no defined correlation with firm risk. Distinguishing between the different scopes of emissions and different forms of firm risk seems to be important when making decisions in the context of carbon emissions and associated risks or opportunities. This becomes even clearer when looking at the change in emissions where I show that coefficients carry the opposite sign compared to emission levels and intensities. Furthermore, managers should adjust decision-making during times of elevated investor awareness as the negative impact of higher carbon emissions on firm profitability amplifies.

Keywords: Carbon Emissions, Firm Profitability, Firm Risk, Investor Awareness

RESUMO

Esta tese tem como objetivo avaliar a relação entre a rendibilidade e o risco de 568 empresas europeias entre 2010 e 2020, considerando períodos de maior sensibilização dos investidores. O retorno das ações, o retorno sobre ativos, a volatilidade dos retornos das ações e a volatilidade da rendibilidade operacional são utilizados como variáveis auxiliares ao calcular as regressões em painel, diferenciando entre três âmbitos de emissões e três variáveis de emissão. Os resultados sugerem uma relação negativa entre o nível e as intensidades das emissões de carbono e a rendibilidade da empresa, embora não haja correlação definida com o risco da empresa. A distinção entre os diferentes âmbitos de emissões e as diferentes formas de risco da empresa aparenta ser importante na tomada de decisões no contexto das emissões de carbono e respetivos riscos ou oportunidades associadas. Esta conclusão fica ainda mais clara após analisar a alteração nas emissões, onde verifico que os coeficientes apresentam o sinal oposto quando em comparação com os níveis e intensidades de emissão. Além disso, os gerentes devem ajustar a tomada de decisões durante os períodos de maior sensibilidade do investidor, pois o impacto negativo das emissões de carbono mais altas na rendibilidade da empresa aumenta.

Palvras-chave: Emissões de carbono, Rentabilidade da empresa, Risco da empresa, Sensibilização dos investidores

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List of Abbreviations

CDS	Credit Default Swap
CSR	Corporate Social Responsibility
ESG	Environmental Social Governance
FE	Fixed Effects
GIC	Global Industry Classification
GHG	Greenhouse Gas
ISIN	International Securities Identification Numbering
MSCI	Morgan Stanley Capital International
RE	Random Effects
S&P 500	Standard & Poor's 500
US	United States

1. Introduction

How much does the company emit? Do we need to report the companies' carbon emissions? Should we reduce them? Can we profit from reducing emissions? How do investors react to large changes in emissions? There are many questions a manager can ask in the context of carbon emissions. It is very important to incorporate increasing prices of fossil fuels and CO2 certificates, leading to an increasing number of companies trying to reduce their carbon emissions. On the other hand, renewable energy and the transition to clean production demand immense investments that mostly only pay off years after. The management has to decide what is best for the company. However, one can also investigate the investors' perspective as they might question investing in companies with high carbon emissions. Not only because of the associated risks that emerged in recent years but also scrutinizing the consequences of their decision to invest in carbon-intensive companies. Environmentally and socially responsible investors as well as others therefore must deal with carbon emissions and their impact on the companies, they invest in.

This thesis will examine the impact of carbon emissions on firm profitability and firm risk from 2010 until 2020 in Europe. I test two proxies of each using panel regressions with three emission variables for each scope of carbon emissions. This not only helps investors in answering the question of whether or not companies with high carbon emissions incorporate higher risks but also helps managers understand the impact of an increase or decrease in carbon emissions on their firm's profitability. Furthermore, the effect of investor awareness on the relationship between carbon emissions and both stock returns and stock return volatility will be tested using the Doha Amendment and the Paris Agreement as reference dates for elevated public climate change awareness. In the analysis, carbon emissions will be distinguished between scope 1, scope 2, and scope 3 emissions. Scope 1 includes direct emissions from production, scope 2 indirect emissions from the use of purchased electricity, heat, or steam, and scope 3 incorporates other indirect emissions, typically along the supply chain.

There are several theories regarding the impact of carbon emissions on stock returns. On the one hand, the carbon risk premium hypothesis assumes that companies with higher carbon emissions are more exposed to carbon pricing risk and other regulatory risks. Furthermore, a greater reliance on fossil fuel energy results in a greater exposure to technology risk from low-cost renewable energy. Thus, investors might require a higher compensation. On the other hand, the divestment hypothesis states that socially responsible investors 'shun' the stocks of firms with high emissions. In addition, companies with high carbon emissions may face significant risks and costs associated with climate change regulations, such as carbon taxes. As a result, companies with high carbon risk exposure may experience lower profits, higher costs, and reduced competitiveness in an increasingly low-carbon economy, leading to lower stock returns. In contrast, companies with little carbon exposure may be better positioned to adapt to a low-carbon economy and may experience higher stock returns (Bolton & Kacperczyk, 2021a). This thesis aims to explore the impact of carbon emissions on the European market.

The results imply a negative relationship between the level and intensity of carbon emissions and firm profitability but discover an unclear relation between carbon emissions and firm risk. While carbon emissions display a positive effect on stock return volatility, they show a negative influence on operating-income volatility. The change in emissions carries the opposite sign compared to the level of emissions. However, these are only broad findings. It is essential to differentiate between the three scopes of emissions as each scope has a different influence on firm performance and risk. Moreover, the results suggest that higher investor awareness has an impact on the connection between carbon emissions and firm profitability and firm risk.

The remainder of this paper is structured as follows. The literature review is presented in Section 2. Methodology and data are described in Section 3. Empirical results as well as their discussion are reported in Section 4. The limitations and further research suggestions are given in Section 5. Finally, the conclusion and implications of the results are portrayed in Section 6.

2. Literature Review

CSR, ESG, carbon emissions, and policy risk and their impact on stock prices, firm performance, and the price of equity capital are topics discussed frequently in recent literature. There are several hypotheses regarding the way in which carbon emissions can have an impact on stock returns or other measures of firm performance, where a positive relationship is often called the 'carbon premium'. Several studies have found that this carbon premium holds in markets around the world. Others found contradicting evidence. The following section will present an overview of the existing literature.

2.1 Carbon Emissions and Firm Performance

2.1.1 Evidence of a Carbon Premium

Bolton and Kacperczyk (2021a, 2021b) examine the impact of carbon transition risk in several studies. First, they studied the carbon premium for the US from 2005 to 2017 and then rolled it out to markets around the world for a sample period of 2005 to 2018. In both studies, they discover a positive relationship between total carbon emissions and stock returns and year-to-year change in carbon emissions and stock returns. However, they could not find a significant impact of carbon intensity on returns. In their studies, they differentiate between the three scopes of emissions and three categories of emission variables (Bolton & Kacperczyk, 2021a, 2021b).

When studying the US market, they focus on examining three hypotheses about the link between carbon emissions and stock returns, the carbon risk premium hypothesis, the market inefficiency/carbon alpha hypothesis, and the divestment hypothesis. Hence, apart from finding evidence in cross-sectional returns they relate the carbon premium to traditional risk factors and examine portfolio holdings of institutional investors where they cannot find evidence of a divestment effect. Furthermore, they test how the carbon premium behaves in times with higher investor awareness, by comparing the period before the Paris Agreement with the period after. They confirm that investor awareness enhances the carbon premium (Bolton & Kacperczyk, 2021a).

In addition to comparing carbon premia around the world in their second paper, Bolton and Kacperczyk (2021b) examine if a country's economic development or other risk factors such as the technology mix, the social-political environment, climate policy tightness, a firm's reputation, or physical risk can affect the carbon premium. Amongst other results, they observe that, in the long term, economic development is not as relevant as one might think. At the same time, a higher share of renewable energy in one country can negatively influence the carbon premium. Again, they examine the impact of investor awareness by means of the Paris Agreement. Here, comparing two years preceding the agreement and two years after. Once more, they find a significant and positive premium (Bolton & Kacperczyk, 2021b). In a third study, Bolton et al. (2022) examine greenhouse gas (GHG) emissions in relation to the price-to-earnings ratio for the US and Europe from 2016 to 2020. In line with their earlier findings, they discover an increasingly negative relationship between carbon emissions and the price-to-earnings ratio, and an existing, but smaller link to other GHG. Furthermore, they extend their study to debt markets using CDS. For larger companies, they do not find a significant impact while observing a small effect for small-cap companies (Bolton et al., 2022).

This thesis adds to Bolton and Kacperczyk (2021b, 2021a) and Bolton et al. (2022) not only by examining two stages of risen investor awareness, but adding carbon emissions impacts on firm risk, which can help a firms management in decision-making as well as investors.

Ilhan et al. (2021) study the impact of climate policy uncertainty on the option market and find that carbon-intensive firms pay more for the protection against downside tail risk using mainly scope 1 carbon intensity (scope 1 emissions divided by the company's market value) and option market measures of firms in the S&P 500. Moreover, they examine if the increased awareness of climate change magnifies their findings. They confirm this hypothesis for the negative climate change index by Engle et al. (2020) but have to reject it using Google search volume data. Finally, the authors find that Donald Trump's election in 2016 decreased the cost of downward option protection with him being recognized as a climate change sceptic (Ilhan et al., 2021). Ilhan et al. (2021), thus, support the hypothesis that climate risk affects financial markets. While they focus on the US option market, this thesis will focus on stock markets, firm profitability, and risk profiles in Europe.

Kim et al. (2015) test the relation of carbon intensity to the cost of equity capital for Korean firms from 2007 to 2011. While finding a positive relationship that is even stronger for companies in low-emission industries, they find that there is no difference between voluntary and non-voluntary disclosure (Kim et al., 2015). Their study is one of the first empirical studies in the field, but this thesis concentrates on a market recognized to be ahead in regulation while differentiating between the different scopes of emissions for a more recent period.

2.1.2 Contradicting Evidence

While the studies of Bolton and Kacperczyk (2021a, 2021b) suggest a positive relationship between carbon emissions and stock returns, some authors find contradicting evidence. Garvey et al. (2018) study the change in carbon ratio (corresponds to carbon intensity) in relation to the financial performance of firms, return on assets, and stock returns. For the period from 2011 to 2015 in the MSCI universe they discover that a reduction in carbon intensity can lead to a better future performance and a positive return when using the carbon ratio as a method for selecting shares (Garvey et al., 2018). In their research, they focus on scope 1 and scope 2 emissions. Not only does this thesis study scope 3 emissions as well, but it also takes the level of emissions and change in emissions into account for a longer period.

Cheema-Fox et al. (2021) analyze portfolio outcomes that are based on several climate metrics, such as operational carbon efficiency (scope 1 & scope 2), total value chain carbon intensity (scope 3), and analyst rating data. Their sample covers firms in the US for a period from 2013 to 2020. In their paper, portfolios are constructed in such a way that the investor goes long on stocks that are better prepared for a low-carbon economy and short stocks where companies are less prepared for a low-carbon economy. They find portfolios with considerably heterogeneous returns and risk profiles, where portfolios based on analyst ratings and operational carbon efficiency outperform portfolios that are built based on the total value chain (Cheema-Fox et al., 2021). This thesis adds to their studies by incorporating the firm perspective as well as the investors' perspective using different proxies for firm profitability and firm risk.

Considering the ongoing discussion, this paper aims to look further into the matter of carbon emissions impact on firm performance, adding to it the impact on firm risk.

3. Methodology and Data

In this thesis, I base my methodology on the approach of Bolton and Kacperczyk (2021a). To examine the impact of carbon emissions on firm profitability and firm risk, I ran several panel regressions. Furthermore, the importance of investor awareness will be tested by splitting the sample into three periods, before the Doha Amendment, in-between the Doha Amendment and the Paris Agreement, and after the Paris Agreement leading to four sets of results.

3.1 Method

In panel data analysis, there are two commonly used models: fixed effects (FE) and random effects (RE). In a fixed effects model, included variables can be correlated with the unobserved individual effects. It might be reasonable to model the individual specific constant terms as randomly distributed across cross-sectional units if the individual effects are strictly uncorrelated with the regressors. This approach has the benefit of reducing the number of parameters that must be estimated. Should the assumption prove to be incorrect, there might be a potential for inconsistent estimators. Running the Hausman test resulted in a probability of 0.0000 for the chi-square statistic indicating that the RE model is inconsistent and the FE model should be used instead (Greene, 2012; Hausman, 1978). Additionally, to ensure reliable, unbiased results, the model needs to be tested for endogeneity. Endogeneity refers to a situation where a predictor variable is correlated with the error term. The Hausman test indicates that endogeneity might be present in the RE model, which the FE model is better equipped to handle. Thus, the regression includes quarter fixed effects. To add robustness, firm fixed effects will be added in the second step of the analysis, and industry fixed effects in the third. As errors in variances specific to the different firms might be present, I calculated the modified Wald statistic for groupwise heteroskedasticity. A probability for a chi-square statistic of 0.0000 suggests that heteroskedasticity is present. Hence, robust standard errors were added to the regression equations (Greene, 2012; Hausman, 1978).

