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Impact of climate change risks on the financial markets

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IMPACT OF CLIMATE CHANGE RISKS ON THE FINANCIAL MARKETS

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Finally, I am indebted to my husband, Roman, who is my source of sanity, motivation, love, and support. Without him by my side, I never would have made it.

> *The ability to perceive a change in a quantity*
> *decreases in proportion to its magnitude.*
>
> *Weber's law*

Once I learned about Weber's law, it began to appear everywhere. And for an understandable reason: this observation was confirmed to work for weight, length, reward, loudness, brightness, number (here will be no references because there will be plenty of them later—just not on this topic), and most importantly, time. Indeed, the first year of my Ph.D. candidacy lasted an eternity, the second, only half-of-eternity, and the last two resembled minutes. Four years of dissertation writing may feel like nothing compared with *years* of previous education. Weber's law at work, obviously. The same applies to progress. In the beginning, every page was a huge leap; later *pages* of writing seemed like no progress. Luckily, this is just perception.

I could not emphasize more the gratitude I have for the people who were with me during these years. They helped me see my huge and tiny achievements in the right magnitudes throughout the whole journey, which was so long and so short at the same time.

Yevheniia Antoniuk
Bodø, 2021

ABSTRACT

The financial sector that provides funding for climate change mitigation and adaptation is not protected from climate change. However, there is a lack of knowledge about financial markets' response to climate change regarding asset pricing. The main concern is effects of climate change on companies and their performance in the long term. This thesis studies how climate risks impact financial markets by analyzing assets' market performance. Interested in climate risk in general, the thesis also investigates regulatory climate risk as being the most recognized by companies.

This thesis comprises four scientific articles that present the results of quantitative empirical research conducted on secondary market data. Two of these articles apply event study methodology to assess the market reaction to events related to climate policy, linking them to the regulatory climate risk. The findings show that climate-policy-related events, such as the adoption of the Paris Agreement, significantly affect stock returns and even cause a long-term shift in price fluctuations. In the case of green bonds, such events also influence their return per unit risk and correlation with other assets. The other two articles depart from the assumptions of sustainable investments and investigate the performance of sustainable and climate-aligned investments in the Norwegian context. The results suggest a significant underperformance of high-climate-risk stocks and a neglectable return difference between low and high sustainable stocks. A long-short climate-aligned investment strategy was found to be profitable and thus preferable.

Overall, this thesis discovers a significant impact of climate risk on asset prices and argues that investors might benefit from distinguishing assets by their climate risk exposure. Recognition of climate risks becomes even more important for long-term-oriented value-driven investors.

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List of abbreviations

AMH adaptive market hypothesis.

CAPM capital asset pricing model.

CSR corporate social responsibility.

DJSND Dow Jones Sustainability Index Nordic.

EMH efficient market hypothesis.

ESG environmental, social, and governmental.

ETF exchange-traded fund.

EW equal-weigting.

FF3 Fama-French three-factor model.

GB green bond.

GHG greenhouse gas.

HML high-minus-low.

MOM momentum factor.

OSE Oslo Stock Exchange.

OSEBX Oslo Stock Exchange Benchmark Index.

SMB small-minus-big.

SRI socially-responsible investment.

VW value-weigting.

PART I

SYNOPSYS

1 INTRODUCTION

Various studies from natural sciences have shed light on drivers of climate change (Phillips et al., 2020; Andreae et al., 2005), and thus have helped to understand the scope and pace of upcoming irreversible changes that we, as a society, will face (Nordhaus, 2019; Hsiang et al., 2017; Dell et al., 2014; Miao and Popp, 2014). This climate research uses models and scenarios to describe the potential impacts of climate change on the planet and economy. They suggest that major adjustments are needed to limit the pace of global warming, mitigate its consequences, and adapt to climate change. This requires that political actions be supported by significant financing, which signifies the role of the financial sector in this process.

The relationship between the financial sector and climate change is bidirectional. *Climate finance* provides financing on different levels to facilitate the transition to a low-carbon economy (Hong et al., 2020), meaning that the financial sector provides a channel to affect climate change. Mechanisms and tools for climate finance are still in development because of some challenges they must overcome (as identified in Fankhauser et al., 2016; Buchholz and Rübbelke, 2020; Warren, 2020). However, uncertainty has stemmed from various climate change scenarios, and climate change itself is translated into the risk—*climate change risk*, which actors in the financial markets are willing to quantify, reduce, and compensate for. However, new risks for companies ae expcted to accompany the transition to a low-carbon economy. These risks originate from market and policy adjustments and changes in customer behavior. Thus, climate change affects financial markets via physical and transition risks (Giglio et al., 2021).

