Is decarbonization priced in? – Evidence on the carbon risk hypothesis from the European Green Deal leakage shock

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On November 29, 2019, twelve days before the official announcement, information was leaked regarding the ambitions of the European Green Deal, i.e., the full decarbonization of the European Union by 2050 and lifting of 2030 emissions targets from 40% to 55%. The leakage should have triggered a Europe-wide systemic shock to financial markets without an accompanying announcement of supportive measures. Applying event study methodology to a sample of 600 European large and mid-cap stocks, we find that the overall market reaction was indeed significantly negative, albeit moderate. Abnormal returns gradually decline with increasing GHG emissions. Conversely, the official announcement emphasizing financial support and the green growth narrative did not ignite a positive market reaction. OLS regressions reveal that GHG emissions explain negative market reactions in response to the leak, whereas environmental performance and commitment are negatively related to returns obtained over intermediate horizons. We conclude that market participants incorporate available information on GHG emissions in (short-term) reaction to the proclamation of a significant change environmental policies.

Keywords:

Carbon risk, climate policy, European Green Deal, event study, energy policy, GHG emissions, environmental pollution

1. Introduction

On December 11, 2019, the European Commission presented its European Green Deal as a central pillar of European climate and economic policies (European Commission, 2019c). The Green Deal aims at fully decarbonizing the European economies by 2050, implying a deep transformation of the economic structures, as decarbonization efforts affect all economic sectors, "notably transport, energy, agriculture, buildings, and industries such as steel, cement, ICT, textiles, and chemicals." (European Commission, 2019d). The European Commission argues that transforming European industries will trigger innovation and strengthen international competitiveness, resulting in "green growth." (European Commission, 2019c). On Friday, November 29, 2019, twelve days before the official announcement, a five-page bullet-point list that enumerated new or stepped-up regulatory policy measures and, as such, signaled increased regulatory stringency to the markets (euractiv, 2019) was leaked. The document foreshadowed the 2021 climate law by announcing a binding objective of climate neutrality by 2050 and a raised target of a minimum of 50% by 2030, against the then ambition level of 40%. The leaked information about the enhanced regulatory stringency may constitute an unvarnished systemic shock to the European industry and stock market. In contrast, the official announcement of the European Green Deal emphasized the "green growth" narrative and announced support for the European industries, *inter alia* by the declaration to mobilize 100 billion euros for structural transformation (European Commission, 2019d), again a massive increase compared to the 2019 budget share for "growth and jobs" at 23 billion euros.

The effect of green policy announcements (GPA) on financial markets has widely been debated in academic literature (e.g., Borghesi et al., 2022; Birindelli and Chiappini, 2021; Li et al., 2020; Pham et al., 2019; Ramiah et al., 2013, 2015; Zeng et al., 2021). The empirical evidence is, however, mixed. Studies frequently conclude that market-wide reactions differ in sign and magnitude, especially due to sector-by-sector differences (Ramiah et al., 2013; Clarkson, 2015; Birindelli and Chiappini, 2021). While previous studies focus primarily on country-specific GPA, the European Green Deal differs from country-level green policy announcements as it is an EU-wide regulation announcement that simultaneously affects all EU member states. Accounting-based studies confirm a negative impact on firm valuation under specific circumstances. Clarkson et al. (2015) find that carbon emissions impact firm value when GHG emissions exceed allowances, and the firm is unable to pass on the additional costs to its customers.

A second strand of literature in empirical finance differentiates between environmentally friendly ("green") assets and environmentally unfriendly ("brown") assets (Pàstor et al., 2021, Pedersen et al., 2021). In theory, investors demand compensation for bearing environmental risks, such as uncertainty about the future cost of regulation. Therefore, agents holding brown assets require prospectively higher returns in a state of equilibrium. Current empirical research debates whether carbon emissions constitute a significant risk factor in asset pricing. Krueger et al. (2020) find that institutional investors consider corporate carbon emissions a significant risk factor. Bolton and Kacperczyk (2021) provide initial empirical evidence for the existence of a carbon premium. Aswani et al., (2023) raise concerns about robustness of the derived results, as vendor-estimated emission data is mechanically correlated with firm fundamentals.

The announcement of the European Green Deal, especially the initial information leakage, provides a natural experimental setting to critically analyze equity market reactions to ambitious yet distant emission targets becoming binding law and, accordingly, whether carbon emissions are associated with stock returns (Aswani et al., 2023). Green policy announcements typically lead to two separate and potentially contradictory effects, which may explain the dispersion of results in previous studies. First, the announcement of stricter environmental regulations is likely to lead to negative price reactions due to the costs of regulation and (non-)compliance. Second, the announcement of supportive measures and subsidies may be perceived positively by stock markets. The information about enhanced environmental regulation was leaked twelve days before the official announcement, so both events are temporally separated. Bolton and Kacperczyk (2021) note that carbon emissions may pose a systemic risk factor if regulatory interventions to cut emissions apply uniformly to all emissions, i.e., "if a large federal carbon tax were to be introduced, this would be a systematic shock affecting all companies with significant emissions." We thus assume that the leakage date of the European Green Deal on November 29, 2019, constitutes such a systematic shock to the European market.

We thus take this event as an opportunity to conduct a natural experiment. We investigate the European stock market's response to the leakage and official announcement of the European Green Deal using event study methodology. We analyze all 600 constituents of the EURO Stoxx 600 index, thereby capturing approximately 88% of Europe's market capitalization. We find that the overall stock market reaction following the leakage was moderate yet negative. Greenhouse gas (GHG) emissions seem to determine cross-sectional stock returns, yet the results do not hold in multivariate regressions.

Our contribution to the literature is threefold: To the best of our knowledge, our study is the first to analyze the effect of an ambitious yet distant emission target, such as Europe's full decarbonization by 2050 becoming binding law, without a simultaneous announcement of financially supportive measures. We depart from previous literature, which considers corporate environmental commitment as a possible factor in mitigating stock returns (Borghesi et al., 2022; Birindelli and Chiappini, 2021). We employ firms' total GHG emissions as a raw and objective measure for carbon risk following Bolton and Kacperczyk (2021), additionally controlling for environmental commitment in later models. We tereby contribute to the current debate on the carbon risk hypothesis. While we do find that investors seem to incorporate available data on GHG emissions into their investment decisions around such an distinct event, we also detect correlations between emission data and firm fundamentals as, i.e., in Aswani et al. (2023). Over a longer horizon, we find that environmental performance, proxied via Environmental Pillar Scores, is negatively associated with stock returns, thereby fostering the assumption that investors are left unconvinced.

The remainder of the paper is organized as follows. Section 2 provides the literature background. Section 3 explains the data and methodology. Section 4 presents the results. Section 5 provides additional insights with regard to the elections in the U.K. Section 6 discusses the results and concludes.

2. Background and Study Hypotheses

Our study aims to bridge the gap between carbon risk premium as a distinct risk factor in empirical asset pricing as well as the analysis of stock market reactions to Green Policy Announcements (GPAs). We review the underlying literature in the following chapter. After delineating the theoretical framework, we outline the European Green Deal and state our hypotheses.

2.1 Carbon Risk in Asset Pricing

Empirical asset pricing theory, more specifically, the efficient market hypothesis (Fama et al., 1970), states that stock prices fully incorporate all information available to investors. Accordingly, stock prices reflect investors' perception of expected future profitability, incorporating all possible determinants adequately. Recently, scholars have proposed theoretical frameworks for how sustainability factors affect stock prices (Pedersen et al., 2021; Pàstor et al., 2021). In equilibrium, investors in green assets accept lower financial returns due to their individual preferences or the mitigation of excessive environmental, social, or governance-related risk exposure. Green assets yield a negative CAPM alpha; brown assets yield a positive CAPM alpha (Pàstor et al., 2021). If new information penetrates the market, stock prices adjust until they adequately reflect all information correctly and thus reach a new state of equilibrium.

There is a lively debate in the literature about whether carbon risk is priced as a significant risk factor (e.g., Bolton & Kacperzyk, 2021, Aswani et al., 2023). Following the theorem of Pàstor et al. (2021), the question is whether investors price the uncertainty about the future regulation of carbon emissions. A survey by Krueger et al. (2020) reveals that institutional investors consider carbon emissions a material risk factor. Bolton and Kacperczyk (2021) identify three channels of how carbon emissions may influence stock returns: First, carbon emissions are a relatively direct function of energy consumption and, therefore, a proxy for dependency on energy prices and commodity risk. Second, carbon risk may be priced inefficiently due to the use of narrow cash-flow models ignoring broader risks such as climate risks and global warming. Third, carbon-intensive stocks may pose some sort of "sin-stocks" following Hong and Kacperczyk (2009). Lower investor demand may lead to investors in sin stocks requiring higher returns.