3.1.1 Regressions with Firm Profitability

To determine the relationship between carbon emissions and firm profitability, I ran multiple panel regressions using a fixed effects model. I chose two proxies for firm profitability, stock returns and return on assets, whereas the former offers an investors' and the latter a firm perspective (Bolton & Kacperczyk, 2021a; Garvey et al., 2018).

First, following Bolton and Kacperczyk (2021a), I look at stock returns relative to the three categories of emissions, the level of company emissions, the year-to-year growth in emissions, and emission intensity:

$$RET_{i,t} = a_0 + a_1 LOG(TOT\ Emissions)_{i,t} + a_2 LOGSIZE_{i,t} + a_3 BM_{i,t} + a_4 ROE_{i,t} + a_5 LEVERAGE_{i,t} + a_6 RETEARN_{i,t} + \mu_t + \varepsilon_i$$

(1)

Accordingly, I estimate a regression with return on assets as a second proxy for firm performance:

$$ROA_{i,t} = a_0 + a_1 LOG(TOT\ Emissions)_{i,t} + a_2 LOGSIZE_{i,t} + a_3 BM_{i,t} + a_4 ROE_{i,t} + a_5 LEVERAGE_{i,t} + a_6 RETEARN_{i,t} + \mu_t + \varepsilon_i$$

(2)

Both regression equations include time fixed effects (μ_t) and robust standard errors. ε_i presents an error term clustered at the firm level.

3.1.2 Regressions with Firm Risk

The examination of the relationship between carbon emissions and firm risk follows the methods used for firm profitability. Here, return volatility and operating-income volatility will serve as proxies for firm risk from an investors' perspective and a firm perspective, respectively (Bodie et al., 2018; Guay, 1999). Again, all sources of carbon emissions will in turn be inserted as the independent variable for the total level of emissions, the year-to-year change in emissions, and emission intensity, correspondingly.

$$RETVOLA_{i,t} = a_0 + a_1 LOG(TOT\ Emissions)_{i,t} + a_2 LOGSIZE_{i,t} + a_3 BM_{i,t} + a_4 ROE_{i,t} + a_5 LEVERAGE_{i,t} + a_6 RETEARN_{i,t} + \mu_t + \varepsilon_i$$

(3)

$$OPVOLA_{i,t} = a_0 + a_1 LOG(TOT\ Emissions)_{i,t} + a_2 LOGSIZE_{i,t} + a_3 BM_{i,t} + a_4 ROE_{i,t} + a_5 LEVERAGE_{i,t} + a_6 RETEARN_{i,t} + \mu_t + \varepsilon_i$$

(4)

In both equations, μ_t represents quarter fixed effects (Bolton & Kacperczyk, 2021a). Also, both regressions are computed with robust standard errors. ε_i presents an error term clustered at the firm level.

3.1.3 Investor Awareness

To test if rising investor awareness has an impact on the link between carbon emissions and firm profitability and firm risk, the sample period was further divided into three. A first period from 2010: Q1 until the Doha Amendment in 2012: Q4, a second period from 2013: Q1 until the Paris Agreement in 2015: Q4, and a third period after the Paris Agreement. Both are international agreements that have the goal of reducing greenhouse gas emissions. The Kyoto Protocol was amended in 2012 during the 18th Conference of the Parties in Doha, Qatar. The "Doha Amendment" allows for the unilateral strengthening of obligations by individual parties and provides a second commitment term from 2013 to 2020. It also includes nitrogen trifluoride in the list of greenhouse gases. At the UN Climate Change Conference (COP21) in Paris on December 12th, 2015, the Paris Agreement was approved by 196 Parties. Its main objective is to pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels" and keep "the increase in global average temperature to well below 2°C above pre-industrial levels." (United Nations Climate Change, 2023a, 2023b). The regressions seen above will then be computed again for each period leading to four sets of results, one full sample, and three time periods. As this part of the analysis should focus on the investor's perspective, only stock returns and stock return volatility will be analyzed.

3.2 Data

The dataset contains quarterly data for firms listed on the Stoxx 600, an index replicating the 600 largest companies in Europe from 2010 to 2020 (Qontigo, 2023). I retrieved data on carbon emissions as well as firm fundamentals from Datastream. For the industry classification, the 6-digit GIC code was downloaded from Compustat and merged on ISIN with the rest of the data. As carbon emissions are only available annually, I assume an even distribution throughout the quarters and divide the annual figures by four. After removing all companies for which carbon emissions are not reported, the sample consists of 575 companies. Furthermore, as financial firms have unique characteristics that differ from non-financial firms, which can confound the results of productivity analyses, financial firms were removed from the sample, resulting in 568 firms being included in the sample (Corrado et al., 2005). Appendix B presents the distribution of firms in the sample with respect to the GIC 6 industry classification. The five most represented industries in the sample are Machinery (6.69%), Food Products (5.11%), Chemicals (4.93%), Textiles, Apparel & Luxury Goods (4.23%), and Hotels, Restaurants & Leisure (3.87%). Additionally, Table 1 indicates the distribution across countries. Great Britain, France, Sweden, and Germany are the countries that are represented most in the sample at 22.54%, 14.44%, 13.56%, and 12.32%, respectively.

Table 1: Distribution of firms across countries.

Country	Freq.	Percent	Cum.
Austria	7	1.23	1.23
Belgium	9	1.58	2.81
Denmark	45	7.92	10.73
Finland	11	1.94	12.67
France	82	14.44	27.11
Germany	70	12.32	39.43
Great Britain	128	22.54	61.97
Ireland	7	1.23	63.20
Italy	25	4.40	67.60
Luxembourg	10	1.76	69.36
Netherlands	24	4.23	73.59
Norway	7	1.23	74.82
Poland	3	0.53	75.35
Portugal	3	0.53	75.88
Spain	23	4.05	79.93
Sweden	77	13.56	93.49
Switzerland	37	6.51	100.00
Total	568	100.00	

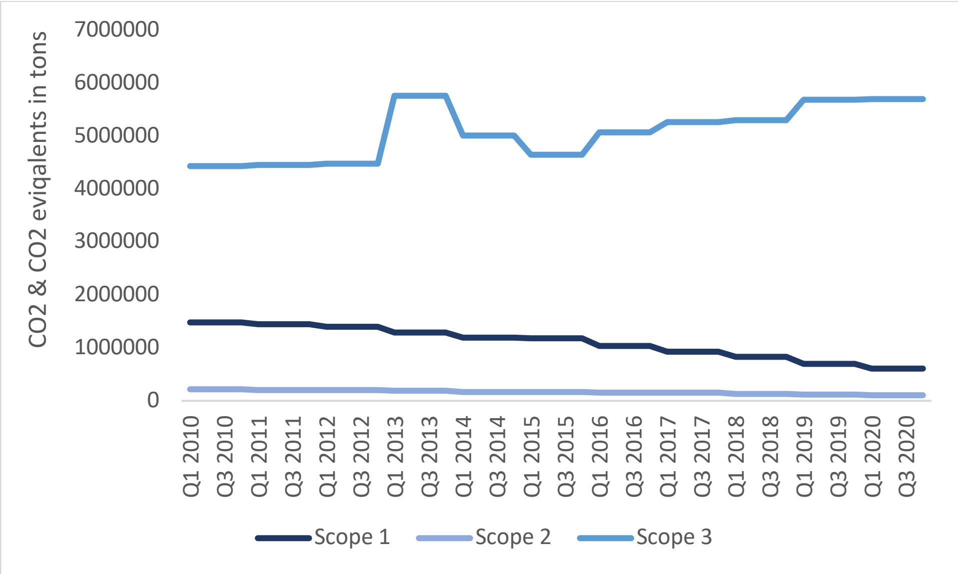
This table displays the distribution of firms across countries. Freq. represents the total number of firms in each country in the sample.

3.2.1 Data on Carbon Emissions

The carbon emissions data downloaded from Datastream follows the Greenhouse Gas Protocol. Hence, one must distinguish between scope 1, scope 2, and scope 3, whereas scope 1 emissions are direct emissions, and scope 2 and scope 3 comprise indirect emissions. Scope 1 therefore includes emissions that "occur from sources that are owned or controlled by the company" (Greenhouse Gas Protocol, 2004, p. 25), scope 2 "emissions from the generation of purchased electricity consumed by the company" (Greenhouse Gas Protocol, 2004, p. 25), and scope 3 incorporates "consequence(s) of the activities of the company, but occur from sources not owned or controlled by the company" (Greenhouse Gas Protocol, 2004, p. 25).

Datastream reports CO2 and CO2 equivalent emissions in tons, where scope 2 includes the "consumption of purchased electricity, heat or steam which occur at the facility where electricity, steam or heat is generated" and scope 3 "emissions from contractor-owned vehicles, employee business travel (by rail or air), waste disposal, outsourced activities emissions from product use by customers, emission from the production of purchased materials, emissions from electricity purchased for resale". Figure 1 displays the average firm emissions of the three different sources of emissions over time. Scope 1 and scope 2 emissions steadily decrease, whereas scope 1 shows a steeper curve converging from around 1,500,000 tons in 2010 to around 610,000 tons in 2020. In contrast, scope 3 increases over time. Scope 3 emissions increased from around 4,400,000 in 2010 through 2012, then peaked in 2013, decreasing through 2015, and then show a steady increase to around 5,700,000 tons in 2020. However, these results might be biased as more companies with higher scope 3 carbon records had to publish their carbon emission figures in recent years.

Figure 1: Average carbon emissions over time.



This research includes three categories of emission variables which in turn will be inserted in the regression equations (1) to (4). First, the level of emissions for all three scopes is normalized using the natural logarithm. Also, the year-on-year change in emissions which is calculated as a percentage change and winsorized at 1%. And third, carbon intensity which is computed by dividing the level of emissions by net sales, too winsorized at a 1% level. Emission levels thereby reflect a firm's carbon risk exposure in the long term, while the growth in emission figures captures the short-term risk exposure (Bolton & Kacperczyk, 2021a). Table 2 Panel A shows the summary statistics of the emission variables.

Table 2: Summary statistics.

Variables	Obs.	Mean	Std. Dev.	Min	Max
		Panel A: Emission variables			
LOGSCOPE1	17160	9.710	3.254	-2.303	17.632
LOGSCOPE2	17084	9.853	2.410	-0.322	15.474
LOGSCOPE3	13380	10.639	3.481	1.012	19.979
SCOPE1GROWTH	16534	-0.030	1.323	-6.960	7.107
SCOPE2GROWTH	16461	-0.119	1.151	-6.374	4.900
SCOPE3GROWTH	12766	0.255	3.005	-10.435	22.258
SCOPE1INT	17236	0.041	0.124	0.000	0.866
SCOPE2INT	17144	0.011	0.021	0.000	0.125
SCOPE3INT	13428	0.110	0.279	0.000	1.825
		Panel B: Dependent variables			
RET	22888	0.032	0.152	-1.000	1.000
ROA	24165	0.057	0.122	-2.407	2.634
RETVOLA	22953	0.282	0.114	0.117	0.718
OPVOLA	22364	0.079	0.262	-1.066	1.663
		Panel C: Controls			
LOGSIZE	22972	19.012	2.454	13.448	25.278
BM	22972	0.110	0.264	0.000	1.825
ROE	24169	0.142	0.174	-0.448	1.033
LEVERAGE	24165	0.242	0.160	0.000	0.649
RETEARN	23673	0.255	0.294	-4.441	1.429

This table reports the summary statistics (observations, mean, standard deviation, minimum, and maximum) for all variables used in this thesis. Panel A reports the descriptive statistics for the emission variables, Panel B for the dependent variables, and Panel C for the controls.

To deepen the understanding of the emission variables, Table 3 shows the cross-correlations amongst the emission variables for all sources of emissions. Predictably, all variables are positively correlated. The strongest correlations can be detected between the level of emissions and the corresponding emission intensities. However, with the highest correlation being 0.72, one can conclude that firms with the same intensity can have different levels of emissions. Moreover, the emission variables were tested for serial correlation by estimating the AR (1) model. The results are shown in Appendix C. As expected, emission levels for all scopes are highly correlated with autocorrelation coefficients of 0.94, 0.84, and 0.75 for scope 1, scope 2, and scope 3, respectively, each at a 1% significance level. The same applies for emission intensities with 0.96, 0.93, and 0.67 for scopes 1, 2, and 3. However, results for the year-on-year change in emissions are not statistically significant.

Table 3: Cross-correlation amongst emission variables.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) SCOPE1TOT	1.000					
(2) SCOPE2TOT	0.573	1.000				
(3) SCOPE3TOT	0.319	0.479	1.000			
(4) SCOPE1INT	0.722	0.402	0.097	1.000		
(5) SCOPE2INT	0.246	0.545	0.074	0.383	1.000	
(6) SCOPE3INT	0.264	0.332	0.622	0.254	0.212	1.000

This table reports the cross-correlation between the total level of emissions and emission intensities for each scope.