Leading finance research has avoided studies on *climate finance*. According to explanations proposed by Diaz-Rainey et al. (2017), research on this topic has fitted poorly with traditional finance research methods due to its novelty, scarcity of data, and strong practical rather than theoretical focus. However, since this void has been detected, climate change has steadily increased its presence in sustainable finance literature (Daugaard, 2020) and in special issues of high-ranked finance journals. Early studies looked at the definition and types of climate risk (Allen et al., 2015; Buhr, 2017) and how climate change can affect capital assets (Dietz et al., 2016). Because climate change is strongly linked with global warming, the main cause of the latter—fossil fuel burning (NASA, 2021)—has become of major interest. Thus, fossil fuel *divestment* has been suggested as a solution. This means that investors exclude companies that operate within fossil fuel extraction from their investment universe. Studies have shown that investors will not sacrifice their rewards by practicing divestment (Hunt and Weber, 2019; Plantinga and Scholtens, 2021). However, fossil fuel companies experience a stock price decline (Dordi and Weber, 2019). They also must consider which assets could become *stranded*—those that prematurely lose the ability to provide an economic return (Ritchie and Dowlatabadi, 2015).

Carbon emissions and carbon risk have also been addressed for two reasons. First, heavy air polluters contribute significantly to global warming, meaning that investors might exclude them from the portfolio due to their low sustainability. Second, during the transition to a low-carbon economy, companies with high emissions rates will be impacted by new regulations and emission quotas, meaning they have a higher *carbon risk*. Recent studies on carbon risk have found that companies with higher emissions have a higher cost of debt (Pizzutilo et al., 2020) and provide higher returns to compensate for this risk (Bolton and Kacperczyk, 2021). However, climate transition risk should not be reduced to only carbon risk, especially because historical emissions are not a forward-looking measure. As sustainable finance is interested in long-term investments, carbon exposure is not a sufficient measure for decision-making. This thesis intends to use climate-related disclosures to assess climate risk exposure for companies and use it as a criterion for portfolio formation.

Thus, the thesis aims to contribute to the growing area of research concerned with the relationship between climate change and financial markets and to be of evidential value for why climate risk must be considered. Special focus will be given to regulatory risks that “result from (potential) regulatory changes implemented in response to climate change” (Sakhel, 2017, p.103). Companies expect the effects of regulatory risk to be realized sooner than those of other climate risks (Kouloukoui et al., 2019; Stroebel and Wurgler, 2021), if not already (Krueger et al., 2020). By looking at regulatory risks, this thesis will shed light on how climate change *already* affects investments.

This thesis contributes to the literature on sustainable finance by exploring the following overarching question: *What is the impact of climate risk on asset prices?* This question is divided into three subquestions, each of which has been addressed in a designated article.

Because climate change is already considered within an environmental dimension of ESG factors, portfolios based on the ESG consideration can already capture climate risk alongside more complex issues covered by the ESG framework. This means that investors can rely on an overarching ESG-related strategy to ensure their investments’ sustainable (and climate) alignment. To investigate this through the first research sub-question is:

RQ1: *How does stocks’ sensitivity to sustainable factors affect the investments in the Norwegian stock market?*

Because previous studies have presented mixed research results on these issues in different contexts, it is hard to hypothesize what impact could be discovered. However, the impact of climate change alone should be significant enough to affect asset pricing. To discover this particular effect, I address the following research question:

RQ2: *How does stocks’ climate risk exposure affect the investments in the Norwegian stock market?*

I propose using a firm-specific climate-related disclosure as a proxy for climate risk exposure. Information presented in the disclosure covers current (historical) levels of GHG emissions *and* climate-induced challenges and opportunities, strategies, and plans for climate adaptation. Therefore, investors might distinguish companies based on climate disclosure. To study RQ2, I hypothesize the following:

H_0: *Portfolios constructed from companies with different levels of climate disclosure show differences in risk-adjusted returns.*