Research on carbon risk is still far from reaching a consensus[1]. Bolton and Kacperczyk (2021) find that higher returns are associated with higher emissions, thereby providing the first evidence for the existence of a carbon premium and, thus, a positive CAPM alpha following the notation of Pàstor et al. (2021). The premium remains statistically significant after controlling for size, value, and momentum risk, as well as firm characteristics such as plant and equipment and investment over assets. Their findings suggest that investors price absolute carbon emissions at the firm level and that these firm-level effects outweigh divestment effects at the industry level. However, other studies report opposing results. Görgen et al. (2020) show that although carbon risk explains cross-sectional return variations well, they do not find a significant carbon risk premium. The authors argue that investors may be unable to price accurately the uncertainties associated with carbon risk. In a recent article, Aswani et al. (2023) analyze the association between carbon emissions and stock returns and operating performance for US firms from 2005 to 2019. They challenge previous findings that link emissions to financial performance, emphasizing potential sources of bias that emerge with using vendor-estimated emissions and the use of unscaled emission data.

2.2 Stock Market Reactions to Green Policy Announcements

Other studies examine the short-term impact of Europe-wide events related to carbon and climate risks to assess whether investors are pricing in (regulatory) carbon risks. Ramelli et al. (2021) analyzed stock price reactions to the first Global Climate Strike on a broad sample of European stocks. Carbon intensity was negatively associated with stock returns, albeit the cross-sectional mean cumulative 5-days CAPM- (FF3-) adjusted CARs were at 0.089 (0.245) positive, yet economically insignificant. Bolton and Kacperczyk (2021) note that carbon emissions may pose a systematic risk factor if (expected) regulatory interventions to cut emissions apply uniformly to all emissions, i.e., the introduction of a large federal carbon tax. Contrarily, most regulatory interventions may be introduced piecemeal at the state, industry, and municipal levels (Bolton and Kacperzyk,

[1] The question of whether GHG emissions impact firm valuation has also been subject to accounting-based studies before (e.g., Clarkson et al., 2015, Matsumura et al., 2014). The results of these studies are, however, mixed. Clarkson et al. (2015), find that carbon emissions impact firm value when GHG emissions exceed allowances, and the firm is unable to pass on the additional costs to its customer, similar to the conclusion of Ramiah et al. (2013).

2021). Such green policy announcements (GPAs) have been subject to empirical studies. Li et al. (2020) show that the Chinese stock market reactions following the announcement of China's action plan for air pollution prevention were inconclusive, yet polluting industries performed significantly worse than non-polluting industries. Ramiah et al. (2013), focusing on the Australian market, document that the abnormal returns of the largest polluters (i.e., electricity generators) were zero, despite the Australian government's intention to penalize these particular companies in the course of their introduced policy framework. Birindelli and Chiappini (2021) analyze whether a company's environmental commitment states a significant determinant of cross-sectional abnormal stock returns following green policy announcements in the EU. Overall, they observed predominantly negative market responses, yet industry-specific impacts outweighed firm-level variables. Borghesi et al. (2022) focus on the effect of country-level GPA of major European governments in 2020, following the European Green Deal announcement on 100 stocks of the STOXX Europe 100 index. They document positive abnormal returns for both green and brown sectors, with the former significantly outperforming the latter. They also link the funding volume announced to the magnitude of abnormal returns. Their findings show that investors' sentiment effect is stronger for greener industries, underlining the argument of the green growth narrative.

2.3 The European Green Deal

The European Green Deal (EGD) is Europe's climate and growth strategy. It aims at turning the European Union into the first carbon neutral continent by 2050 while maintaining economic growth at the same time (EC - European Commission 2019). A key component of this climate transformation strategy is the decarbonisation of the energy sector, responsible for some 80% of the EU's greenhouse gas emissions. The strategy and its underlying climate scenarios (Hainsch et al. 2022; Capros et al. 2018) conceived the Green Deal as a long-term strategy, phasing out the use of fossil energies across the coming decades (Elkerbout et al. 2020).

The Green Deal differs from earlier policies regarding several features: First, earlier climate and energy scenarios such as the Energy Roadmap 2050 (European Commission, 2011b) or the Climate Roadmap (European Commission, 2011a) emphasized that decarbonization levels of 80-

95% would come at high additional costs. The Green Deal and its underpinning Climate 2050 strategy (European Commission, 2020b, 2020c) implicitly necessitate stronger regulatory interventions (Herold et al., 2019). Second, earlier climate frameworks such as the 2020 and 2030 climate and energy objectives (European Commission, 2012; European Council, 2019, 2014; Gawel, 2019; Geden and Schenuit, 2019) largely committed the EU (European Commission, 2018a, 2018b, 2016) (European Commission, 2019a, 2019b, 2018c, 2018d) but left leeway to its member states (Ringel and Knodt, 2018), putting a stronger focus on monitoring (Economidou et al., 2020, 2022). In contrast, the EU's "climate law" is binding (European Commission, 2020a), and the Green Deal Roadmap sets out 47 concrete legislative proposals covering all sectors. Third, the Commission tied up with earlier win-win arguments, underscoring that ambitious climate policies form Europe's "green growth strategy"(Ringel et al., 2016). It proclaimed the Green Deal a European growth strategy fostering innovation and first-mover advantages. Fourth, the strategy pledges to protect European industries against eco-dumping and carbon leakage (Greaker, 2003; IEA, 2020) through a "carbon border adjustment mechanism." These elements combined sum up a political argument that the green transformation of the EU comes at a short-term cost that is outweighed by both short-term and long-term benefits in "green" sectors.

The European Treaty allows the European Commission to enforce EU legislation and take EU Member States to court in case of infringements in its role as “guardian of the Treaty” (Akse 2020). Especially with the Green Deal and its derived legislation, the European Commission has adopted a method of “harder soft governance” (Knodt et al. 2020) that is designed to constitute a more effective and more immediate compliance mechanism. This implies that Member States need to publicly justify their (non-) action, taking the burden of proof. This is done in a monitoring process via the National Energy and Climate Plans (NECPs) that allows a certain degree of blaming and shaming (Economidou et al. 2022). Furthermore, many provisions such as the European climate law, the energy efficiency and the renewable energy directive foresee automatic EU action in case the EU member states do not follow up on the climate and energy commitments (“gap filling mechanism”) allowing the European level to act quickly. Both elements strengthen the Commission’s ability to enforce European decisions.

2.4 Hypotheses

The European Green Deal, especially the leaked paper prior to the official announcement, provides an excellent framework to test the carbon risk hypothesis. A five-page list of bullet points specifically stating that the full decarbonization of the EU will be put into binding law and that the 2030 emission targets will be lifted to at least 50% was leaked on November 29, 2019. Without accompanying announcements of supportive measures, the leakage day should constitute an unadorned systematic shock that most likely affects companies across the European Union equally. However, if the market prices carbon risk adequately, the leaked document about enhanced environmental stringency may not pose new information to the market, and reactions remain absent. Alternatively, the leaked information on enhanced environmental stringency may alter the perception of future corporate profitability if the market has not adequately priced the carbon risk premium yet. Investors may thus demand higher compensation for bearing carbon risk. Prospectively higher expected returns result in an erosion of shareholder value. Hence, we propose the first hypothesis as follows:

H1: The information leak has a significant impact on the European financial market. CARs are negative and statistically significant.

Depending on whether our results support the first hypothesis, we may analyze the determinants of cross-sectional abnormal returns. If investors explicitly account for cross-sectional and systematic carbon risk premia, we expect that GHG emissions state a significant determinant of cumulative average abnormal returns. Hence, our second hypothesis reads as follows:

H2: Higher levels of corporate GHG emissions are significantly related to lower CARs.

In the spirit of Borghesi et al. (2022), we hypothesize that the official announcement of the European Commission to channel funding toward a green transition will result in a positive market reaction. Accordingly, our third hypothesis reads as follows.

H3: The official announcement and the supportive measures and subsidies reduce (future) carbon risk significantly. CARs are positive and statistically significant.