3.2.2 Data for Panel Regressions

Quarterly fundamental firm data was retrieved from Datastream. Stock returns were calculated as holding period returns with $RET_{i,t} = (P_{i,t} - P_{i,t-1})/P_{i,t-1}$, while return on assets (ROA) is net income to common shareholders divided by total assets (Bodie et al., 2018; Fiechter et al., 2022). To improve reliability and accuracy, outliers in returns greater than 100% were removed from the sample. Thereby, eight observations were dropped, not materially affecting the results. Historical volatility five years in Datastream represents RETVOLA and is calculated after the following formula: $\sigma^2 = \frac{1}{n}\sum_{s=1}^{n}[r(s) - r]^2$ (Bodie et al., 2018). The second proxy for risk, represented by operating income volatility, is the standard deviation of operating income for t-3 through t-1 divided by the average operating income for t-3 through t-1 (Guay, 1999). Table 2 Panel B shows the summary statistics of all dependent variables.

LOGSIZE, BM, LEVERAGE, ROE, and RETEARN were included as control variables. LOGSIZE is computed as the natural logarithm of the market capitalization of a company, whereas market capitalization depicts as common shares outstanding multiplied by the share price. BM displays the book value of equity divided by the market value of equity represented by the market capitalization, while LEVERAGE is calculated as the book value of debt divided by the book value of total assets. ROE presenting return on equity is net income divided by the value of equity (Bolton & Kacperczyk, 2021a; Fama & French, 1995). Finally, retained earnings (RETEARN) were used as a proxy for the age of a firm and computed as retained earnings over total assets (Altman, 1968). The summary statistics of the control variables are shown in Table 2 Panel C.

4. Results

4.1 Firm Profitability

Table 4 presents the results of regression equation (1). Overall, there seems to be a negative relationship between the level of carbon emissions and stock returns. Thus, with increasing carbon emissions, stock returns seem to decline. A one-unit increase in scope 1 (scope 2) emissions results in returns declining by 0.20% (0.24%). These results are significant at a 1% level for scope 1 and scope 2 emissions in the model with time fixed effects. Controlling for firm characteristics, the coefficient for scope 2 emissions loses its significance. For scope 1 emissions, the impact on stock returns seems to be stronger as a one-unit increase in scope 1 leads to a 0.65% decrease in stock returns. In both cases, with firm fixed effects and without, the level of scope 3 emissions does not seem to have a significant impact on stock returns. Overall, these results suggest that companies with higher carbon emissions are more likely to experience a decline in stock returns. This might be due to several reasons, such as increasing regulatory pressure to reduce carbon emissions, growing public concern about climate change, and the potential costs associated with mitigating climate risks. The fact that the impact of scope 2 emissions loses its significance when controlling for firm factors can be explained by a dilution of the effect due to other firm-specific factors. General market conditions seem to have less of an impact. On the other hand, the stronger impact of scope 1 emissions on stock returns could be related to the fact that this source of emissions is more directly related to the core operations of companies, such as production and transportation. Finally, the lack of a significant impact of scope 3 emissions could be attributed to the limited observations for this variable, which may reduce the statistical power of the analysis. Another explanation may be that investors do not incorporate scope 3 emissions in their decisions as these are not controlled or owned by the company.

In Panel B, the results show a positive impact of the year-on-year change in carbon emissions on stock returns. In a model with only time fixed effects, if the change in scope 1 (scope 2, scope 3) carbon emissions increases by one percentage point, stock returns increase by 0.21 (0.19, 0.12) percentage points. The coefficients of the growth in scope 1 and scope 3, thereby, are significant at a 1% level and at 5% for scope 2. When adding firm fixed effects, each emission variable coefficient loses significance and declines, indicating a weaker correlation. Scope 1 and scope 3 coefficients are significant at a 5% level, while the scope 2 coefficient does not show significant results, suggesting that the relationship between the change in scope 2 carbon emissions and stock returns may be driven by firm-specific factors rather than the general market conditions. As the level of carbon emissions and change in carbon emissions represent the long-term and short-term risk perspective, respectively, it can be concluded that risks associated with scope 2 emissions have a stronger influence in the long term compared to scope 3 emissions, which only show significant results short term. The positive relationship between the change in carbon emissions and stock returns might be due to investors demanding compensation for big, unexpected changes in emissions.

When regressing emission intensity on stock returns, Panel C overall presents a negative relationship, whereas only scope 1 emission intensity shows significance at a 1% level with a coefficient of -0.0275 in a model with time fixed effects. This represents the strongest effect on stock returns within the preceding analysis. Also scope 2 shows a higher coefficient, yet it is not significant. Adding firm fixed effects, the effect of scope 1 intensity on stock returns loses its significance, implying unobserved firm-specific factors influencing the relationship between emission intensity and stock returns. Interestingly, the coefficient of scope 3 emission intensity shows significance at a 10% level, where a one-unit increase leads to a 1.93 percentage point increase in returns, suggesting that investors demand a higher compensation for firms with higher scope 3 emission intensities. As high emission intensities suggest that a company is producing a lot of carbon emissions relative to its sales, and scope 3 emissions can be associated with a company's supply chain, even more risks must be taken into account for all firms involved in risk accounting through the supply chain.

These results indicate a different conclusion compared to Bolton and Kacperczyk (2021a, 2021b), which might be due to the slightly different approach of a panel regression instead of a cross-sectional. The main reason, however, could be the difference in time, as this research includes data from 2010 to 2020, while Bolton and Kacperczyk (2021a, 2021b) include data from 2005 onwards. In the former, investors might already have adapted to the higher carbon risk so that price and returns already include the investor's demand for risk compensation and are more influenced by other factors. Furthermore, the included financial crisis data might influence results. Also, this thesis concentrates on the 600 largest companies in Europe, while Bolton and Kacperczyk (2021b) also incorporate smaller firms. Another explanation can be found in Bolton and Kacperczyk (2021b), where they find that a higher share of renewable energy in one country can impact the carbon premium negatively. Thus, a high share of renewable energy in European countries might be one reason for the diverse results.

Overall, the negative relationship between carbon emissions and stock returns might be due to the fact that with higher carbon emissions, there is a lower demand for holding a stock in that company as investors prefer an environmentally and socially responsible investment.

Here, it might be appropriate to test the divestment hypothesis for a more recent period. Moreover, companies that invested in a cleaner production process several years ago, whose carbon emissions decreased, can report higher returns as the demand in stocks of companies with lower emissions increases.

Table 4: Carbon emissions and stock returns.

			Panel A: Level of emissions			
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	RET	RET	RET	RET	RET	RET
LOGSCOPE1	-0.0020***			-0.0064***		
	(0.0004)			(0.0020)		
LOGSCOPE2		-0.0024**			-0.0015	
		(0.0005)			(0.0023)	
LOGSCOPE3			-0.0006			-0.00002
			(0.0004)			(0.0010)
LOGSIZE	-0.0012*	-0.0014**	-0.0020***	0.0631***	0.0620***	0.0656***
	(0.0006)	(0.0006)	(0.0006)	(0.0040)	(0.0041)	(0.0046)
BM	-0.0328***	-0.0310***	-0.0311***	-0.0801***	0.0804***	-0.0680**
	(0.0072)	(0.0068)	(0.0081)	(0.0249)	(0.0255)	(0.0311)
ROE	0.0411***	0.0409***	0.0443***	0.0114	0.0131	0.0079
	(0.0121)	(0.0118)	(0.0127)	(0.0146)	(0.0149)	(0.0174)
LEVERAGE	-0.0320***	-0.0292***	-0.0361***	-0.0801***	-0.0788***	-0.0770***
	(0.0086)	(0.0083)	(0.0082)	(0.0241)	(0.0243)	(0.0262)
RETEARN	0.0072	0.0091*	0.0078	-0.0399**	-0.0424**	-0.0461**
	(0.0056)	(0.0054)	(0.0053)	(0.0159)	(0.0166)	(0.0187)
Constant	0.1070***	0.1130***	0.1120***	-1.0450***	-1.0690***	-1.1580***
	(0.0153)	(0.0150)	(0.0142)	(0.0778)	(0.0799)	(0.0885)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	16,721	16,656	13,030	16,721	16,656	13,030
R-squared	0.341	0.341	0.359	0.371	0.370	0.388
Adj. R-squared				0.369	0.368	0.386
Number of firms	538	541	477	538	541	477
			Panel B: Change in emissions			
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	RET	RET	RET	RET	RET	RET
SCOPE1GROWTH	0.0021***			0.0013**		
	(0.0006)			(0.0006)		
SCOPE2GROWTH		0.0019**			0.0011	
		(0.0009)			(0.0009)	
SCOPE3GROWTH			0.0012***			0.0009**
			(0.0004)			(0.0004)
LOGSIZE	-0.0017***	-0.0019***	-0.0013*	0.0616***	0.0619***	0.0662***
	(0.0006)	(0.0006)	(0.0007)	(0.0042)	(0.0042)	(0.0047)
BM	-0.0399***	-0.0375***	-0.0366***	-0.0825***	0.0794***	-0.0617*
	(0.0079)	(0.0075)	(0.0095)	(0.0275)	(0.0277)	(0.0341)

Table 4
(continued)

Panel B: Change in emissions

Variables	(1)	(2)	(3)	(4)	(5)	(6)
ROE	0.0427***	0.0427***	0.0448***	0.0098	0.0115	0.0082
	(0.0127)	(0.0124)	(0.0142)	(0.0150)	(0.0150)	(0.0174)
LEVERAGE	-0.0418***	-0.0372***	-0.0409***	-0.0855***	-0.0807***	-0.0804***
	(0.0092)	(0.0089)	(0.0093)	(0.0247)	(0.0249)	(0.0270)
RETEARN	0.0044	0.0068	0.0030	-0.0414***	-0.0441***	-0.0529***
	(0.0059)	(0.0057)	(0.0060)	(0.0158)	(0.0166)	(0.0191)
Constant	-0.0058	-0.0024	-0.0231	-1.1800***	-1.1850***	-1.2860***
	(0.0145)	(0.0142)	(0.0155)	(0.0794)	(0.0802)	(0.0912)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	16,153	16,089	12,461	16,153	16,089	12,461
R-squared	0.343	0.343	0.357	0.373	0.372	0.385
Adj. R-squared				0.371	0.370	0.382
Number of firms	538	541	477	538	541	477

Panel C: Emission intensity

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	RET	RET	RET	RET	RET	RET
SCOPE1INT	-0.0275***			-0.0228		
	(0.0093)			(0.0581)		
SCOPE2INT		-0.0144			0.0565	
		(0.0451)			(0.1910)	
SCOPE3INT			-0.0008			0.0193*
			(0.0041)			(0.0105)
LOGSIZE	-0.0020***	-0.0022***	-0.0023***	0.0614***	0.0618***	0.0663***
	(0.0006)	(0.0006)	(0.0006)	(0.0040)	(0.0041)	(0.0045)
BM	-0.0365***	-0.0352***	-0.0324***	-0.0815***	0.0815***	-0.0707**
	(0.0073)	(0.0071)	(0.0082)	(0.0250)	(0.0256)	(0.0318)
ROE	0.0433***	0.0442***	0.0420***	0.0125	0.0130	0.0033
	(0.0121)	(0.0119)	(0.0126)	(0.0147)	(0.0148)	(0.0175)
LEVERAGE	-0.0369***	-0.0350***	-0.0378***	-0.0833***	0.0798***	-0.0815***
	(0.0087)	(0.0086)	(0.0081)	(0.0239)	(0.0243)	(0.0260)
RETEARN	0.0069	0.0090*	0.0089*	-0.0394**	-0.0411**	-0.0453**
	(0.0055)	(0.0055)	(0.0054)	(0.0158)	(0.0163)	(0.0178)
Constant	0.1040***	0.1050***	0.1120***	-1.0720***	-1.0820***	-1.1720***
	(0.0152)	(0.0150)	(0.0142)	(0.0775)	(0.0781)	(0.0875)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	16,809	16,718	13,090	16,809	16,718	13,090
R-squared	0.340	0.340	0.358	0.370	0.370	0.388
Adj. R-squared				0.368	0.368	0.386
Number of firms	540	542	478	540	542	478

This table reports the results of regression equation (1), whereas Panel A presents the results for emission levels, Panel B for the change in emissions, and Panel C for emission intensities. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.

Table 5 reports the relationship between carbon emissions and ROA. As can be seen in Panel A, the levels of scope 2 and scope 3 emissions have a negative impact on the return on assets at a 5% significance level in a model that includes time fixed effects only. A one-unit increase in scope 2 and scope 3 emissions leads to a 0.29% and 0.12% decrease in ROA, respectively. Scope 2 loses its significance when controlling for time-invariant firm characteristics, while the coefficient of scope 3 shows significance at a 10% level. The effect, moreover, decreases by 0.03 percentage points, suggesting that the bigger effect comes from individual firm characteristics. Also the impact of scope 2 emissions on ROA varies depending on the characteristics of the company. In both models, the level of scope 1 emissions does not display a significant impact on ROA, which might be due to other environmental factors like water scarcity or waste management overshadowing any impact on the company's financial performance. The overall negative relationship can be due to several reasons. One might be that higher carbon emissions influence a company's reputation not only towards investors but banks who demand higher interest on their loans leading to a lower profit. Also, as with the impact on stock returns, firms with early investments in carbon emission reduction now profit through lower costs and a better reputation.