Because some climate risks can be realized sooner than others, it is reasonable to

Table 1.1: An overview of the scientific articles with their publication status and research question (RQ)

No	*Title*	*Author(s)*	*RQ*	*Status*
1	”Climate Change Events and Stock Market Returns”	Antoniuk, Y., Leirvik, T.	RQ3	– Published (2021) in *Journal of Sustainable Finance and Investment*; DOI: 10.1080/20430795.2021.1929804 – Presented (2019) at the *5th Symposium on Quantitative Finance and Risk Analysis*
2	”Climate Transition Risk and the Impact on Green Bonds”			– Published (2021) in *Journal of Risk and Financial Management*; DOI: 10.3390/jrfm14120597
3	”Sustainable Investments in the Norwegian Stock Market”	Fiskerstrand, S., Fjerdavli, S., Leirvik, T., Antoniuk, Y., Nenadić, O.	RQ1	– Published (2019) in *Journal of Sustainable Finance and Investment 10(3)*; DOI: 10.1080/20430795.2019.1677441
4	”The Effect of Climate Disclosure on Stock Market Performance: Evidence from Norway”	Antoniuk, Y.	RQ2	– Submitted (2021) to *Sustainable Development* – Presented (2020) at *FIBE Conference ”Making Money in a Sustainable Future”*

focus on those whose impacts can already be captured by the market. According to previous research, transition risk, especially regulatory risk, is of greater concern to investors (Krueger et al., 2020). This means that climate policies that are formulated and adopted today form the public perception of climate risk and define industry growth to some extent. Thus, the last following research sub-question is as follows:

***RQ3:** What is the impact of climate transition risk on asset pricing?*

I answer these questions from the perspective of sustainable finance and empirical asset pricing. Quantitative methods and statistical inference are used to discover suggested relationships. As *RQ1* and *RQ2* suggest, they are investigated in the context of the Norwegian stock market. *RQ3* focuses on regulatory risks proxied through events related to climate change on the global level. Therefore, I use the US and global markets to study their impact. Moreover, *RQ3* is addressed for the stock and bond markets separately to gain a nuanced understanding of climate risk’s impact.

The results of the conducted research are reported in four scientific articles. Table 1.1 briefly presents the research question and topic for each article and how research findings were disseminated via presentations at the conferences and publications in the scientific journals.

This thesis consists of a synopsis (Part 1) and scientific articles (Part 2). Part 1 starts with Chapter 1 by addressing the background and motivation along with the research question and subquestions for the dissertation. Chapter 2 describes the theoretical framework used for the research. Each section refers to specific topics within *sustainable finance* with a focus on climate change. A review of recent studies is given parallel with theory to strengthen its viewpoints and show empirical evidence. Chapter 3 presents philosophical and methodological reflections, data description, research design, and ethics. Chapter 4 summarizes the scientific articles' findings and thesis contributions and describes the studies' limitations and suggestions for further research.

Part 2 includes four chapters with scientific articles. Chapter 6 and Chapter 7 explore the last research subquestion (RQ3) and present the results for the stock and secondary bond markets, respectively. Chapter 9 focuses on the first research subquestion, and Chapter 8 answers the second one in the context of the Norwegian stock market.

2 THEORETICAL FRAMEWORK

This chapter outlines the theoretical background and assumptions used for the thesis. Each section covers a different aspect related to *sustainable finance* and introduces a relevant overview of recent scientific findings. Section 2.1 explains how sustainable finance is different from mainstream finance research from theoretical and empirical viewpoints, thus laying the groundwork for Article 3.

Sections 2.2 and 2.3 present why climate change and associated risks are an issue and must be studied from the financial market perspective. They showcase why RQ2 and RQ3 are relevant.

Theoretical assumptions about climate-aligned stock investments and their profitability are given in Section 2.4. They help to formulate a hypothesis and explain the results for Article 4. Section 2.5 overviews green investments made with fixed-income instruments that are also affected by climate risks. This section provides topical insight for Article 2.

2.1 SUSTAINABLE FINANCE

Sustainable finance, according to the European Commission's (2021) definition,

> refers to the process of taking due account of environmental, social and governance (ESG) considerations when making investment decisions in the financial sector, leading to increased longer-term investments into sustainable economic activities and projects.