3. Data and Methodology

3.1. Data Sources

The study analyses the European stock market's response to the (leaked information of) the European Commission's plan to put full decarbonization by 2050 in binding law. All stock data is retrieved from Refinitiv Eikon. Data on risk-free rates, market premiums, and factor premia were gratefully taken from the Kenneth French Data library (French, 2022). We focus on all shares listed in the STOXX Europe 600 index, which comprises 600 European stocks covering large and medium-capitalized firms. Index constituents and control variables are obtained as of November 28, 2019, one day before the initial information leak.

Variables included in the empirical analysis comprise daily stock returns adjusted for dividends and splits and standard firm-specific control variables, including leverage, calculated as total debt divided by total assets, return on assets, book-to-market ratio, and size, proxied by market capitalization obtained one day prior to the leakage date.

Additionally, we employ companies' total GHG emissions, expressed via the Total CO_2 Emission provided by Refinitiv, as well as companies' environmental pillar scores and Scope 2 carbon emission for further robustness checks. Sector and industry classification relies on the global industry classification standard (GICS), and returns are noted in percentages throughout the study.

3.2. Methodology

Our empirical design follows a two-step procedure. First, we conduct a standard event study for two different dates following the approach of Brown and Warner (1980, 1985). After that, we perform multivariate regressions to assess the determinants of cross-sectional abnormal stock returns. Initial information was leaked on November 29, 2019 (euractiv, 2019). Market reactions, if any, should be notified shortly after the leakage following the semi-strong version of the efficient market hypothesis (Fama et al., 1969). The official announcement followed then on December 11, 2019. Three- and seven-day event windows are specified as [-1,1], hereafter short window, and [-3,3], hereafter long window, around each event, where t = 0 determines the day of the respective event. We provide further robustness by adopting a long-term event window of 33 days spanning

[-5,28], hereafter referred to as the extended window. The length may seem arbitrary at first but is closely related to the event window of Borghesi et al. (2022) spanning [-5,20] around the respective GPA dates. Similarly, our window starts five days before the initial information leak and ends 20 days after the official announcement of the European Green Deal. We count trading days, thereby omitting weekends and public holidays. We estimate the parameters ($\hat{\alpha}_i$, $\hat{\beta}_i$) for expected stock returns over a 250-days estimation period spanning [-260, -10] concerning the leakage date by regressing the excess return of stock *i* at time *t* over the risk-free rate, denoted as $r_{it} - r_{ft}$, on the excess return of the market at time *t* denoted as $r_{mt} - r_{ft}$:

$$r_{it} - r_{ft} = \widehat{\alpha_i} + \widehat{\beta_i}(r_{mt} - r_{ft}) + \varepsilon_{it}$$

where ε_{it} denotes the remaining residuals with a mean of zero and variance ${\sigma_i}^2$. The expected risk-adjusted return is then estimated based on the capital asset pricing model (CAPM), formally written as:

$$E[r_{it}] = r_{ft} + \alpha_i + \beta_i(r_{mt} - r_{ft})$$

We additionally estimate expected returns based on the Fama-French three-factor model, hereafter FF3 (Fama & French, 1993), to account for size and value effects.

$$E[r_{it}] = r_{ft} + \alpha_i + \beta_{1i}(r_{mt} - r_{ft}) + \beta_{2i}SMB_t + \beta_{3\mathrm{i}}HML_t$$

where SMB_t and HML_t denote the small-minus big and high-minus-low factor premia at time t, respectively. The estimation of $\widehat{\alpha_i}$ and $\widehat{\beta_{in}}$ is similar to the procedure based on the CAPM. We employ Developed Market factors as we are interested in the abnormal performance of the overall European market, thereby treating the market and factor returns as exogenous factors. Therefore, the estimated results may tend to be biased towards an underestimation and are considered conservative estimates of the real effect. An abnormal return of stock i at time t is calculated as the difference between the observed return and the respective expected return, formally written as:

$$AR_{it} = r_{it} - E[r_{it}]$$

The cumulative abnormal return (CAR) is then calculated as the sum of daily abnormal returns of stock i over the event window $[\tau 1 : \tau 2]$:

$$CAR_{i[\tau 1:\tau 2]} = \sum_{i=1}^{N} AR_{it}$$

The cross-sectional statistical significance of the findings is tested using a difference in mean tests (t-test) and Wilcoxon signed rank difference in median tests (Wilcoxon, 1945). Correcting t-statistics for excess skewness in the distribution of CARs following Hall (1992) yields virtually similar results.

In the second step, we use OLS regressions to examine whether a firm's raw and cumulative abnormal returns are influenced by its level of total GHG emissions after controlling for firm-specific controls. All models control for industry-fixed effects, and standard errors are clustered at the industry level. The baseline model reads as follows:

$$CAR_i = \gamma_0 + \gamma_1 CO2\_T_i + \gamma' X_i + \delta_k + \varepsilon_i$$

where γ_0 denotes the intercept, $CO2\_T_i$ denotes the natural logarithm of a stock's GHG emissions, δ_k captures k industry-fixed effects, and $X_i$denotes the set of firm-specific control variables, including leverage, book-to-market ratio, market capitalization and return on assets. The selection of control variables follows previous literature, e.g., Ramelli et al. (2021) and Aswani et al. (2023).

The remaining idiosyncratic error term is denoted by ε_i.Later models employ scope 2 emissions as a substitute for total GHG emissions as well as companies environmental performance, proxied by Refinitiv Environmental Pillar Scores. We also include a relative measure of carbon emissions, i.e., GHG emissions scaled by total assets.

3.3. Selection of Variables and Controls

Before embarking on the empirical results, we provide an overview of the descriptive statistics in Table 1, the correlation matrix in Table 2, and some reflections on the choice of control variables and asset pricing models. Ratios are winsorized at the 1% and 99% levels to mitigate the influence of outliers.

[INSERT TABLE 1 ABOUT HERE]

[INSERT TABLE 2 ABOUT HERE]

There are no worrisome correlations between the dependent variables. As expected, the total GHG emissions correlate with Scope 2 carbon emissions. We also observe a negative correlation at -0.39 between the dummy variable indicating stocks with missing data on GHG emissions and their corresponding environmental pillar score (ES).

The literature is inconclusive on which measure to use to proxy carbon emissions. Some employ relative measures for emission intensity, i.e., emissions scaled by total assets or revenues. Aswani et al. (2023) argue that vendor-estimated emission data is mechanically correlated with firm fundamentals such as size or revenues, and findings of a carbon risk premium may thus be interpreted as a traditional factor premium, rather than a risk premium that is solely attributable to carbon emissions. However, we follow Bolton and Kacperzyk (2021) in using an absolute measure of GHG emissions to proxy for carbon risk. Regulations limiting emissions are more likely to target activities with the highest emissions. Moreover, we are interrested in answering the question whether investors incorporate (available) emission data into their investment decision. Since our study focuses on the short-term response to a significant GPA, we assume that the short-term responses, if any, are driven by emissions rather than firm fundamentals, which alleviates endogeneity concerns. The leaked document specifically states that the European Commission aims to eliminate all sources of pollution, adopting concrete measures to tackle air pollution (euractiv, 2019), thus we include data on total greenhouse gas emissions as our main variable of interest. In later models, we control for environmental commitment proxied via Environmental Pillar Scores following Borghesi et al. (2022) and Birindelli & Chiappini (2021) and include Scope 2 carbon emissions and emissions scaled by total assets.

Ackkowledging the ongoing dicussion in current literature, we illustrate the anticipated differences in results when using different asset pricing models to estimate abnormal returns. The FF3 model extends the traditional CAPM model by the SMB and HML factors to control for the difference between small and large caps and between high and low-valued companies, respectively. We assume that a large fraction of companies with high levels of GHG emissions, hereafter brown stocks, show, on average, an increased need for investment capital, e.g., a large stock of production facilities and machinery in place. We may expect that brown companies carry, on average, higher loadings on the HML risk factor, as the larger asset stock inflates book-to-market ratios. Griffin and Lemmon (2002) suggest that asset-intensive firms' higher leverage may drive the value premium, which may increase the likelihood of financial distress. Zhang (2006) argues that assets in place are more costly and harder to reduce. Considering the European Commission's decarbonization strategy, we suspect that a large stock of often highly specialized production facilities limits the adaptability of companies. The lower level of flexibility and the resulting inertia possibly constitute a significant risk factor concerning enhanced environmental stringency. Employing the FF3 model accounts partially for differences between green and brown stocks. We expect the effect of GHG emissions on (abnormal) returns, if any, to decrease with the employment of CAPM and FF3 adjusted returns.