Panel B presents the effects of the change in carbon emissions on ROA. The change in scope 1 and scope 2 has a positive effect on ROA, while the growth of scope 3 displays a negative relation to ROA. However, these results are not significant for both models, implying that short-term risk exposure does not have a significant impact on the variation in return on assets, and therefore on the efficient use of assets of a company. A reason might be the timing and magnitude of the fluctuations. If the changes are small and gradual, they may not have a significant impact on the company's financial performance. Moreover, if the changes occur in a short time span, they may not allow the company to adjust its operations to offset any negative impacts on its financial performance.

As can be observed in Panel C, scope 1 emission intensity has a positive impact on ROA while scope 2 and scope 3 intensities can be linked with a negative effect on ROA, whereas only scope 2 coefficients are significant at a 1% level for the model with only time fixed effects as well as when controlling for firm-specific characteristics. In the time fixed effects model (time and firm fixed effects model), as scope 1 intensity increases by one, ROA decreases by 22.00 (24.00) percentage points. These results indicate that there is a strong connection between indirect emissions that are consumed by the company and a company's efficient use of assets.

The level, the change, or the intensity of scope 1 emissions, hence, emissions directly related to a company's core operations, do not affect the return on assets significantly. In addition to any effect possibly being overshadowed by other factors, another explanation might be that the company invested in a cleaner production process, energy-efficient technologies, or renewable energy sources and thereby mitigating the effect of its emissions on its operations. Also, the absence of significance might be due to the lack of pricing in risks associated with high emissions.

Table 5: Carbon emissions and return on assets.

			Panel A: Level of emissions			
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	ROA	ROA	ROA	ROA	ROA	ROA
LOGSCOPE1	-0.0013			-0.0005		
	(0.0013)			(0.0018)		
LOGSCOPE2		-0.0029**			-0.0023	
		(0.0012)			(0.0017)	
LOGSCOPE3			-0.0012**			-0.0009*
			(0.0005)			(0.0005)
LOGSIZE	0.0117***	0.0118***	0.0112***	0.0166***	0.0168***	0.0167***
	(0.0033)	(0.0032)	(0.0031)	(0.0046)	(0.0046)	(0.0044)
BM	0.0129*	0.0164**	0.0215*	0.0172**	0.0208**	0.0276**
	(0.0074)	(0.0079)	(0.0118)	(0.0086)	(0.0092)	(0.0135)
ROE	0.1910***	0.1930***	0.2080***	0.1870***	0.1890***	0.2030***
	(0.0286)	(0.0292)	(0.0282)	(0.0281)	(0.0287)	(0.0274)
LEVERAGE	-0.1240***	-0.1240***	-0.1260***	-0.1300***	-0.1300***	-0.1330***
	(0.0179)	(0.0183)	(0.0282)	(0.0182)	(0.0187)	(0.0292)
RETEARN	0.0180	0.0181	0.0004	0.0128	0.0127	-0.0078
	(0.0336)	(0.0345)	(0.0390)	(0.0348)	(0.0357)	(0.0405)
Constant	-0.1470***	-0.1340**	-0.1420**	-0.2510***	-0.2370***	-0.2520***
	(0.0553)	(0.0542)	(0.0587)	(0.0809)	(0.0805)	(0.0835)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	16,765	16,698	13,058	16,765	16,698	13,058
R-squared	0.222	0.233	0.235	0.319	0.318	0.336
Adj. R-squared				0.317	0.316	0.333
Number of firms	540	543	479	540	543	479
			Panel B: Change in emissions			
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	ROA	ROA	ROA	ROA	ROA	ROA
SCOPE1GROWTH	0.0005			0.0004		
	(0.0004)			(0.0004)		
SCOPE2GROWTH		0.0006			0.0005	
		(0.0004)			(0.0004)	
SCOPE3GROWTH			-0.0003			-0.0003
			(0.0003)			(0.0003)
LOGSIZE	0.0110***	0.0107***	0.0106***	0.0165***	0.0164***	0.0167***
	(0.0031)	(0.0031)	(0.0030)	(0.0046)	(0.0047)	(0.0044)

Table 5
(continued)

Panel B: Change in emissions						
Variables	(1)	(2)	(3)	(4)	(5)	(6)
BM	0.0126*	0.0148*	0.0216*	0.0180**	0.0205**	0.0285**
	(0.0074)	(0.0077)	(0.0118)	(0.0089)	(0.0093)	(0.0137)
ROE	0.1930***	0.1950***	0.2090***	0.1880***	0.1900***	0.2030***
	(0.0288)	(0.0295)	(0.0284)	(0.0284)	(0.0290)	(0.0275)
LEVERAGE	-0.1250***	-0.1250***	-0.1280***	-0.1300***	-0.1310***	-0.1350***
	(0.0182)	(0.0186)	(0.0281)	(0.0186)	(0.0190)	(0.0292)
RETEARN	0.0191	0.0197	0.0015	0.0135	0.0138	-0.0076
	(0.0346)	(0.0356)	(0.0403)	(0.0359)	(0.0371)	(0.0423)
Constant	-0.1470***	-0.1420**	-0.1410**	-0.2560***	-0.2530***	-0.2610***
	(0.0562)	(0.0560)	(0.0570)	(0.0854)	(0.0862)	(0.0844)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	16,193	16,128	12,488	16,193	16,128	12,488
R-squared	0.223	0.228	0.233	0.317	0.316	0.332
Adj. R-squared				0.315	0.314	0.329
Number of firms	540	543	479	540	543	479

Panel C: Emission intensity						
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	ROA	ROA	ROA	ROA	ROA	ROA
SCOPE1INT	0.0011			0.0044		
	(0.0242)			(0.0241)		
SCOPE2INT		-0.2200***			-0.2410***	
		(0.0739)			(0.0809)	
SCOPE3INT			-0.0094			-0.0077
			(0.0069)			(0.0068)
LOGSIZE	0.0113***	0.0110***	0.0109***	0.0164***	0.0162***	0.0171***
	(0.0031)	(0.0031)	(0.0029)	(0.0045)	(0.0045)	(0.0042)
BM	0.0134*	0.0149*	0.0188	0.0185**	0.0202**	0.0255*
	(0.0075)	(0.0077)	(0.0115)	(0.0088)	(0.0091)	(0.0134)
ROE	0.1950***	0.1940***	0.1900***	0.1900***	0.1900***	0.1840***
	(0.0289)	(0.0290)	(0.0312)	(0.0285)	(0.0285)	(0.0305)
LEVERAGE	-0.1260***	-0.1270***	-0.1340***	-0.1320***	-0.1330***	-0.1410***
	(0.0177)	(0.0180)	(0.0287)	(0.0180)	(0.0184)	(0.0297)
RETEARN	0.0180	0.0175	0.0111	0.0126	0.0117	0.0022
	(0.0337)	(0.0347)	(0.0395)	(0.0349)	(0.0360)	(0.0412)
Constant	-0.1510***	-0.1420**	-0.1420***	-0.2530***	-0.2450***	-0.2650***
	(0.0558)	(0.0559)	(0.0549)	(0.0823)	(0.0830)	(0.0809)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	16,853	16,761	13,118	16,853	16,761	13,118
R-squared	0.222	0.219	0.216	0.322	0.321	0.290
Adj. R-squared				0.320	0.319	0.288
Number of firms	542	544	480	542	544	480

This table reports the results of regression equation (2), whereas Panel A presents the results for emission levels, Panel B for the change in emissions, and Panel C for emission intensities. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.

To add robustness to the analysis, Appendix D (Appendix E, Appendix F) presents all regressions with time and industry fixed effects for emission levels (emission growth, emission intensity). From there, it can be concluded that using time and industry fixed effects gives the most significant and strongest results overall, indicating that the industry in which a company operates does not have a big influence in explaining the variation in stock returns and return on assets. For emission levels, emission growth, and emission intensities the coefficients show an equal or stronger correlation for stock returns as well as ROA. Furthermore, scope 3 emission levels which do not have a significant effect within the models used before, display a significant negative impact on stock returns at a 10% level. This indicates that common shocks or regulations within an industry are less influential in explaining the variation of stock returns through scope 3 emission levels than firm-specific factors. However, adding industry fixed effects to explore the impact of the year-to-year change in emissions does not change the results considerably, indicating that industry specific characteristics do not influence the effect of all emission variables on stock returns or return on assets. This is in line with the findings of Bolton and Kacperczyk (2021a) when they control for industry effects.

While the results differ from Bolton and Kacperczyk (2021a, 2021b), they are in line with the findings of Garvey et al. (2018) and Cheema-Fox et al. (2021). The results cannot prove the existence of a carbon premium but find a negative relationship between the level and intensities of carbon emissions and firm profitability.

4.2 Firm Risk

To explore the connection between carbon emissions and firm risk, Table 6 presents the results for regression equation (3). The levels of scope 1 and 2 have a significant positive impact on stock return volatility, whereas scope 3 displays a negative insignificant relation. The positive impact of scope 1 and 2 gets stronger when adding firm fixed effects, rising from an 0.40% to 0.57% increase and 0.50% to 0.58%, respectively. Thus, with increasing scope 1 and scope 2 emission levels, stock return volatility increases, while for scope 1, firm-specific characteristics are less influential than market factors.

The change in emissions overall presents a negative relationship to stock return volatility, whereas all coefficients decrease when controlling for firm-specific characteristics. Hence, as the change in emissions grows, stock return volatility decreases. With a one-percentage point increase in the growth of scope 1 (scope 2) stock return volatility decreases significantly by 0.05 (0.06) percentage points in a time fixed effect model. It can be deduced that for scope 1 and 2 a company's risk decreases when short-term carbon risk increases, and it increases from the long-term carbon risk perspective.

Panel C shows that emission intensities have a positive but insignificant impact on stock return volatility, indicating that a company's carbon efficiency does not influence firm risk significantly from an investor's perspective.

Table 6: Carbon emissions and stock return volatility.

Panel A: Level of emissions						
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA
LOGSCOPE1	0.0040*			0.0057**		
	(0.0021)			(0.0028)		
LOGSCOPE2		0.0050*			0.0058*	
		(0.0026)			(0.0032)	
LOGSCOPE3			-0.0003			-0.0007
			(0.0012)			(0.0013)
LOGSIZE	-0.0285***	-0.0281***	-0.0290***	-0.0406***	0.0400***	-0.0441***
	(0.0047)	(0.0047)	(0.0050)	(0.0069)	(0.0069)	(0.0078)
BM	0.0136	0.0147	0.0024	0.0142	0.0157	-0.0022
	(0.0185)	(0.0186)	(0.0192)	(0.0217)	(0.0220)	(0.0233)
ROE	-0.0056	-0.0049	-0.0204*	-0.0002	0.0004	-0.0138
	(0.0106)	(0.0105)	(0.0109)	(0.0106)	(0.0105)	(0.0107)
LEVERAGE	0.0307	0.0327	0.0460	0.0402	0.0433	0.0559
	(0.0329)	(0.0332)	(0.0380)	(0.0347)	(0.0349)	(0.0399)
RETEARN	-0.0506**	-0.0542***	-0.0287	-0.0456**	-0.0491**	-0.0201
	(0.0198)	(0.0206)	(0.0226)	(0.0206)	(0.0214)	(0.0229)
Constant	0.8410***	0.8200***	0.8830***	1.0540***	1.0390***	1.1750***
	(0.0865)	(0.0859)	(0.0982)	(0.1310)	(0.1310)	(0.1540)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	16,756	16,690	13,051	16,756	16,690	13,051
R-squared	0.126	0.128	0.118	0.442	0.448	0.448
Adj. R-squared				0.440	0.447	0.446
Number of firms	540	543	479	540	543	479
Panel B: Change in emissions						
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA
SCOPE1GROWTH	-0.0005*			-0.0005		
	(0.0003)			(0.0003)		
SCOPE2GROWTH		-0.0006*			-0.0006*	
		(0.0003)			(0.0003)	
SCOPE3GROWTH			-0.0001			-0.00009
			(0.0002)			(0.0001)
LOGSIZE	-0.0269***	-0.0265***	-0.0284***	-0.0393***	-0.0389***	-0.0441***
	(0.0046)	(0.0045)	(0.0050)	(0.0069)	(0.0069)	(0.0079)

Table 6
(continued)