Thus, sustainable finance connects with corporate social responsibility (CSR), which includes environmental, social, and governmental (ESG) considerations into strategic management, financial decision-making and investors' portfolio decisions (Liang and Renneboog, 2020).

The concept of sustainability raises intertemporal implications by considering future generations' quality of life during decision-making. For this to be realized from a financial perspective, investors are likely to sacrifice their short-term profits to ensure increased welfare in the longer term. In terms of mainstream finance, it seems impossible because sustainable practices are seen as malfunctions, which lower the rate of investment, market share, profitability, and firms' market value, and increase production costs (Friedman 1970, as mentioned in Lagoarde-Segot, 2019, p.6). As a result, a tension between money and value (Lagoarde-Segot, 2015, 2019) or shareholder (financial) value and shareholder welfare (Schoenmaker and Schramade, 2019) should be addressed.

Schoenmaker and Schramade (2019) state that a shift to sustainable finance as a new financial paradigm solves this and other inconsistencies (Figure 2.1). Thus, an investor should actively hold ESG-evaluated concentrated portfolios of stocks that provide long-term value creation.

This approach explicitly allows for incorporating climate change into the analysis, as it includes an environmental dimension and has a longer investment horizon.

In addition to accounting for ESG-related risks in portfolio formation, investors have direct and indirect contribution mechanisms for sustainability matters (Kölbel et al., 2020). Investors as shareholders have an opportunity to shape sustainable corporate performance via engagement. Their impact is also realized via selective fund allocation to assets that already support sustainable development. Investors' decisions about divestment from unsustainable companies and public promotion of sustainability indirectly impact sustainable investing.

Review of previous research

The literature on sustainable finance is extensive. It asks questions about the relationship between CSR and financial performance and looks for investors' rewards from socially responsible investment.

Findings from studies on CSR and financial performance deliver mixed conclu-

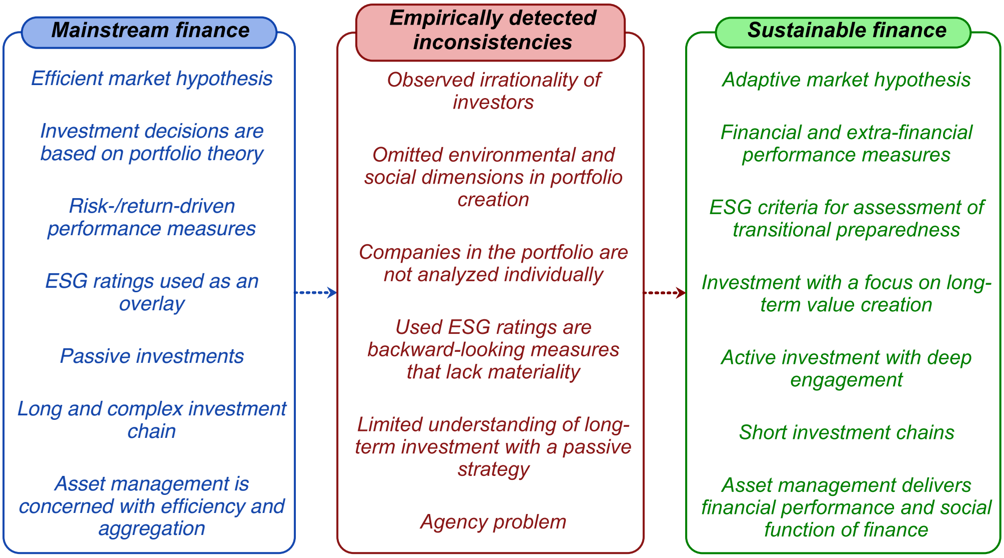

Figure 2.1: Distinctive features of mainstream and sustainable finance (adapted from Schoenmaker and Schramade, 2019).

sions. These studies try to answer whether a company that cares about the environment can generate better financial results. Review articles, for example, show that mostly the relation is slightly positive (Margolis et al., 2012) or nonnegative (Friede et al., 2015) at most, while the most recent work of Atz et al. (2020) claim it to be positive. Trumpp and Guenther (2017) argue that mixed findings could be produced by a wrongly specified direction of the relationship, as the authors find this relationship to be U-shaped, meaning that a negative (positive) relationship is observed for companies with low (high) environmental performance.