To verify our assumptions, we run daily cross-sectional regressions of observed stock returns over the estimation period on the natural logarithm of corporate GHG emissions and return on assets, leverage, and book-to-market ratio as controls.The extracted coefficients (an estimated carbon risk premium) are at 0.268 moderately yet highly significantly correlated (p=0.000015) with the value premium, and at -0,232 moderately and negatively, yet equally significantly correlated (p=0.000197) with the size premium. Furthermore, we also find that the extracted coefficients are significantly correlated with the market premium (0.294, p=0.000001). That is, brown stocks have a higher exposure to systematic and value-based risk, but a lower exposure to size risk. In other words, our findings confirm a correlation between (partially estimated) emission data and firm fundamentals, and, consequently, the exposure towards incumbent risk factors, as stated in Aswani et al. (2023).

As a result, any differences in abnormal returns remaining after controlling for size and value premia may provide evidence that GHG emissions pose a significant determinant of abnormal returns following the leak and the announcement of the European Green Deal, thereby rejecting the hypothesis that carbon risk is (adequately) priced by the market.

After the initial univariate analysis, we provide finer-grained insights in multivariate regressions. We use return on assets to account for firm profitability, as we assume that more profitable firms are more likely to be capable of adapting to more stringent environmental regulations and stem necessary investments. We further control for financial leverage for identical reasons. In line with Wagner et al. (2018), we also control for stock market capitalization, despite using FF3 adjusted returns. As stated, we assume that an EU-wide event does not drive developed market factor premia. Accordingly, employing these factors does not account for the event-induced effect. For example, if small companies are more affected by the event, the asset pricing model (based on global factors) will not, or inadequately, account for this. Accordingly, controlling for size in multivariate regressions is still appropriate. Similar reasoning applies to the use of book-to-market ratio as a control.

4. Results and discussion

4.1. Univariate analysis

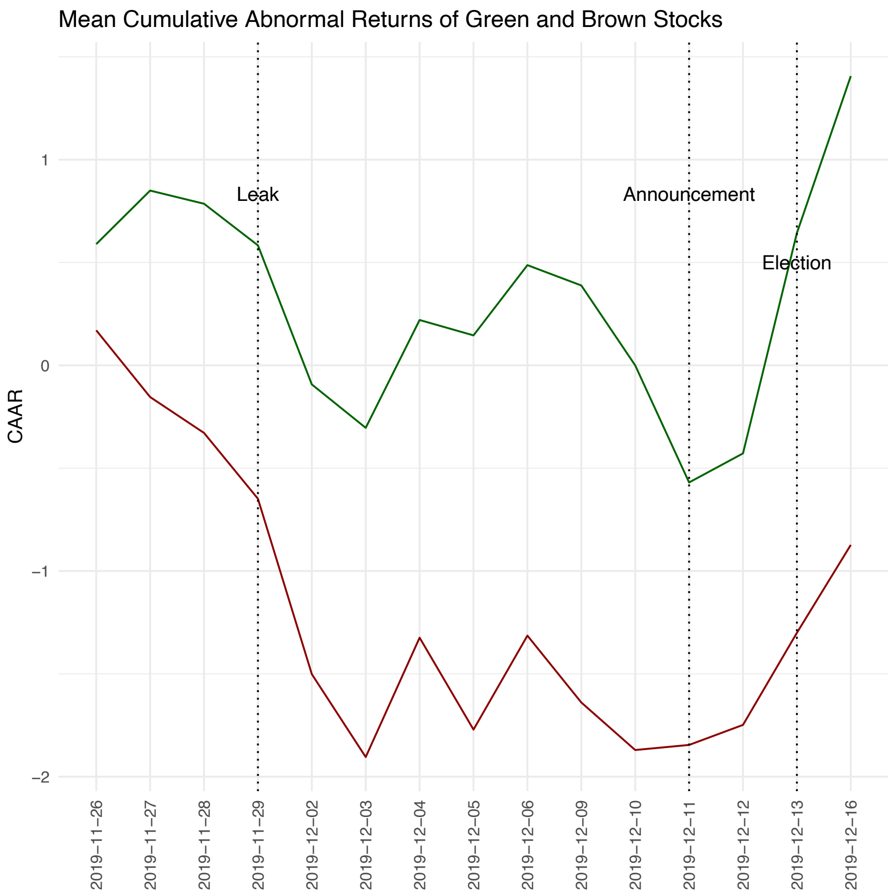

Figure 1 This figure plots the average cumulated abnornal returns obtained via the CAPM model for brown and green stocks in our sample. We beginn at November 26, 2019 which marks the first day of the applied [-3, 3] window around the leakage date ("Leak") and end on December 16, 2019 which marks the last day of the [-3,3] window around the official announement.("Annoucement"). We also plot the date where the result of the U.K. election became known ("Election"). Sorting scheme is similar to the results shown in Table 3.

We begin the empirical analysis with a graphical illustration. Figure 1 shows the performance of green and brown stocks during the sample period. Green stocks outperformed brown stocks, and the results are largely due to performance in the first half of the sample. Thus, the information leak appears to have had a more negative impact on stocks with high GHG emissions than on stocks with low or medium emissions. Table 3 presents the obtained CARs, with Panel A showing the results around the leakage date and Panel B showing the results around the announcement date. We report CAPM- and FF3-adjusted CARs obtained over seven- and three-day event windows to assess robustness. In addition, we report mean and median CARs to evaluate whether the results may be driven by outliers. Stocks are sorted in terciles according to their level of GHG emissions (hereafter: low GHG = green, medium GHG = medium-emission, high GHG = brown).

Remarkably, Panel A shows a gradual decrease in CARs when GHG emissions increase. Over the short window, brown stocks yield average CAPM-adjusted CARs of -1.347 compared to -1.228 and -0.943 for medium-emission and green stocks, respectively. All CARs over the short window are significant at the 1% level.

[TABLE 3 ABOUT HERE]

The findings are robust to the FF3 model, although the differences are, as expected, less pronounced. Extending the event window amplifies the differences. The mean and median CARs of green stocks and stocks with missing emission data are rendered insignificant. The CARs of brown and medium-emission stocks remain significantly depressed.

Around the day of the official announcement, however, the picture is reversed. While CAPM-adjusted CARs of brown stocks appear close to zero, they turn negative and statistically significant in the FF3 model. Yet green or medium-emission stocks reveal considerably more negative CARs in both models around the announcement. However, we find large differences between mean and median CARs, suggesting that factors other than emissions influence these results.[2]

As such a systematic pattern, especially around the leak, appears interesting, we also performed two-tailed paired t-tests and Wilcoxon tests to determine whether there were statistically significant differences between the mean and median of the three groups. For brevity, the results are reported in Table A1 in the Appendix. We find a statistically significant difference in mean and median of between green and brown stocks for the leakage over the short window. Over the long time window, we find statistically significant differences for all possible sorting schemes and asset pricing models, except high minus medium in the three-factor model. Differences in mean and median around the official announcement, however, are statistically largely insignificant. The results, therefore, support hypotheses H1 and H2.

[2] We address the U.K. election as a potentially confounding event in a seperate chapter.

To verify the robustness of our results, we also applied a seemingly unrelated regression model as in, e.g, Doidge & Dyck (2015). The results are shown in Table A2 in the appendix. Although the magnitude of the coefficients varies, the gradual decrease in CARs with increasing GHG emissions around the leakage date remains evident.

4.2 Cross-Sectional Multivariate Regressions

We conduct multivariate regressions to assess the determinants of abnormal returns. Table 4 reports the results for the leakage date. Panel A reports raw returns, Panel B and C CPAM- and FF3-adjusted returns, respectively. The coefficients of GHG emissions are largely insignificant. However, we find at -0.209 a statistically and economically significant influence of GHG emissions on cumulative raw returns (CRR) denoted in the third column. Economically, the coefficient can be interpreted as follows. A 1% increase in GHG emissions is associated with a decrease in CRR by 0.209 bps.

[TABLE 4 ABOUT HERE]

The control variables are largely insignificant. Size, in terms of market capitalization, had a positive effect on the day of the leakage date. For CRR over the long window, the book-to-market ratio had a negative impact, which aligns with the finding that loadings on GHG emissions correlate with the value premium. Over the extended period applied by Borghesi et al. (2022), we find no significant impact of carbon emissions, although the coefficient remains negative and economically substantial. Comparing the results to models employing CAPM and FF3 adjusted returns confirms our findings. The effect of GHG emissions on CARs weakens when employing CAPM returns and is rendered insignificant when employing FF3-adjusted returns. Remarkably, control variables are largely insignificant in Panel C. However, we find that the influence of size remains statistically significant. That is, employing FF3-adjusted returns does not control for event-induced overreactions of small-cap stocks.