Panel B: Change in emissions						
Variables	(1)	(2)	(3)	(4)	(5)	(6)
BM	0.0147	0.0163	0.00316	0.0144	0.0167	-0.0005
	(0.0170)	(0.0172)	(0.0189)	(0.0203)	(0.0206)	(0.0228)
ROE	-0.0059	-0.0055	-0.0208*	-0.0002	0.0001	-0.0141
	(0.0105)	(0.0104)	(0.0107)	(0.0105)	(0.0104)	(0.0104)
LEVERAGE	0.0361	0.0371	0.0513	0.0453	0.0468	0.0609
	(0.0327)	(0.0329)	(0.0370)	(0.0345)	(0.0347)	(0.0389)
RETEARN	-0.0484**	-0.0538***	-0.0285	-0.0434**	-0.0489**	-0.0198
	(0.0197)	(0.0205)	(0.0221)	(0.0208)	(0.0215)	(0.0225)
Constant	0.8450***	0.8350***	0.8670***	1.0800***	1.0730***	1.1630***
	(0.0860)	(0.0859)	(0.0961)	(0.1320)	(0.1320)	(0.1530)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	16,185	16,121	12,482	16,185	16,121	12,482
R-squared	0.127	0.127	0.117	0.439	0.445	0.450
Adj. R-squared				0.437	0.444	0.448
Number of firms	540	543	479	540	543	479

Panel C: Emission intensity						
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA
SCOPE1INT	0.0141			0.0098		
	(0.0571)			(0.0584)		
SCOPE2INT		0.3650			0.3740	
		(0.2230)			(0.2400)	
SCOPE3INT			0.0066			0.0025
			(0.0100)			(0.0107)
LOGSIZE	-0.0272***	-0.0265***	-0.0290***	-0.0392***	-0.0384***	-0.0443***
	(0.0046)	(0.0045)	(0.0051)	(0.0068)	(0.0068)	(0.0079)
BM	0.0163	0.0179	0.0024	0.0160	0.0182	-0.0021
	(0.0183)	(0.0185)	(0.0192)	(0.0217)	(0.0220)	(0.0232)
ROE	-0.0064	-0.0066	-0.0225**	-0.0008	-0.0011	-0.0161
	(0.0106)	(0.0107)	(0.0110)	(0.0106)	(0.0106)	(0.0107)
LEVERAGE	0.0344	0.0356	0.0430	0.0440	0.0460	0.0523
	(0.0329)	(0.0329)	(0.0381)	(0.0347)	(0.0347)	(0.0401)
RETEARN	-0.0515***	-0.0535***	-0.0299	-0.0466**	-0.0484**	-0.0213
	(0.0200)	(0.0205)	(0.0224)	(0.0209)	(0.0214)	(0.0227)
Constant	0.8520***	0.8310***	0.8820***	1.0810***	1.0610***	1.1730***
	(0.0863)	(0.0843)	(0.0975)	(0.1310)	(0.1280)	(0.1530)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	16,844	16,752	13,111	16,844	16,752	13,111
R-squared	0.129	0.129	0.120	0.442	0.447	0.449
Adj. R-squared				0.440	0.445	0.447
Number of firms	542	544	480	542	544	480

This table reports the results of regression equation (3), whereas Panel A presents the results for emission levels, Panel B for the change in emissions, and Panel C for emission intensities. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.

As a second proxy for risk, Table 7 presents the results of regression equation (4). Looking at the emission levels, it can be concluded that scope 1 and scope 3 behave in a similar way. Both show a negative relationship to operating-income volatility that becomes weaker when adding firm fixed effects but is not significant. Scope 2 emissions, however, display a positive insignificant impact in a time fixed model that becomes negative when adding firm fixed effects and significant at a 5% level. Thus, controlling for time-invariant firm characteristics adds robustness to the model. With a one-unit increase in scope 2 emissions, stock return volatility decreases by 0.97%. This relation between scope 2 emissions and operating-income volatility might be due to the assumption that a company with higher scope 2 emissions might be more likely to invest in stable, long-term energy contracts, which can reduce the volatility of its operating costs over time. Furthermore, companies with high scope 2 emissions might be more likely to hedge their exposure to energy price volatility.

As for the change in emissions, scope 2 and 3 behave similarly, showing a positive relation, while scope 1 displays a weak but negative relation. However, these results do not show significance, suggesting that short-term carbon risk exposure does not statistically impact a firm's risk measured by operating-income volatility. Also emission intensities do not have a significant impact on operating-income volatility. Concluding, these results indicate that there might be none to a weak correlation between carbon emissions and operating-income volatility. Market conditions like changes in interest rates, currency fluctuations or consumer demand might be more influential to a company's operating performance than carbon emissions.

Table 7: Carbon emissions and operating-income volatility.

			Panel A: Level of emissions			
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	OPVOLA	OPVOLA	OPVOLA	OPVOLA	OPVOLA	OPVOLA
LOGSCOPE1	-0.0009			-0.0037		
	(0.0007)			(0.0038)		
LOGSCOPE2		0.0003			-0.0097**	
		(0.0011)			(0.0045)	
LOGSCOPE3			-0.0006			-0.0034
			(0.0008)			(0.0021)
LOGSIZE	0.0034***	0.0028**	0.0027**	-0.0033	-0.0037	-0.0045
	(0.0010)	(0.0011)	(0.0012)	(0.0070)	(0.0073)	(0.0083)
BM	0.0074	0.0021	0.0048	-0.0155	-0.0177	-0.0336
	(0.0081)	(0.0081)	(0.0106)	(0.0272)	(0.0273)	(0.0351)
ROE	-0.0009	0.0016	0.0087	0.0088	0.0066	0.0155
	(0.0154)	(0.0154)	(0.0164)	(0.0205)	(0.0209)	(0.0204)
LEVERAGE	0.0119	0.0091	0.0206	0.0010	0.0091	0.0371
	(0.0155)	(0.0156)	(0.0170)	(0.0427)	(0.0433)	(0.0512)
RETEARN	0.0118	0.0091	-0.0040	0.0426*	0.0439*	0.0149
	(0.0095)	(0.0093)	(0.0105)	(0.0255)	(0.0262)	(0.0327)
Constant	0.0159	0.0170	0.0118	0.1680	0.2330	0.1710
	(0.0299)	(0.0306)	(0.0312)	(0.1410)	(0.1420)	(0.1650)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	15,219	15,141	11,823	15,219	15,141	11,823
R-squared	0.009	0.009	0.010	0.009	0.010	0.011
Adj. R-squared				0.006	0.006	0.007
Number of firms	539	542	478	539	542	478
			Panel B: Change in emissions			
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	OPVOLA	OPVOLA	OPVOLA	OPVOLA	OPVOLA	OPVOLA
SCOPE1GROWTH	-0.00008			-0.00004		
	(0.0016)			(0.0016)		
SCOPE2GROWTH		0.0014			0.0011	
		(0.0022)			(0.0023)	
SCOPE3GROWTH			0.0002			0.0002
			(0.0010)			(0.0009)
LOGSIZE	0.0025**	0.0023**	0.0013	-0.0062	-0.0070	-0.0072
	(0.0010)	(0.0010)	(0.0011)	(0.0070)	(0.0071)	(0.0081)
BM	0.0034	0.0008	-0.0062	-0.0259	-0.0315	-0.0595*
	(0.0080)	(0.0079)	(0.0092)	(0.0285)	(0.0285)	(0.0336)
ROE	0.0028	0.0029	0.0110	0.0068	0.0052	0.0127
	(0.0155)	(0.0158)	(0.0181)	(0.0209)	(0.0210)	(0.0205)
LEVERAGE	0.0076	0.0074	0.0168	0.0019	0.0064	0.0330
	(0.0154)	(0.0152)	(0.0167)	(0.0429)	(0.0430)	(0.0520)
RETEARN	0.0095	0.0062	-0.0092	0.0488*	0.0512*	0.0124
	(0.0095)	(0.0092)	(0.0103)	(0.0257)	(0.0265)	(0.0332)
Constant	0.0139	0.0248	0.0443	0.1730	0.1940	0.2010
	(0.0281)	(0.0292)	(0.0315)	(0.1370)	(0.1390)	(0.1580)

Table 7
(continued)

Panel B: Change in emissions						
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	14,679	14,605	11,296	14,679	14,605	11,296
R-squared	0.009	0.009	0.011	0.010	0.010	0.011
Adj. R-squared				0.006	0.006	0.007
Number of firms	539	542	478	539	542	478

Panel C: Emission intensity						
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	OPVOLA	OPVOLA	OPVOLA	OPVOLA	OPVOLA	OPVOLA
SCOPE1INT	0.0041			0.0959		
	(0.0183)			(0.0720)		
SCOPE2INT		0.1040			-0.0709	
		(0.0976)			(0.2810)	
SCOPE3INT			0.0029			-0.0023
			(0.0077)			(0.0184)
LOGSIZE	0.0030***	0.0029***	0.0023**	-0.0042	-0.0053	-0.0046
	(0.0010)	(0.0010)	(0.0011)	(0.0071)	(0.0072)	(0.0083)
BM	0.0057	0.0027	0.0034	-0.0145	-0.0222	-0.0345
	(0.0079)	(0.0078)	(0.0105)	(0.0274)	(0.0270)	(0.0346)
ROE	0.0020	0.0029	0.0068	0.0112	0.0096	0.0082
	(0.0151)	(0.0152)	(0.0170)	(0.0211)	(0.0208)	(0.0219)
LEVERAGE	0.0089	0.0074	0.0196	0.0022	0.0056	0.0324
	(0.0153)	(0.0154)	(0.0167)	(0.0422)	(0.0431)	(0.0512)
RETEARN	0.0121	0.0079	-0.0028	0.0418	0.0440*	0.0225
	(0.0094)	(0.0092)	(0.0105)	(0.0254)	(0.0263)	(0.0331)
Constant	0.0132	0.0165	0.0128	0.1420	0.1690	0.1420
	(0.0296)	(0.0300)	(0.0309)	(0.1390)	(0.1400)	(0.1630)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Observations	15,296	15,201	11,878	15,296	15,201	11,878
R-squared	0.009	0.009	0.010	0.009	0.009	0.011
Adj. R-squared				0.006	0.006	0.007
Number of firms	541	543	479	541	543	479

This table reports the results of regression equation (4), whereas Panel A presents the results for emission levels, Panel B for the change in emissions, and Panel C for emission intensities. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.

Adding industry fixed effects to the model instead of firm fixed effects gives various outcomes (see Appendix D, Appendix E, Appendix F). For stock return volatility, controlling for industry gives more significant results, especially for the emission variables level of emissions and change in emissions. However, when looking at operating-income volatility, controlling for industry is inferior to controlling for firm characteristics, when assessing the impact of emission levels, indicating that industry-specific factors might be more influential to the outcome than firm-specific factors.

Overall, there appears to be no defined correlation between carbon emissions and firm risk. There seems to be a positive (negative) relationship between the level of scope 1 and 2 emissions (the change in scope 1 and 2) and stock return volatility. On the contrary, the results suggest a negative relationship between the level of scope 2 emissions and operating income volatility. Emission intensities do not show a significant connection to firm risk.

4.3 Investor Awareness

As the time and industry fixed effects model broadly gave the most significant results, this model was chosen for the investor awareness analysis. Appendix G presents the results for the level of emissions. One can conclude that after the first shock, the Doha Amendment, stock returns significantly decreased with higher carbon emissions for all scopes. This could be due to investors realizing the long-term risk exposure coming from high carbon emissions. Furthermore, companies in high-emission industries may have faced increased costs and operational challenges, while high levels of emissions had implications for a company's reputation. Also, the demand for stocks of high-emission firms might have decreased, as institutional investors might have divested. After the Paris Agreement, the results still show a significant negative but weaker relationship between scope 1 and 2 and stock returns, while the results for scope 3 are insignificant. An explanation could be that the market had already adapted and considered long-term transition risk in pricing stocks, so the second shock, the Paris Agreement, while still significant, has less economic impact. After the Paris Agreement, more companies report scope 3 emissions while in proportion not as many investors incorporate scope 3 emissions in decision-making as the composition of scope 3 is complex.

Looking at the impact on firm risk, the results show a significant positive relationship between scope 2 emissions and stock return volatility after the Paris Agreement. Thus, with increasing scope 2 emissions, stock return volatility decreased. A reason might be that scope 2 displays a firm's vulnerability to increases in energy prices. As traditional energy production gets more expensive, average electricity prices increase in Europe due to the introduction of renewable energy, which is more expensive to produce at that point in time. Thus, a company's risk can increase significantly.

When inspecting the change in emissions, Appendix H reports a significant positive relationship with stock returns for all scopes after 2015. This could illustrate how important short-term carbon risk exposure got to investors after the Paris Agreement. Meanwhile, with a greater change in emissions, stock return volatility significantly decreases for scope 1 (scope 3) at a 1% (10%) level. From this, it could be deduced that as emission levels and their growth increase, stock returns increase but with less fluctuation.

Appendix I shows that the significant negative effect of scope 1 emission intensities on stock returns seems to derive from 2013 until 2015, where scope 1, scope 2 and scope 3 intensities have a strong and significant negative impact. In the whole sample, the impact of scope 2 and 3 might have been overshadowed by other factors. Scope 1 also displays a significant negative relationship before the Doha Amendment. However, emission intensities do not have a significant impact on stock return volatility, which supports earlier findings that indicate that other market conditions have a greater influence on firm risk than a company's carbon efficiency.