Around the official announcement, reported in Table 5, GHG emissions have a statistically significant positive impact on stock returns over the large window. The magnitude is similar to the results obtained around the leakage date, and, as expected, the coefficient diminishes gradually with employing CAPM and FF3-adjusted returns.

[TABLE 5 ABOUT HERE]

4.3 The Role of Environmental Commitment

Thus far, our results concentrate on firms' total level of GHG emissions to proxy carbon risk. We provide robustness to our findings by incorporating a firm's Environmental Pillar Score to proxy environmental commitment, as used in Bhorgesi et al. (2022) and Birindelli & Chiappini (2021). We also employ alternative measures to proxy carbon risk, i.e., Scope 2 Carbon and GHG emissions scaled by total assets. We focus on the results obtained with CAPM-adjusted CARs and the leakage date for brevity. The results are reported in Table 6. Panel A reports the results for total GHG emissions while controlling for ES.

[TABLE 6 ABOUT HERE]

The coefficient of GHG is of similar magnitude compared to previous findings but is no longer statistically significant. The coefficient of ES is negative and statistically significant over the extended period applied by Borghesi et al. (2022). That is, companies with better environmental performance performed worse than companies with lower environmental performance. Similar results are obtained when using Scope 2 carbon emissions, although the coefficient remains statistically significant over the long window, reported in Panel B. Eventually, employing GHG emission intensity in Panel C renders the coefficient of ES significant in both the long and the extended window, as projected by Aswani et al. (2023).

5. Robustness: U.K. Elections

On December 13, 2019, two days after the official announcement, Boris Johnson was elected as Prime Minister of the U.K. There is extant literature on how stock markets react to election outcomes ex post and ex ante. (e.g., Wagner et al., 2018, Hanke et al., 2020, Mueller et al., 2023). Ramelli et al. (2019) studied stock-price reactions and institutional investors' portfolio adjustments after the election of Donald Trump as President of the United States. They find that carbon-intensive companies benefited from the election outcome anticipating more lax environmental regulation, especially as Scott Pruitt, a climate skeptic, was announced to lead the Environmental Protection Agency, indicating shifted expectations about prospective stringency of environmental regulation, the achievement of emission targets and therefore potentially reduced carbon risk.

The election of Boris Johnson is a confounding event for our analysis in several ways: The U.K. accounts for the largest share of market capitalization in both the EU and the Euro STOXX 600 index. Following Wagner et al. (2018) and Hanke et al. (2020), we may expect stock prices to reflect election outcome probabilities ex ante and adjust accordingly. Given that the U.K. was the second largest emitter of GHG emissions in 2019 and the party's election platform expressed significant support for fossil fuels from Scottish industry and increased efforts to accelerate Brexit (CarbonBrief, 2019), it is questionable whether these conflicting expectations affect our results. The timely proximity of the election of Boris Johnson and the European Commission's announcement of the EU Green Deal allows for a direct comparison of both, the election of a populistic regime potentially relaxing environmental regulation in one of the largest economies in the EU at that time, and the effect of the (leakage of) the announcement of an ambitious, EU-wide emission reduction target. Following the work of Ramelli et al. (2019), we assume that if the market already prices a carbon risk premium, the election of a populistic regime results in significant positive stock price reactions, especially in British stock markets.

Although a full-fledged analysis of market reactions in response to the British election is outside the scope of this analysis, we acknowledge the possibly confounding influence of this event. However, we leave a detailed analysis of stock price reactions in response to the vote for future research. Considering that British stocks account for the lion's share of the European STOXX 600 index and that the election of Prime Minister Boris Johnson closely coincided with the announcement of the European Green Deal, we replicate the univariate sorts and multivariate regressions for the subsample excluding all British stocks.

The results are appear overall robust. For the sake of brevity, we provide the tabulated results in the appendix and limit ourselves to verbatim elaborations. The univariate results for the leakage date, provided in Panel A of Table A3, are of similar sign and magnitude compared to the results obtained from the full sample. The gradual decline in CARs remains evident and statistical significante is similar to the results obtained from the full sample (see Table A4). However, regarding the results around the announcement date, reported in Panel B, substantial differences emerge. The majority of results obtained over the long window, which overlaps with the election in the U.K., are statistically indistinguishable from zero after excluding British stocks. That is, accounting for the potentially confounding event, investors were largely undeterred by the official announcement of the European Green Deal.

The multivariate analysis of returns around the time of exit, reported in Table A5, also appears to be robust, albeit less significant. The negative coefficient of GHG emissions is only significant for the long window employing CRR and is rendered insignificant when analyzing CAPM- and FF3-adjusted CARs. Interestingly, the coefficient remains significant for the extended period of Borghesi et al. (2022) in Panel A and B, emphasizing again the stark effect of the election outcome on British stocks. Conversely, the results around the announcement date, reported in Table A6, are rendered statistically insignificant. The coefficient of GHG emissions is at 0.107, moderate and statistically significant at the 10% level when analyzing CRR. We thus conclude that the announcement had no economically significant impact on the European market, once accounting for the effect of the British election outcome. Investors seem largely unconvinced by the announced financial support. In contrast, GHG emissions seem a stark driver of returns of British stocks in response to Boris Johnson becoming Prime Minister of the U.K., further supporting the hypothesis that the stock market investors indeed price carbon risk.

6. Discussion and Conclusion

Stock market reactions to the initial information leak were moderately negative despite the novelty and importance of the European Green Deal and it's exogenous character. Conversely, we find no evidence of a significant market reaction in response to the official announcement, which does not appear to be attributable to the British election outcome. Around the leakage date, CARs decrease gradually with increasing GHG emissions. Such a distinct and statistically significant pattern supports the differentiating findings of Bolton and Kacperczyk (2021) and implies that investors account for GHG emissions at the firm level rather than the industry level. The findings are most pronounced when considering extended event-windows of seven trading days. The results remain somewhat robust in OLS regressions controlling for firm-level characteristics and industry-fixed effects. However, the coefficient of GHG emissions in OLS regressions decreases gradually with employing CAPM- and FF3-adjusted CARs and eventually looses significance. This is somewhat expected, especially in view of the findings provided in Aswani et al. (2023). If vendor-estimated emission data is mechanically correlated with firm fundamentals such as size, then accounting for these effects in the respective asset pricing model mitigates the observed effect. However, while this problem may significantly bias the results of long-term studies such as Bolton and Kacperczyk (2021), it is less of an issue for the implications of our (short-term) results, as there is no apparent reason why larger firms or firms with higher revenues should perform better in response to the (presumably exogenous) leakage of information about increased emissions targets and stricter environmental regulations.

In further regression models, we also account for a firm's environmental performance or commitment by including a firm's Environmental Pillar Score (ES), following Borghesi et al. (2022) and Birindelli & Chiappini (2021). Environmental Pillar Scores are negatively related to CARs derived over an intermediate horizon. We interpret this result as follows. The absolute level of GHG or carbon emissions primarily drove immediate market reactions following the leak. Investors assumed that the higher the emissions, the greater the economic impact of enhanced environmental regulation, consistent with Bolton and Kacperczyk (2021). After the official announcement of the Green Deal and the supportive measures, investors revise their assessments. Companies with poor environmental performance and commitment outperformed. At first, this may be interpreted as investors' conviction that the financial subsidies are considered supportive. However, the ES and not the total level of GHG emissions determine these returns. ES comprises information on risk exposure at the company level, i.e., a company's exposure to environment-related risks and its ability to manage them. The market seems to assume that the regulatory risk previously priced in is actually lower after the official announcement. However, the risk is assumed to be lower for those companies that are worse at managing these risks rather than those that were deemed to have been most affected based on their absolute level of GHG emissions. Arguably, the observation window is rather long, so confounding information may influence the results and the findings must therefore be interpreted with caution.

Substantial differences between the results obtained from the full sample and a subsample excluding British stocks induce that the election of Prime Minister Johnson has had a tremendous effect on the valuation of British stocks and that GHG emissions seem to constitute a significant determinant of these effects. The positive impact of GHG emissions on returns around the announcement loses statistical significance when British equities are excluded. These results further support the carbon risk hypothesis and imply that the market has already priced carbon risk to some extent. The election of populistic governments and prospectively more lax environmental regulation reduces regulatory carbon risk and thus results in positive stock price reactions, in line with prior findings of Ramelli et al. (2019) and Mueller et al. (2023).