The period between the Doha Amendment and the Paris Agreement saw increased attention towards climate change and sustainability issues, with more companies reporting on their emissions and setting targets for reduction. As a result, companies that were reporting higher emissions during this period may have faced greater scrutiny and potential reputational risks. This is supported by the results, which show more and higher significance in the more recent periods, subsequent to COP 18 and COP 21. While the level of emissions and emission intensity exhibit a negative significant relation to stock returns, the change in emissions shows a positive relation. In conclusion, the results prove that higher investor awareness has an impact on the relationship between carbon emissions on firm profitability and firm risk, which is in line with the findings of Bolton and Kacperczyk (2021a, 2021b). Also, it seems that the first shock, the Doha Amendment, had an even bigger impact compared to the Paris Agreement, where the market already began to adapt to a low-carbon economy.

5. Limitations and Outlook

While significantly contributing to existing literature, this thesis has some limitations. First, using Datastream resulted in some missing observations in carbon emissions as well as firm fundamentals, which might enhance the analysis. Additionally, one could use a longer period which in turn results in more observations. Not only more recently, after 2020, but also using figures from before 2010 and testing if the difference in results comes from the earlier observations used in Bolton and Kacperczyk's (2021a) study.

Another drawback might come from the different publishing frequencies of the variables. Carbon emissions are only reported yearly, which is why I had to assume an even distribution throughout the year which might not be the case. Additionally, most of the firm fundamentals are reported quarterly, while stock returns exist daily. Thus, stock returns can be influenced by a lot of other factors like increasing interest. Carbon emissions that were reported for last year might therefore not influence stock returns as well as quarterly firm fundamentals throughout the whole year. Here, an event study might be appropriate to compare the immediate effect after the publication of the annual report. Furthermore, during the winter, more gas and electricity is needed, bearing increased costs for that period.

Furthermore, compared to Bolton and Kacperczyk (2021a), the difference in results infers that this study should again be rolled out to different markets around the world for a more recent period of time. Also, the divestment theory should be tested again, which Bolton and Kacperczyk (2021a) found only to hold for salient industries. In that sense, it might be appropriate to test if the results change when examining different industries separately, as the negative effect might result from industries in which there is a negative impact on firm profitability overshadowing industries in which there is a positive relationship. Here, drawing a random sample with equal industry weights might add robustness to the analysis.

As this thesis shows, different proxies can give different results. Therefore, it might be appropriate to choose more proxies and examine their connection with carbon emissions. Moreover, this thesis examined companies that are listed in the Stoxx 600 now. Using a dynamic approach might be applicable to make more precise statements.

Another approach to studying investor behavior might be to conduct a survey with investor relation managers that have a direct connection to investors holding stocks in their company.

Moreover, incorporating an instrumental variable approach to control for endogeneity in the model can help enhancing the study.

6. Conclusion

This thesis aims at assessing the impact of carbon emissions on firm profitability and firm risk using panel regressions, whereby firm profitability is represented by stock returns and return on assets and firm risk by stock return volatility and operating-income volatility.

The results indicate a negative relationship between the level of emissions and emission intensity and firm profitability and a positive (no) impact of the change in emissions and stock returns (return on assets). However, scope 3 emission levels only have a significant impact on stock returns when controlling for industry, while they do have a significant impact on the return on assets. Thus, the carbon emissions associated with a firm's supply chain influence a firm's efficient use of assets but do not influence the investor sentiment and an investor's future revenues expectation for a company. The short-term risk association of carbon emissions does have an impact on stock returns and therefore an investor's expectation of future performance but is irrelevant to the return on assets. Moreover, when assessing a company's carbon efficiency, the results display no significant impact for scope 2 on stock returns, but a negative influence on return on assets, indicating that an efficient use of purchased electricity does not matter for the investor sentiment, but it is highly relevant for a firm's efficient use of assets and hence financial performance. Overall, the results suggest that higher costs, lower profits, poorer reputation, and lower competitiveness in a low-carbon economy lead to a lower firm performance with increasing carbon emissions. As this negative relationship in turn indicates that with lower carbon emissions, firm performance increases, it can be concluded that firms that have invested in cleaner production processes and detached their operations from fossil fuels now profit and experience better returns.

The relationship between carbon emissions and firm risk could not definitively be explained by the regressions. On the one hand, the levels of scope 1 and 2 emissions have a positive impact on stock return volatility. On the other hand, scope 2 has a negative effect on operating-income volatility while the level of scope 3 emissions does not show any significant effect. The change in emissions displays a significant negative impact on stock return volatility for scope 1 and 2, while there is no significant connection to operating-income volatility. Also, the results suggest that there is no significant impact of carbon emission intensity on either stock return volatility or operating-income volatility concluding that carbon efficiency does not influence a company's risk. Generally, the results indicate that the relationship between carbon emissions and firm risk is not straightforward and more complex. It might be influenced by various other factors that are not captured by the regressions. Furthermore, carbon emissions might influence different types of risk in different ways as they may have an influence on reputational risks that affect stock returns, but at the same time, leads to cost-saving measures that reduce operating-income volatility.

Furthermore, by comparing different time periods, this thesis proved that risen investor awareness is effectively shown in the relationship between carbon emissions and stock returns, and stock return volatility.

Overall, these findings provide insights into the financial implications of carbon emissions for companies and investors, highlighting the importance of managing and disclosing carbon risks and opportunities. Whereas, one should differentiate between the three scopes of emissions carefully as they display distinctive effects.

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Appendix

Appendix A: Variable description and source.

	Panel A: Dependent and Independent Variables		
LOGSCOPE1	Level of scope 1 emissions	The natural logarithm of scope 1 emissions	Datastream
LOGSCOPE2	Level of scope 2 emissions	The natural logarithm of scope 2 emissions	Datastream
LOGSCOPE3	Level of scope 3 emissions	The natural logarithm of scope 3 emissions	Datastream
SCOPE1GROWTH	Change in scope 1 emissions	The year-on-year percentage change of scope 1 emissions	Datastream
SCOPE2GROWTH	Change in scope 2 emissions	The year-on-year percentage change of scope 2 emissions	Datastream
SCOPE3GROWTH	Change in scope 3 emissions	The year-on-year percentage change of scope 3 emissions	Datastream
SCOPE1INT	Scope 1 emission intensity	The ratio of the natural logarithm of scope 1 emissions to net sales	Datastream
SCOPE2INT	Scope 2 emission intensity	The ratio of the natural logarithm of scope 2 emissions to net sales	Datastream
SCOPE3INT	Scope 3 emission intensity	The ratio of the natural logarithm of scope 3 emissions to net sales	Datastream
RET	Stock returns	Holding period return of stock prices	Datastream
ROA	Return on assets	The ratio of net income to total assets	Worldscope
RETVOLA	Stock return volatility	The volatility of stock returns for the last 5 years	Datastream
OPVOLA	Operating-income volatility	The volatility of operating income for the last 3 quarters	Worldscope
	Panel B: Controls		
LOGSIZE	Firm size	The natural logarithm of market capitalization	Worldscope
BM	Book-to-market ratio	The ratio of book value of equity to the market value of equity	Worldscope
ROE	Return on equity	The ratio of net income to the book value of equity	Worldscope
LEVERAGE	Firm leverage	The ratio of total debt to total assets	Worldscope
RETEARN	Age of a company	The ratio of retained earnings to total assets	Worldscope

Appendix B: Distribution of firms across industries.

Industry	Freq.	Percent	Cum.
Aerospace & Defense	17	2.99	2.99
Air Freight & Logistics	2	0.35	3.35
Airlines	4	0.70	4.05
Auto Components	2	0.35	4.40
Automobiles	11	1.94	6.34
Beverages	13	2.29	8.63
Biotechnology	7	1.23	9.86
Building Products	8	1.41	11.27
Chemicals	28	4.93	16.20
Commercial Services & Supplies	10	1.76	17.96
Communications Equipment	4	0.70	18.66
Construction & Engineering	19	3.35	22.01
Construction Materials	5	0.88	22.89
Containers & Packaging	6	1.06	23.94
Distributors	1	0.18	24.12
Diversified Consumer Services	1	0.18	24.30
Diversified Telecommunication Services	8	1.41	25.70
Electric Utilities	11	1.94	27.64
Electrical Equipment	18	3.17	30.81
Electronic Equipment, Instruments & Components	5	0.88	31.69
Energy Equipment & Services	2	0.35	32.04
Entertainment	6	1.06	33.10
Food & Staples Retailing	10	1.76	34.86
Food Products	29	5.11	39.96
Gas Utilities	7	1.23	41.20
Health Care Equipment & Supplies	21	3.70	44.89
Health Care Providers & Services	4	0.70	45.60
Hotels, Restaurants & Leisure	22	3.87	49.47
Household Durables	7	1.23	50.70
Household Products	4	0.70	51.41
IT Services	18	3.17	54.58
Independent Power and Renewable Electricity	6	1.06	55.63
Industrial Conglomerates	13	2.29	57.92
Interactive Media & Services	6	1.06	58.98
Internet & Direct Marketing Retail	9	1.58	60.56
Leisure Products	19	3.35	63.91
Life Sciences Tools & Services	6	1.06	64.96
Machinery	38	6.69	71.65
Marine	3	0.53	72.18
Media	5	0.88	73.06
Metals & Mining	8	1.41	74.47
Multi-Utilities	7	1.23	75.70
Multiline Retail	3	0.53	76.23
Oil, Gas & Consumable Fuels	18	3.17	79.40
Paper & Forest Products	8	1.41	80.81
Personal Products	3	0.53	81.34
Pharmaceuticals	19	3.35	84.68
Professional Services	14	2.46	87.15
Semiconductors & Semiconductor Equipment	12	2.11	89.26
Software	5	0.88	90.14
Specialty Retail	7	1.23	91.37
Technology Hardware, Storage & Peripherals	3	0.53	91.90
Textiles, Apparel & Luxury Goods	24	4.23	96.13
Tobacco	3	0.53	96.65
Trading Companies & Distributors	12	2.11	98.77
Transportation Infrastructure	4	0.70	99.47
Water Utilities	2	0.35	99.82
Wireless Telecommunication Services	1	0.18	100.00
Total	568	100.00	

The table shows the distribution of firms across industries in reference to the GIC 6 industry classification. Freq. displays the total number of firms in each industry in the sample.

Appendix C: Autocorrelation of emission variables.

Variables	(1) LOG SCOPE1	(2) LOG SCOPE2	(3) LOG SCOPE3	(4) SCOPE1 GROWTH	(5) SCOPE2 GROWTH	(6) SCOPE3 GROWTH	(7) SCOPE1 INT	(8) SCOPE2 INT	(9) SCOPE3 INT
$LOGSCOPE1_{t-1}$	0.9410***								
	(0.0073)								
$LOGSCOPE2_{t-1}$		0.8440***							
		(0.0183)							
$LOGSCOPE3_{t-1}$			0.7530***						
			(0.0194)						
$SCOPE1GROWTH_{t-1}$				-0.0339					
				(0.0240)					
$SCOPE2GROWTH_{t-1}$					0.0325				
					(0.0253)				
$SCOPE3GROWTH_{t-1}$						-0.0350			
						(0.0250)			
$SCOPE1INT_{t-1}$							0.9630***		
							(0.0142)		
$SCOPE2INT_{t-1}$								0.9290***	
								(0.0139)	
$SCOPE3INT_{t-1}$									0.6740***
									(0.0448)
Constant	0.7300***	1.9390***	1.2040***	-0.0439	0.0523	-0.0699	0.0146**	0.0041***	-0.0440***
	(0.1080)	(0.1940)	(0.2380)	(0.0311)	(0.0412)	(0.0516)	(0.0061)	(0.0009)	(0.0124)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,494	15,390	11,572	14,917	14,819	11,044	15,568	15,463	11,630
R-squared	0.973	0.949	0.878	0.031	0.081	0.070	0.930	0.912	0.790

This table reports the coefficients from estimating the AR (1) model for the three emission variables. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Appendix D: Level of emissions with firm profitability and firm risk.