Our results open avenues for further research. While we empirically confirm that investors incorporate available emission data, despite well-known drawbacks of vendor-estimated data, into their investment decisions, we also confirm the correlation of these data with firm fundamentals and thus existing risk factors. It remains an open task for scholars to assess the degree of which traditional risk factors, i.e., size and value factors are themselves driven by the emergence of a carbon risk premium. Eventually, stock returns reflect the aggregated results of buy and sell decisions made by market participants. Hence, information on the pricing of carbon risk may be derived ex post from the historical performance of factor premiums and significant deviation from the underlying fundamentals of the companies. We leave this question to further research.

List of Tables

Table 1: Descriptive statistics.

Panel A: Firm characteristics		N Obs.	Q0.25	Mean	Median	Q0.75	SD
	Size	599	4605	39216	10616	31646	108647
	ROA (in %)	547	1,69	5,94	4,92	8,53	9,26
	Leverage	582	0,14	0,26	0,24	0,36	0,16
	B2M	586	0,48	4,53	1,08	2,59	10,04
	CO2_T (Mt)	569	0,02	2,98	0,11	0,58	11,99
	CO2_S2 (Mt)	544	0,01	0,45	0,04	0,21	1,65
	ES	599	56,00	68,64	74,00	84,00	21,21
Panel B: Factor loadings		N Obs.	Q0.25	Mean	Median	Q0.75	SD
CAPM	Loading on market factor	600	-0,13	0,90	0,88	2,95	0,46
FF3	Loading on market factor	600	-0,21	0,93	0,91	3,22	0,54
	Loading on size factor	600	-5,05	-0,07	-0,08	1,42	0,43
	Loading on value factor	600	-1,44	0,30	0,23	2,80	0,78

Table 2: Correlation matrix.

	Size	ROA	Lev	B2M	CO2_T	CO2_S2	ES	CO2_NA
Size	1							
ROA	0,13	1						
Lev	-0,13	-0,13	1					
B2M	-0,25	-0,04	-0,16	1				
CO2_T	0,19	-0,12	0,19	-0,06	1			
CO2_S2	0,21	-0,08	0,20	-0,04	0,87	1		
ES	0,30	-0,04	0,03	-0,05	0,30	0,29	1	
CO2_NA	-0,14	-0,02	-0,04	0,16		0,06	-0,39	1

Table 3: Univariate results.

The table shows mean and median cumulative abnormal returns of stocks, sorted in terciles according to total GHG emissions. P-values are given in parentheses. Panel A shows the results for the leakage date (29.11.2019), Panel B for the announcement (11.12.2019). *, **, *** denotes statistical significance at the 10%, 5%, and 1% level, respectively.

		Low Emissions			Medium Emissions			High Emissions			Emissions NA		
		Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
Panel A: Leak													
[-1,1]	CAPM	-0.942 ***	-0.938 ***	188	-1.228 ***	-1.188 ***	187	-1.347 ***	-1.350 ***	194	-1.070 ***	-1.058 ***	31
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)	
	FF3	-0.961 ***	-0.984 ***	188	-1.208 ***	-1.201 ***	187	-1.292 ***	-1.277 ***	194	-1.158 ***	-1.152 ***	31
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)	
[-3,3]	CAPM	0.220	-0.272	188	-0.978 ***	-1.111 ***	187	-1.324 ***	-1.395 ***	194	-0.450	-0.577	31
		(0.356)	(0.954)		(0.000)	(0.000)		(0.000)	(0.000)		(0.451)	(0.399)	
	FF3	0.364	-0.106	188	-0.682 ***	-0.609 ***	187	-0.754 ***	-0.811 ***	194	-0.576	-0.089	31
		(0.145)	(0.500)		(0.001)	(0.000)		(0.000)	(0.000)		(0.292)	(0.29)	
Panel B: Announcement													
[-1,1]	CAPM	-0.805 ***	-0.743 ***	187	-0.586 ***	-0.679 ***	187	-0.116	-0.075 *	194	-0.690	-0.548	31
		(0.000)	(0.000)		(0.000)	(0.000)		(0.672)	(0.057)		(0.169)	(0.130)	
	FF3	-0.985 ***	-1.015 ***	187	-0.844 ***	-0.867 ***	187	-0.587 **	-0.664 ***	194	-0.712	-0.623 *	31
		(0.000)	(0.000)		(0.000)	(0.000)		(0.030)	(0.000)		(0.129)	(0.098)	
[-3,3]	CAPM	1.242 ***	0.579 ***	184	1.061 ***	0.303 **	179	0.919 ***	0.580 ***	188	-0.145	-0.368	31
		(0.000)	(0.001)		(0.002)	(0.023)		(0.006)	(0.001)		(0.841)	(0.900)	
	FF3	0.961 ***	0.568 ***	184	0.714 **	0.186	179	0.307	-0.101	188	-0.275	-0.343	31
		(0.002)	(0.004)		(0.030)	(0.239)		(0.367)	(0.330)		(0.703)	(0.529)	

Table 4: OLS regression results, leakage date.
This table presents OLS regressions of stocks' (cumulative) raw returns (CRR) in Panel A and (cumulative) abnormal returns (CAR) in Panel B and C on GHG emissions and standard control variables. Standard errors are clustered at industry level and denoted in parentheses. *, **. and *** denotes statistical significance at the 10, 5, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	[0,0]	[-1,1]	[-3,3]	[-5,28]
Panel A: Raw returns				
CO2_T	-0.021	-0.034	-0.209 **	-0.312
	(0.044)	(0.064)	(0.083)	(0.198)
Lev	0.404	0.070	-1.217	-2.666
	(0.497)	(0.734)	(1.043)	(3.388)
ROA	-0.007	-0.003	-0.010	0.049
	(0.010)	(0.010)	(0.018)	(0.042)
B2M	0.004	0.002	-0.006 *	0.002
	(0.003)	(0.003)	(0.003)	(0.009)
Size	0.172 **	-0.035	-0.056	0.644 **
	(0.074)	(0.136)	(0.188)	(0.293)
Intercept	-4.354 ***	-1.754	0.932	-9.007
	(1.572)	(3.044)	(4.266)	(6.578)
Industry FE	Yes	Yes	Yes	Yes
Adj. R^2	0.083	-0.001	0.120	0.249
N Obs.	513	513	513	496
Panel B: CAPM-adj. returns				
CO2_T	-0.002	0.013	-0.155 *	-0.289
	(0.044)	(0.067)	(0.088)	(0.267)
Lev	0.349	-0.072	-1.362	-2.470
	(0.463)	(0.719)	(1.071)	(3.8)
ROA	-0.008	-0.006	-0.012	0.059
	(0.010)	(0.010)	(0.017)	(0.047)
B2M	0.005	0.004	-0.003	0.007
	(0.003)	(0.004)	(0.004)	(0.008)
Size	0.137 *	-0.127	-0.176	0.461
	(0.071)	(0.136)	(0.176)	(0.321)
Intercept	-3.343 **	0.844	3.515	-10.562
	(1.514)	(3.069)	(4.142)	(7.662)
Industry FE	Yes	Yes	Yes	Yes
Adj. R^2	0.041	0.032	0.097	0.229
N Obs.	513	513	513	496
Panel C: FF-adj. returns				
CO2_T	0.027	0.031	-0.042	-0.050
	(0.044)	(0.068)	(0.091)	(0.268)
Lev	0.223	-0.146	-1.844	-3.442
	(0.447)	(0.713)	(1.143)	(3.715)
ROA	-0.009	-0.003	-0.014	0.059
	(0.010)	(0.010)	(0.017)	(0.047)
B2M	0.005	0.004	-0.001	0.010
	(0.004)	(0.003)	(0.004)	(0.007)
Size	0.118 *	-0.092	-0.208	0.453
	(0.070)	(0.139)	(0.180)	(0.326)
Intercept	-3.123 **	-0.034	3.401	-12.105
	(1.486)	(3.130)	(4.283)	(7.914)
Industry FE	Yes	Yes	Yes	Yes
Adj. R^2	0.012	0.022	0.093	0.219
N Obs.	513	513	513	496

Table 5: OLS regression results, announcement date.