Variables	(1) RET	(2) RET	(3) RET	(4) ROA	(5) ROA	(6) ROA	(7) RETVOLA	(8) RETVOLA	(9) RETVOLA	(10) OPVOLA	(11) OPVOLA	(12) OPVOLA
LOGSCOPE1	-0.0021***			-0.0013			0.0042**			-0.0006		
	(0.0004)			(0.0014)			(0.0022)			(0.0007)		
LOGSCOPE2		-0.0025***			-0.0029**			0.0052**			0.0005	
		(0.0006)			(0.0013)			(0.0027)			(0.0011)	
LOGSCOPE3			-0.0006*			-0.0011**			-0.0003			-0.0008
			(0.0004)			(0.0005)			(0.0012)			(0.0008)
LOGSIZE	-0.0014**	-0.0015**	0.0019***	0.0120***	0.0121***	0.0116***	-0.0291***	-0.0288***	-0.0299***	0.0029***	0.0023**	0.0027**
	(0.0006)	(0.0006)	(0.0006)	(0.0034)	(0.0034)	(0.0033)	(0.0047)	(0.0047)	(0.0052)	(0.0011)	(0.0011)	(0.0012)
BM	-0.0329***	-0.0307***	-0.0310***	0.0129*	0.0168**	0.0221*	0.0136	0.0148	0.0020	0.0038	-0.0013	0.0020
	(0.0068)	(0.0065)	(0.0078)	(0.0076)	(0.0081)	(0.0121)	(0.0187)	(0.0189)	(0.0196)	(0.0087)	(0.0086)	(0.0110)
ROE	0.0452***	0.0445***	0.0416***	0.1910***	0.1930***	0.2070***	-0.0052	-0.0044	-0.0198*	-0.0037	-0.0013	0.0045
	(0.0118)	(0.0115)	(0.0123)	(0.0286)	(0.0292)	(0.0281)	(0.0106)	(0.0105)	(0.0109)	(0.0158)	(0.0159)	(0.0169)
LEVERAGE	-0.0297***	-0.0260***	-0.0319***	-0.1250***	-0.1250***	-0.1270***	0.0342	0.0362	0.0496	0.0239	0.0214	0.0296
	(0.0093)	(0.0090)	(0.0090)	(0.0177)	(0.0182)	(0.0283)	(0.0333)	(0.0335)	(0.0385)	(0.0164)	(0.0163)	(0.0182)
RETEARN	0.0036	0.0054	0.0072	0.0172	0.0173	-0.0008	-0.0493**	-0.0529**	-0.0271	0.0139	0.0102	-0.0085
	(0.0054)	(0.0052)	(0.0054)	(0.0339)	(0.0348)	(0.0394)	(0.0199)	(0.0207)	(0.0227)	(0.0094)	(0.0092)	(0.0099)
Constant	0.1040***	0.1130***	0.1110***	-0.0532	-0.0352	-0.0301	0.8510***	0.8350***	0.8970***	0.0135	0.0197	0.0193
	(0.0164)	(0.0163)	(0.0154)	(0.1420)	(0.1400)	(0.1580)	(0.0940)	(0.0930)	(0.1060)	(0.0307)	(0.0319)	(0.0330)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.340	0.340	0.360	0.255	0.265	0.284	0.194	0.197	0.186	0.013	0.013	0.016
Observations	16,727	16,662	13,033	16,765	16,698	13,058	16,756	16,690	13,051	15,219	15,141	11,823
Number of firms	538	541	477	540	543	479	540	543	479	539	542	478

This table presents the results of regression equations (1), (2), (3), and (4) for the level of emissions with time and industry fixed effects. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.

Appendix E: Change in emissions with firm profitability and firm risk.

Variables	(1) RET	(2) RET	(3) RET	(4) ROA	(5) ROA	(6) ROA	(7) RETVOLA	(8) RETVOLA	(9) RETVOLA	(10) OPVOLA	(11) OPVOLA	(12) OPVOLA
SCOPE1GROWTH	0.0021***			0.0005			-0.0005*			-0.00003		
	(0.0006)			(0.0004)			(0.0003)			(0.0016)		
SCOPE2GROWTH		0.0019**			0.0006			-0.0006*			0.0015	
		(0.0009)			(0.0004)			(0.0003)			(0.0022)	
SCOPE3GROWTH			0.0012***			-0.0003			-0.0001			0.0002
			(0.0004)			(0.0003)			(0.0002)			(0.0009)
LOGSIZE	-0.0019***	-0.0021***	-0.0012*	0.0112***	0.0110***	0.0110***	-0.0275***	-0.0271***	-0.0295***	0.0021**	0.0019*	0.0014
	(0.0006)	(0.0006)	(0.0007)	(0.0033)	(0.0033)	(0.0032)	(0.0046)	(0.0046)	(0.0051)	(0.0010)	(0.0010)	(0.0011)
BM	-0.0400***	-0.0376***	-0.0371***	0.0126*	0.0152*	0.0223*	0.0146	0.0165	0.0027	0.0015	-0.0013	-0.0083
	(0.0077)	(0.0073)	(0.0093)	(0.0076)	(0.0080)	(0.0121)	(0.0173)	(0.0175)	(0.0193)	(0.0083)	(0.0082)	(0.0083)
ROE	0.0476***	0.0473***	0.0415***	0.1930***	0.1950***	0.2080***	-0.0055	-0.0051	-0.0202*	-0.0005	-0.0003	0.0069
	(0.0123)	(0.0120)	(0.0137)	(0.0288)	(0.0295)	(0.0284)	(0.0105)	(0.0104)	(0.0106)	(0.0159)	(0.0161)	(0.0180)
LEVERAGE	-0.0389***	-0.0339***	-0.0372***	-0.1260***	-0.1260***	-0.1290***	0.0396	0.0404	0.0550	0.0219	0.0205	0.0285
	(0.0099)	(0.0096)	(0.0103)	(0.0181)	(0.0185)	(0.0283)	(0.0331)	(0.0333)	(0.0376)	(0.0161)	(0.0158)	(0.0181)
RETEARN	0.0005	0.0028	0.0015	0.0182	0.0188	0.00007	-0.0472**	-0.0528**	-0.0268	0.0116	0.0067	-0.0129
	(0.0057)	(0.0055)	(0.0060)	(0.0349)	(0.0359)	(0.0409)	(0.0198)	(0.0207)	(0.0222)	(0.0093)	(0.0091)	(0.0097)
Constant	-0.0085	-0.0032	-0.0230	-0.0523	-0.0414	-0.0276	0.8530***	0.8460***	0.8830***	0.0162	0.0287	0.0487
	(0.0160)	(0.0158)	(0.0173)	(0.1450)	(0.1440)	(0.1580)	(0.0931)	(0.0928)	(0.1050)	(0.0295)	(0.0308)	(0.0332)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.342	0.342	0.358	0.255	0.260	0.283	0.196	0.194	0.185	0.013	0.013	0.016
Observations	16,159	16,095	12,464	16,193	16,128	12,488	16,185	16,121	12,482	14,679	14,605	11,296
Number of firms	538	541	477	540	543	479	540	543	479	539	542	478

This table presents the results of regression equations (1), (2), (3), and (4) for the change in emissions with time and industry fixed effects. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.

Appendix F: Emission intensity with firm profitability and firm risk.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Variables	RET	RET	RET	ROA	ROA	ROA	RETVOLA	RETVOLA	RETVOLA	OPVOLA	OPVOLA	OPVOLA
SCOPE1INT	-0.0293***			0.0017			0.0130			0.0142		
	(0.0099)			(0.0244)			(0.0578)			(0.0212)		
SCOPE2INT		-0.0446			-0.2200***			0.3650			0.1420	
		(0.0471)			(0.0733)			(0.2230)			(0.1070)	
SCOPE3INT			-0.0009			-0.0093			0.0060			0.0002
			(0.0043)			(0.0070)			(0.0100)			(0.0080)
LOGSIZE	0.0022***	0.0023***	0.0022***	0.0115***	0.0112***	0.0112***	-0.0278***	-0.0271***	-0.0300***	0.0028***	0.0026**	0.0022*
	(0.0006)	(0.0006)	(0.0006)	(0.0033)	(0.0033)	(0.0030)	(0.0046)	(0.0046)	(0.0052)	(0.0010)	(0.0010)	(0.0012)
BM	-0.0366***	-0.0352***	-0.0324***	0.0135*	0.0153*	0.0193	0.0162	0.0181	0.0020	0.0028	-0.0000009	0.00002
	(0.0069)	(0.0068)	(0.0079)	(0.0077)	(0.0079)	(0.0118)	(0.0186)	(0.0188)	(0.0196)	(0.0086)	(0.0084)	(0.0108)
ROE	0.0477***	0.0480***	0.0397***	0.1950***	0.1940***	0.1900***	-0.0060	-0.0061	-0.0219**	-0.0009	-0.00003	0.0028
	(0.0117)	(0.0115)	(0.0122)	(0.0290)	(0.0290)	(0.0312)	(0.0106)	(0.0107)	(0.0110)	(0.0156)	(0.0157)	(0.0175)
LEVERAGE	-0.0342***	-0.0306***	-0.0332***	-0.1270***	-0.1270***	-0.1350***	0.0378	0.0392	0.0464	0.0213	0.0201	0.0289
	(0.0093)	(0.0091)	(0.0090)	(0.0175)	(0.0179)	(0.0288)	(0.0333)	(0.0334)	(0.0386)	(0.0163)	(0.0161)	(0.0182)
RETEARN	0.0037	0.0061	0.0080	0.0171	0.0167	0.0097	-0.0504**	-0.0524**	-0.0285	0.0142	0.0092	-0.0075
	(0.0053)	(0.0053)	(0.0054)	(0.0340)	(0.0350)	(0.0400)	(0.0201)	(0.0207)	(0.0225)	(0.0093)	(0.0090)	(0.0100)
Constant	0.1030***	0.1070***	0.1130***	-0.0566	-0.0428	-0.0283	0.8620***	0.8440***	0.8960***	0.0113	0.0179	0.0219
	(0.0164)	(0.0164)	(0.0154)	(0.1440)	(0.1440)	(0.1570)	(0.0938)	(0.0917)	(0.1060)	(0.0306)	(0.0314)	(0.0329)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.339	0.339	0.359	0.254	0.253	0.266	0.198	0.197	0.186	0.012	0.013	0.016
Observations	16,815	16,724	13,093	16,853	16,761	13,118	16,844	16,752	13,111	15,296	15,201	11,878
Number of firms	540	542	478	542	544	480	542	544	480	541	543	479

This table presents the results of regression equations (1), (2), (3), and (4) for emission intensity with time and industry fixed effects. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.

Appendix G: Time comparison with emission levels.

	Panel A: Stock returns								
		2010-2012			2013-2015			2016-2020	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	RET	RET	RET	RET	RET	RET	RET	RET	RET
LOGSCOPE1	-0.0010			-0.0040***			-0.0013**		
	(0.0006)			(0.0007)			(0.0006)		
LOGSCOPE2		-0.0015			-0.0057***			-0.0018**	
		(0.0009)			(0.0011)			(0.0007)	
LOGSCOPE3			-0.0007			-0.0025***			-0.00007
			(0.0006)			(0.0007)			(0.0005)
LOGSIZE	-0.0013	-0.0008	-0.0004	-0.0012	-0.0011	-0.0021*	-0.0024***	-0.0024***	-0.0032***
	(0.0010)	(0.0010)	(0.0010)	(0.0012)	(0.0012)	(0.0012)	(0.0008)	(0.0008)	(0.0007)
BM	-0.0166*	-0.0153*	-0.0186	-0.0345***	-0.0363***	-0.0370**	-0.0320***	-0.0297***	-0.0340***
	(0.0089)	(0.0089)	(0.0120)	(0.0107)	(0.0105)	(0.0158)	(0.0073)	(0.0072)	(0.0090)
ROE	0.0878***	0.0824***	0.0742***	0.0250*	0.0257*	0.0373***	0.0276	0.0268	0.0244
	(0.0140)	(0.0137)	(0.0145)	(0.0128)	(0.0132)	(0.0114)	(0.0172)	(0.0168)	(0.0184)
LEVERAGE	-0.0542***	-0.0423***	-0.0486***	-0.0005	-0.0123	-0.0109	-0.0168	-0.0138	-0.0230*
	(0.0153)	(0.0162)	(0.0167)	(0.0156)	(0.0157)	(0.0159)	(0.0120)	(0.0118)	(0.0125)
RETEARN	0.0070	0.0091	0.0126	-0.0093	-0.0148	-0.0126	0.0221***	0.0237***	0.0195***
	(0.0095)	(0.0093)	(0.0096)	(0.0098)	(0.0098)	(0.0104)	(0.0071)	(0.0070)	(0.0070)
Constant	0.1040***	0.0981***	0.0912***	0.1330***	0.1520***	0.1330***	-0.0040	0.0047	0.0018
	(0.0233)	(0.0236)	(0.0237)	(0.0291)	(0.0293)	(0.0263)	(0.0184)	(0.0187)	(0.0178)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.344	0.345	0.371	0.285	0.284	0.304	0.362	0.361	0.378
Observations	3,592	3,556	3,074	4,076	4,049	2,866	9,059	9,057	7,093
Number of firms	337	331	302	373	373	276	527	530	453

Appendix G
(continued)