This table presents OLS regressions of stocks' (cumulative) raw returns (CRR) in Panel A and (cumulative) abnormal returns (CAR) in Panel B and C on GHG emissions and standard control variables. Standard errors are clustered at industry level and denoted in parentheses. *, **. and *** denotes statistical significance at the 10, 5, and 1% level, respectively.

	(1)	(2)	(3)
	[0,0]	[-1,1]	[-3,3]
Panel A: Raw returns			
CO2_T	-0.001	0.064	0.249 ***
	(0.039)	(0.079)	(0.079)
Lev	1.502	1.322	2.566
	(1.212)	(3.512)	(2.203)
ROA	-0.008	0.015	0.006
	(0.010)	(0.014)	(0.031)
B2M	0.001	0.008 **	0.004
	(0.002)	(0.004)	(0.003)
Size	0.025	-0.153	-0.101
	(0.096)	(0.243)	(0.241)
Intercept	-0.863	1.523	0.698
	(2.308)	(5.847)	(5.908)
Industry FE	Yes	Yes	Yes
Adj. R^2	0.081	0.161	0.240
N Obs.	513	513	496
Panel B: CAPM-adj. returns			
CO2_T	-0.007	0.053	0.200 **
	(0.038)	(0.077)	(0.095)
Lev	1.525	-1.327	-2.271
	(1.206)	(3.129)	(2.327)
ROA	-0.007	0.017	0.012
	(0.010)	(0.014)	(0.035)
B2M	0.001	0.008 **	0.003
	(0.002)	(0.004)	(0.003)
Size	0.030	-0.148	-0.048
	(0.095)	(0.241)	(0.246)
Intercept	-1.317	0.537	3.046
	(2.286)	(5.787)	(6.053)
Industry FE	Yes	Yes	Yes
Adj. R^2	0.075	0.142	0.201
N Obs.	513	513	496
Panel C: FF-adj. returns			
CO2_T	-0.021	-0.030	0.104
	(0.038)	(0.072)	(0.096)
Lev	1.589	3.629	-1.770
	(1.199)	(3.071)	(2.431)
ROA	-0.006	0.022 *	0.020
	(0.010)	(0.012)	(0.035)
B2M	0.000	0.006 **	-0.002
	(0.002)	(0.002)	(0.003)
Size	0.042	-0.059	0.120
	(0.095)	(0.239)	(0.239)
Intercept	-1.464	-0.795	-6.017
	(2.280)	(5.728)	(5.922)
Industry FE	Yes	Yes	Yes
Adj. R^2	0.070	0.076	0.156
N Obs.	513	513	496

Table 6: Extension: OLS regression results, leakage date.
This table presents OLS regressions of CAPM-adjusted CARs on alternative environmental-related variables and standard control variables. All models include industry-fixed effects. Standard errors are clustered at industry level and denoted in parentheses. *, **. and *** denotes statistical significance at the 10, 5, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	[0,0]	[-1,1]	[-3,3]	[-5,28]
Panel A: Total GHG Emissions				
CO2_T	-0.003	0.061	-0.121	0.029
	(0.055)	(0.102)	(0.102)	(0.278)
ES	-0.003	-0.017	-0.020	-0.060 ***
	(0.006)	(0.016)	(0.014)	(0.022)
Intercept	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Adj. R^2	0.041	0.046	0.101	0.253
N Obs.	491	491	491	474
Panel B: Scope 2 Emissions				
CO2_S2	0.003	-0.01	-0.157 **	-0.051
	(0.043)	(0.079)	(0.072)	(0.228)
ES	-0.003	-0.015	-0.02	-0.058 ***
	(0.006)	(0.016)	(0.013)	(0.022)
Intercept	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Adj. R^2	0.041	0.045	0.108	0.253
N Obs.	491	491	491	474
Panel C: Total GHG Emissions scaled by Total Assets				
CO2_T_A	0.027	0.041	-0.017	0.437
	(0.050)	(0.101)	(0.103)	(0.334)
ES	-0.003	-0.015	-0.023 *	-0.065 ***
	(0.006)	(0.015)	(0.013)	(0.021)
Intercept	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Adj. R^2	0.042	0.045	0.097	0.258
N Obs.	491	491	491	474

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Table A1: Difference in Mean and Median Tests
This Table shows the results of two-sided two sample tests between each subsample and the difference in mean and median. The subsamples are similar to the univariate sorts presented in Table 3. We also plot the results for cumulated raw returns (CRR). We report P-values in brackets below the difference in mean and median.

	Medium minus Low		High minus Low		High minus Medium	
	T-Test	Wilcoxon	T-Test	Wilcoxon	T-Test	Wilcoxon
Panel A: Leak [-1,1]						
CRR	-0.3158	-0.4436	-0.5274	-0.5063	-0.2116	-0.0627
	(0.1579)	(0.1052)	(0.0117)	(0.0035)	(0.2135)	(0.2604)
CAPM	-0.2851	-0.2508	-0.4047	-0.4121	-0.1196	-0.1614
	(0.2130)	(0.2275)	(0.0655)	(0.0674)	(0.4931)	(0.5103)
FF	-0.2469	-0.2174	-0.3311	-0.2931	-0.0842	-0.0757
	(0.2794)	(0.3366)	(0.1297)	(0.1785)	(0.6229)	(0.6853)
Panel B: Leak [-3,3]						
CRR	-1.2198	-0.8692	-1.6830	-1.4140	-0.4632	-0.5449
	(0.0032)	(0.0043)	(0.0000)	(0.0000)	(0.0266)	(0.0158)
CAPM	-1.1983	-0.8388	-1.5444	-1.1225	-0.3461	-0.2837
	(0.0030)	(0.0068)	(0.0000)	(0.0000)	(0.0572)	(0.0555)
FF	-1.0461	-0.5029	-1.1181	-0.7049	-0.0720	-0.2020
	(0.0213)	(0.0717)	(0.0009)	(0.0073)	(0.2726)	(0.3518)
Panel C: Announcement [-1,1]						
CRR	0.2385	0.0553	0.7167	0.4571	0.4782	0.4017
	(0.5391)	(0.8601)	(0.2302)	(0.1165)	(0.6155)	(0.1382)
CAPM	0.2189	0.0640	0.6885	0.6679	0.4696	0.6038
	(0.3369)	(0.3364)	(0.0304)	(0.0034)	(0.1413)	(0.0592)
FF	0.1411	0.1485	0.3982	0.3510	0.2571	0.2025
	(0.4996	(0.5166)	(0.1922)	(0.1703)	(0.4030)	(0.4671)
Panel D: Announcement [-3,3]						
CRR	-0.1054	-0.2893	-0.2138	0.1804	-0.1084	0.4697
	(0.5391)	(0.8601)	(0.2302)	(0.1165)	(0.6155)	(0.1382)
CAPM	-0.1811	-0.2753	-0.3229	0.0010	-0.1418	0.2763
	(0.8137)	(0.8101)	(0.5448)	(0.3945)	(0.7245)	(0.2773)
FF	-0.2463	-0.3825	-0.6532	-0.6692	-0.4069	-0.2867
	(0.9981)	(0.5337)	(0.7464)	(0.7723)	(0.7515)	(0.7719)

Table A2: Univariate results, SUR-Model

The table shows mean and median cumulative abnormal returns (CARs) of stocks, grouped according to terciles of the companies total GHG emissions. P-values are given in parentheses. Panel A shows the results for the leakage date (29.11.2019), Panel B for the announcement (11.12.2019). *, **, *** denotes statistical significance at the 10%, 5%, and 1% level, respectively. CARs are calculate using a seemingly unrelated regression model as in, e.g., Doidge & Dyck (2015)

		Low Emissions			Mid Emissions			High Emissions			Emissions NA		
		Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
Panel A: Leak													
[-1,1]	SUR	0.294 ***	0.108 **	188	-0.306 ***	-0.245 ***	187	-0.482 ***	-0.496 ***	194	-0.724 ***	-0.736 ***	31
		(0.009)	(0.039)		(0.001)	(0.001)		(0.001)	(0.001)		(0.001)	(0.002)	
[-3,3]	SUR	0.187	-0.257	188	-0.976 ***	-1.086 ***	187	-1.292 ***	-1.347 ***	194	-0.431	-0.519	31
		(0.436)	(0.971)		(0.000)	(0.000)		(0.000)	(0.000)		(0.464)	(0.399)	
Panel B: Announcement													
[-1,1]	SUR	-0.830 ***	-0.787 ***	187	-0.588 ***	-0.692 ***	187	-0.097	-0.128 *	194	-0.677	-0.566	31
		(0.000)	(0.000)		(0.000)	(0.000)		(0.725)	(0.070)		(0.179)	(0.141)	
[-3,3]	SUR	1.178 ***	0.558 ***	187	1.141 ***	0.286 **	187	0.873 ***	0.498 ***	194	-0.122	-0.349	31
		(0.000)	(0.001)		(0.001)	(0.011)		(0.007)	(0.001)		(0.864)	(0.946)	

Table A3: Univariate results, ex-U.K.