	Panel B: Stock return volatility								
	2010-2012			2013-2015			2016-2020		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA
LOGSCOPE1	-0.00004			-0.0005			0.0014		
	(0.0015)			(0.0014)			(0.0018)		
LOGSCOPE2		0.0011			-0.0026			0.0041*	
		(0.0018)			(0.0023)			(0.0021)	
LOGSCOPE3			-0.0010			-0.0007			-0.0007
			(0.0007)			(0.0019)			(0.0009)
LOGSIZE	-0.0240***	-0.0243***	-0.0246***	-0.0111***	-0.0107***	-0.0121***	-0.0207***	-0.0211***	-0.0218***
	(0.0036)	(0.0037)	(0.0041)	(0.0029)	(0.0030)	(0.0035)	(0.0030)	(0.0030)	(0.0037)
BM	-0.0045	-0.0025	0.0036	0.0161	0.0218	0.0032	0.0135	0.0135	0.0109
	(0.0066)	(0.0068)	(0.0095)	(0.0267)	(0.0264)	(0.0310)	(0.0171)	(0.0171)	(0.0220)
ROE	-0.0149*	-0.0143**	-0.0109	-0.0220***	-0.0222***	-0.0173**	-0.0177*	-0.0183*	-0.0222*
	(0.0077)	(0.0070)	(0.0067)	(0.0078)	(0.0078)	(0.0073)	(0.0103)	(0.0102)	(0.0128)
LEVERAGE	-0.0586***	-0.0607***	-0.0561***	0.0036	0.0059	0.0277	0.0064	0.0069	0.0125
	(0.0220)	(0.0220)	(0.0216)	(0.0589)	(0.0591)	(0.0756)	(0.0175)	(0.0173)	(0.0218)
RETEARN	-0.0360*	-0.0296*	-0.0135	-0.0873**	-0.0916**	-0.1320**	-0.0230	-0.0219	-0.0211
	(0.0187)	(0.0178)	(0.0142)	(0.0339)	(0.0364)	(0.0534)	(0.0148)	(0.0144)	(0.0169)
Constant	0.7770***	0.7710***	0.7700***	0.5660***	0.5790***	0.5990***	0.6460***	0.6330***	0.6870***
	(0.0825)	(0.0832)	(0.0902)	(0.0713)	(0.0734)	(0.0886)	(0.0627)	(0.0627)	(0.0765)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.221	0.236	0.210	0.291	0.287	0.337	0.155	0.149	0.150
Observations	3,596	3,560	3,076	4,085	4,057	2,871	9,075	9,073	7,104
Number of firms	337	331	303	376	376	277	529	532	455

This table reports the results of regression equations (1) and (3) for the level of emissions broken down into three periods. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.

Appendix H: Time comparison with change in emissions.

Panel A: Stock returns

	2010-2012			2013-2015			2016-2020		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	RET	RET	RET	RET	RET	RET	RET	RET	RET
SCOPE1GROWTH	0.00001			0.0032			0.0038***		
	(0.0017)			(0.0019)			(0.0011)		
SCOPE2GROWTH		-0.0015			-0.0009			0.0045***	
		(0.0028)			(0.0024)			(0.0015)	
SCOPE3GROWTH			0.0003			-0.00008			0.0026***
			(0.0006)			(0.0015)			(0.0007)
LOGSIZE	-0.0010	-0.0007	0.0004	-0.0019	-0.0023*	-0.0028**	-0.0027***	-0.0028***	-0.0026***
	(0.0009)	(0.0009)	(0.0010)	(0.0013)	(0.0013)	(0.0013)	(0.0008)	(0.0008)	(0.0008)
BM	-0.0182*	-0.0171*	-0.0158	-0.0460***	-0.0482***	-0.0498***	-0.0378***	-0.0354***	-0.0396***
	(0.0100)	(0.0099)	(0.0151)	(0.0125)	(0.0127)	(0.0183)	(0.0080)	(0.0077)	(0.0096)
ROE	0.0836***	0.0788***	0.0726***	0.0220*	0.0238*	0.0342***	0.0334*	0.0332*	0.0197
	(0.0140)	(0.0137)	(0.0146)	(0.0130)	(0.0135)	(0.0120)	(0.0185)	(0.0178)	(0.0218)
LEVERAGE	-0.0606***	-0.0484***	-0.0403**	-0.0039	-0.0180	-0.0127	-0.0250*	-0.0223*	-0.0263*
	(0.0158)	(0.0166)	(0.0178)	(0.0169)	(0.0175)	(0.0172)	(0.0129)	(0.0124)	(0.0135)
RETEARN	0.0055	0.0089	0.0124	-0.0120	-0.0169	-0.0192*	0.0170**	0.0199***	0.0169**
	(0.0090)	(0.0088)	(0.0095)	(0.0103)	(0.0107)	(0.0108)	(0.0073)	(0.0071)	(0.0074)
Constant	-0.0145	-0.0213	-0.0503**	0.0309	0.0422	0.0557**	0.0034	0.0079	0.0137
	(0.0227)	(0.0228)	(0.0244)	(0.0306)	(0.0305)	(0.0282)	(0.0194)	(0.0193)	(0.0204)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.364	0.366	0.385	0.291	0.288	0.314	0.363	0.361	0.373
Observations	3,256	3,228	2,768	3,711	3,683	2,595	8,541	8,537	6,637
Number of firms	337	331	302	373	373	276	527	530	453

Appendix H
(continued)

	Panel B: Stock return volatility								
	2010-2012			2013-2015			2016-2020		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA
SCOPE1GROWTH	0.00008			-0.0003			-0.0008***		
	(0.0002)			(0.0005)			(0.0002)		
SCOPE2GROWTH		-0.0004*			-0.0001			-0.0002	
		(0.0002)			(0.0006)			(0.0003)	
SCOPE3GROWTH			-0.000008			0.0004			-0.0002*
			(0.00004)			(0.0003)			(0.0001)
LOGSIZE	-0.0238***	-0.0239***	-0.0245***	-0.0110***	-0.0110***	-0.0121***	-0.0209***	-0.0208***	-0.0225***
	(0.0036)	(0.0036)	(0.0040)	(0.0028)	(0.0028)	(0.0033)	(0.0029)	(0.0029)	(0.0037)
BM	-0.0029	-0.0013	0.0028	0.0115	0.0147	-0.0040	0.0119	0.0127	0.0109
	(0.0059)	(0.0060)	(0.0088)	(0.0255)	(0.0252)	(0.0291)	(0.0168)	(0.0171)	(0.0219)
ROE	-0.0153**	-0.0145**	-0.0113*	-0.0220***	-0.0216***	-0.0159**	-0.0192*	-0.0203**	-0.0236*
	(0.0070)	(0.0065)	(0.0062)	(0.0083)	(0.0083)	(0.0069)	(0.0101)	(0.0101)	(0.0130)
LEVERAGE	-0.0578***	-0.0609***	-0.0569***	-0.0005	-0.0048	0.0162	0.0069	0.0057	0.0136
	(0.0224)	(0.0224)	(0.0217)	(0.0565)	(0.0557)	(0.0706)	(0.0170)	(0.0170)	(0.0213)
RETEARN	-0.0339*	-0.0291	-0.0121	-0.0813**	-0.0925***	-0.1340***	-0.0220	-0.0214	-0.0215
	(0.0188)	(0.0184)	(0.0135)	(0.0332)	(0.0340)	(0.0493)	(0.0148)	(0.0148)	(0.0168)
Constant	0.7710***	0.7720***	0.7560***	0.5550***	0.5590***	0.5910***	0.6670***	0.6670***	0.7000***
	(0.0819)	(0.0828)	(0.0899)	(0.0674)	(0.0673)	(0.0828)	(0.0613)	(0.0611)	(0.0779)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.220	0.234	0.207	0.277	0.275	0.326	0.151	0.144	0.149
Observations	3,259	3,231	2,770	3,719	3,691	2,600	8,555	8,551	6,647
Number of firms	337	331	303	376	376	277	529	532	455

This table reports the results of regression equations (1) and (3) for the change in emissions broken down into three periods. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.

Appendix I: Time comparison with emission intensities.

	Panel A: Stock returns								
		2010-2012			2013-2015			2016-2020	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	RET	RET	RET	RET	RET	RET	RET	RET	RET
SCOPE1INT	-0.0388***			-0.0780***			0.0145		
	(0.0143)			(0.0174)			(0.0162)		
SCOPE2INT		-0.0049			-0.3930***			0.1370	
		(0.0861)			(0.1130)			(0.0881)	
SCOPE3INT			0.0019			-0.0409***			0.0004
			(0.0085)			(0.0117)			(0.0054)
LOGSIZE	-0.0018*	-0.0014	-0.0007	-0.0026**	-0.0029**	-0.0029**	-0.0030***	-0.0029***	-0.0032***
	(0.0009)	(0.0009)	(0.0010)	(0.0012)	(0.0012)	(0.0012)	(0.0008)	(0.0008)	(0.0007)
BM	-0.0175**	-0.0169*	-0.0199*	-0.0418***	-0.0439***	-0.0428***	-0.0356***	-0.0325***	-0.0341***
	(0.0086)	(0.0088)	(0.0121)	(0.0106)	(0.0108)	(0.0162)	(0.0075)	(0.0074)	(0.0091)
ROE	0.0849***	0.0850***	0.0748***	0.0303**	0.0302**	0.0257*	0.0322*	0.0328**	0.0244
	(0.0139)	(0.0138)	(0.0143)	(0.0136)	(0.0136)	(0.0140)	(0.0171)	(0.0167)	(0.0184)
LEVERAGE	-0.0522***	-0.0468***	-0.0492***	-0.0169	-0.0169	-0.0070	-0.0208*	-0.0206*	-0.0235*
	(0.0155)	(0.0160)	(0.0166)	(0.0160)	(0.0160)	(0.0162)	(0.0120)	(0.0118)	(0.0122)
RETEARN	0.0104	0.00957	0.0126	-0.0116	-0.0108	-0.0045	0.0217***	0.0234***	0.0192***
	(0.0092)	(0.0095)	(0.0095)	(0.0102)	(0.0100)	(0.0115)	(0.0070)	(0.0068)	(0.0070)
Constant	0.1050***	0.0951***	0.0910***	0.1290***	0.1370***	0.1320***	-0.0051	-0.0017	0.0020
	(0.0236)	(0.0234)	(0.0239)	(0.0294)	(0.0295)	(0.0274)	(0.0185)	(0.0186)	(0.0178)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.345	0.343	0.370	0.282	0.282	0.302	0.362	0.361	0.378
Observations	3,624	3,572	3,106	4,088	4,065	2,882	9,103	9,087	7,105
Number of firms	339	332	303	374	373	277	529	531	453

Appendix I
(continued)

Panel B: Stock return volatility									
	2010-2012			2013-2015			2016-2020		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA	RETVOLA
SCOPE1INT	-0.0138			0.0226			0.0454		
	(0.0108)			(0.0461)			(0.0284)		
SCOPE2INT		-0.0022			0.4990			0.1390	
		(0.1110)			(0.5110)			(0.1070)	
SCOPE3INT			-0.0024			-0.0064			0.0029
			(0.0112)			(0.0250)			(0.0055)
LOGSIZE	-0.0242***	-0.0246***	-0.0246***	-0.0111***	-0.0106***	-0.0123***	-0.0202***	-0.0201***	-0.0219***
	(0.0036)	(0.0036)	(0.0040)	(0.0030)	(0.0028)	(0.0036)	(0.0030)	(0.0030)	(0.0037)
BM	-0.0049	-0.0028	0.0052	0.0150	0.0156	0.0010	0.0141	0.0155	0.0107
	(0.0066)	(0.0068)	(0.0101)	(0.0266)	(0.0261)	(0.0316)	(0.0170)	(0.0174)	(0.0220)
ROE	-0.0143**	-0.0139**	-0.0108	-0.0220***	-0.0214***	-0.0290**	-0.0174*	-0.0183*	-0.0221*
	(0.0072)	(0.0070)	(0.0066)	(0.0078)	(0.0077)	(0.0119)	(0.0102)	(0.0102)	(0.0129)
LEVERAGE	-0.0598***	-0.0610***	-0.0512**	0.0043	-0.0034	0.0139	0.0054	0.0064	0.0110
	(0.0221)	(0.0220)	(0.0215)	(0.0585)	(0.0569)	(0.0754)	(0.0175)	(0.0174)	(0.0217)
RETEARN	-0.0356*	-0.0325*	-0.0128	-0.0865**	-0.0946***	-0.1240**	-0.0252*	-0.0229	-0.0208
	(0.0187)	(0.0183)	(0.0142)	(0.0340)	(0.0363)	(0.0530)	(0.0152)	(0.0149)	(0.0168)
Constant	0.7810***	0.7880***	0.7590***	0.5600***	0.5540***	0.6010***	0.6500***	0.6480***	0.6830***
	(0.0829)	(0.0832)	(0.0899)	(0.0717)	(0.0685)	(0.0885)	(0.0619)	(0.0619)	(0.0762)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.219	0.222	0.206	0.289	0.295	0.336	0.157	0.145	0.145
Observations	3,628	3,576	3,108	4,097	4,073	2,887	9,119	9,103	7,116
Number of firms	339	332	304	377	376	278	531	533	455

This table reports the results of regression equations (1) and (3) for emission intensities broken down into three periods. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Robust standard errors are in parentheses.