The table shows mean and median cumulative abnormal returns of stocks, grouped according to terciles of the companies total GHG emissions. P-values are given in parentheses. Panel A shows the results for the leakage date (29.11.2019), Panel B for the announcement (11.12.2019). *, **, *** denotes statistical significance at the 10%, 5%, and 1% level, respectively.

		Low Emissions			Mid Emissions			High Emissions			Emissions NA		
		Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N
Panel A: Leak													
[-1,1]	CAPM	-1.029 ***	-0.882 ***	140	-1.248 ***	-1.164 ***	140	-1.359 ***	-1.317 ***	145	-0.982 ***	-1.003 ***	30
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)	
	FF3	-1.046 ***	-0.833 ***	140	-1.203 ***	-1.171 ***	140	-1.312 ***	-1.33 ***	145	-1.071 ***	-1.132 ***	30
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)	
[-3,3]	CAPM	0.197	-0.272	140	-0.801 ***	-0.977 ***	140	-1.28 ***	-1.152 ***	145	-0.249	-0.569	30
		(0.428)	(0.969)		(0.000)	(0.000)		(0.000)	(0.000)		(0.666)	(0.556)	
	FF3	0.303	-0.043	140	-0.448 **	-0.406 **	140	-0.736 ***	-0.333 ***	145	-0.358	-0.013	30
		(0.234)	(0.597)		(0.033)	(0.033)		(0.000)	(0.001)		(0.486)	(0.428)	
Panel B: Announcement													
[-1,1]	CAPM	-0.512 ***	-0.625 ***	140	-0.553 ***	-0.695 ***	140	-0.311 *	-0.020	145	-0.672	-0.472	30
		(0.005)	(0.001)		(0.001)	(0.001)		(0.090)	(0.126)		(0.195)	(0.164)	
	FF3	-0.645 ***	-0.670 ***	140	-0.827 ***	-0.849 ***	140	-0.769 ***	-0.636 ***	145	-0.711	-0.460	30
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)		(0.142)	(0.119)	
[-3,3]	CAPM	-0.143	-0.125	137	0.060	-0.324	132	0.039	0.055	139	-0.057	-0.320	30
		(0.650)	(0.702)		(0.860)	(0.520)		(0.889)	(0.507)		(0.938)	(0.968)	
	FF3	-0.350	-0.261	137	-0.278	-0.337 **	132	-0.563 *	-0.560 *	139	-0.213	-0.338	30
		(0.240)	(0.206)		(0.410)	(0.038)		(0.051)	(0.066)		(0.774)	(0.626)	

Table A4: Difference in Mean and Median Tests, ex U.K.
This Table shows the results of two-sided two sample tests between each subsample and the difference in mean and median. The subsamples are similar to the univariate sorts presented in Table 3. We also plot the results for cumulated raw returns (CRR). We report P-values in brackets below the difference in mean and median.

	Medium minus Low		High minus Low		High minus Medium	
	T-Test	Wilcoxon	T-Test	Wilcoxon	T-Test	Wilcoxon
Panel A: Leak [-1,1]						
CRR	-0.2759	-0.5801	-0.4780	-0.6363	-0.2021	-0.0562
	(0.1749)	(0.0651)	(0.0118)	(0.0021)	(0.2912)	(0.2989)
CAPM	-0.2188	-0.2818	-0.3302	-0.4353	-0.1114	-0.1535
	(0.2915)	(0.1714)	(0.0964)	(0.0561)	(0.5777)	(0.5436)
FF	-0.1568	-0.3386	-0.2660	-0.4968	-0.1091	-0.1583
	(0.4383)	(0.2439)	(0.1712)	(0.1072)	(0.5745)	(0.5237)
Panel B: Leak [-3,3]						
CRR	-1.0037	-0.5889	-1.6088	-1.0651	-0.6051	-0.4763
	(0.0028)	(0.0071)	(0.0000)	(0.0000)	(0.0368)	(0.0174)
CAPM	-0.9982	-0.7046	-1.4779	-0.8792	-0.4797	-0.1746
	(0.0026)	(0.0089)	(0.0000)	(0.0000)	(0.0869)	(0.0729)
FF	-0.7504	-0.3623	-1.0390	-0.2892	-0.2886	0.0731
	(0.0227)	(0.0757)	(0.0011)	(0.0088)	(0.3026)	(0.3762)
Panel C: Announcement [-1,1]						
CRR	0.0336	-0.1129	0.2742	0.3251	0.2406	0.4380
	(0.8905)	(0.9148)	(0.2762)	(0.1047)	(0.3324)	(0.1686)
CAPM	-0.0410	-0.0708	0.2015	0.6042	0.2425	0.6750
	(0.8662)	(0.9277)	(0.4320)	(0.1173)	(0.3227)	(0.1107)
FF	-0.1815	-0.1793	-0.1240	0.0340	0.0575	0.2133
	(0.4076)	(0.4241)	(0.6102)	(0.8625)	(0.8068)	(0.5417)
Panel D: Announcement [-3,3]						
CRR	0.4495	0.2714	0.4226	0.7069	-0.0268	0.4355
	(0.3483)	(0.6176)	(0.3152)	(0.1889)	(0.9533)	(0.3985)
CAPM	0.2031	-0.1995	0.1819	0.1798	-0.0212	0.3793
	(0.6619)	(0.8773)	(0.6655)	(0.4635)	(0.9616)	(0.4187)
FF	0.0717	-0.0762	-0.2130	-0.2985	-0.2847	-0.2223
	(0.8733)	(0.6022)	(0.6056)	(0.6972)	(0.5200)	(0.9920)

Table A5: OLS regression results, leakage date, ex-U.K.

This table presents OLS regressions of stocks' (cumulative) raw returns (CRR) in Panel A and (cumulative) abnormal returns (CAR) in Panel B and C on GHG emissions and standard control variables. Standard errors are clustered at industry level and denoted in parentheses. *, **. and *** denotes statistical significance at the 10, 5, and 1% level, respectively.

	(1)	(2)	(3)	(4)
	[0,0]	[-1,1]	[-3,3]	[-5,28]
Panel A: Raw returns				
CO2_T	-0.032	-0.025	-0.209 **	-0.632 ***
	(0.051)	(0.075)	(0.104)	(0.240)
Intercept	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Adj. R^2	0.093	0.078	0.158	0.293
N Obs.	379	379	379	362
Panel B: CAPM-adj. returns				
CO2_T	-0.014	0.022	-0.155	-0.607 **
	(0.05)	(0.08)	(0.107)	(0.289)
Intercept	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Adj. R^2	0.037	0.108	0.138	0.278
N Obs.	379	379	379	362
Panel C: FF-adj. returns				
CO2_T	0.017	0.038	-0.039	-0.364
	(0.050)	(0.079)	(0.108)	(0.288)
Intercept	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Adj. R^2	-0.013	0.086	0.104	0.249
N Obs.	379	379	379	362

Table A6: OLS regressions, announcement date, ex-U.K.

This table presents OLS regressions of stocks' (cumulative) raw returns (CRR) in Panel A and (cumulative) abnormal returns (CAR) in Panel B and C on GHG emissions and standard control variables. Standard errors are clustered at industry level and denoted in parentheses. *, **. and *** denotes statistical significance at the 10, 5, and 1% level, respectively.

	(1)	(2)	(3)
	[0,0]	[-1,1]	[-3,3]
Panel A: Raw returns			
CO2_T	0.003	0.107 *	0.124
	(0.034)	(0.061)	(0.106)
Intercept	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adj. R^2	0.197	0.302	0.302
N Obs.	379	379	362
Panel B: CAPM-adj. returns			
CO2_T	-0.003	0.095	0.075
	(0.034)	(0.061)	(0.108)
Intercept	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adj. R^2	0.190	0.278	0.251
N Obs.	379	379	362
Panel C: FF-adj. returns			
CO2_T	-0.019	0.007	-0.033
	(0.033)	(0.055)	(0.101)
Intercept	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Adj. R^2	0.188	0.180	0.219
N Obs.	379	379	362