When further comparing financial performance for companies with different environmental performance, it is evident that earlier studies tend to find no differences (Cohen et al., 1997; McWilliams and Siegel, 2000; Renneboog et al., 2008, for Japan, France, and Sweden), while others find the underperformance of the good environmental companies against laggards (Baron et al., 2011, for industry markets) or the market (Renneboog et al., 2008, for the United State, the United Kingdom, and Asia-Pacific region). Later papers document a positive relation (Baron et al., 2011, for consumer markets; Secinaro et al., 2020). According to Kim and Li (2021), ESG practices positively affect profitability and are associated with better credit ratings.

More researchers are interested in the relationship between ESG and market performance (Widyawati, 2019), namely how (whether) information about ESG is priced and what expected return ESG-based investment could deliver.

The market does not like news about pollution (Hamilton, 1995) or accidents (Carpentier and Suret, 2015). It is also quite skeptical about stock inclusion into sustainable indices, as there is no change in the risk and return of the oil companies (Schaeffer et al., 2012; Van Stekelenburg et al., 2015), while German stocks are even penalized for this (Oberndorfer et al., 2013). Van Stekelenburg et al. (2015) also show that firms with high CSR are *rewarded* with a permanent and positive shift in returns' growth. Improved green scores lead to a significant increase in stock returns (Yadav et al., 2016).

This leads to the question of whether there is a difference between returns of high and low CSR stocks. Some findings suggest no difference (Guerard, 1997; Auer and Schuhmacher, 2016; De Spiegeleer et al., 2021) or that leading sustainable companies do not underperform the market (Lee and Faff, 2009; Ashwin Kumar et al., 2016). However, leading sustainable stocks can generate a positive alpha (Bennani et al., 2018; Drei et al., 2019) like long-short portfolios based on the ESG criteria do (Kempf and Osthoff, 2007; Statman and Glushkov, 2009), while environmental-damaging companies have negative risk-adjusted returns (Levi and Newton, 2016). Even though some studies have found that brown (not-green) stocks can outperform green ones (Lee and Faff, 2009; Hübel and Scholz, 2020), sustainable stocks outperform based on the performance measures (de Souza Cunha et al., 2019).

The described discrepancy could originate from the applied screens (Barnett and Salomon, 2006; Kempf and Osthoff, 2007) or the used ESG measure. The ESG ranking agencies remain the main source of data and the enabler of the socially-responsible investment (SRI) market (Widyawati, 2019). However, these data are not flawless. The findings show that the rankings can outweigh environmental and governmental issues (Escrig-Olmedo et al., 2019). Chatterji et al. (2016), Rekker et al. (2019), and Berg et al. (2020) show that ESG rankings have industry-rooting, low correlation and convergence, which impact the conclusion about the performance of the ESG-constrained portfolio (De Spiegeleer et al., 2021).

Boutin-Dufresne and Savaria (2004) and Lee and Faff (2009) show that socially responsible stocks have lower idiosyncratic risk. Socially responsible funds are highly correlated, especially in recent periods (Rehman and Vo, 2020), so it is not advised to include a few of them in a portfolio. It is worth mentioning that SRI returns increase during recessions, which means that they offer hedging for the "bad" times (Brøgger and Kronies, 2020). Mutual funds with low sustainability experience net outflows (Hartzmark and Sussman, 2019), likely for hedging ESG systematic risk (Jin, 2018).

An absence of a clear answer to whether ESG investment is profitable, combined with disadvantages of ESG rankings, motivated the study of the first research question of this thesis.

2.2 CLIMATE CHANGE, LOW-CARBON TRANSITION, AND ASSOCIATED RISKS

Research results show that the Earth experiences changes in long-term weather conditions (Andreae et al., 2005) and increased occurrence of extreme weather (Easterling et al., 2000) and suggest factors and mechanisms that contribute to this (Matthews et al., 2009; Storelvmo et al., 2016). These changes has been linked to an increased presence of greenhouse gases in the atmosphere, particularly those with anthropogenic origins (IPCC, 2014). Climatic changes affect the economy as a whole (Stern, 2008; Dell et al., 2014; Hsiang et al., 2017), as well as separately, for example, the agricultural sector (Mendelsohn et al., 1994; Schlenker and Roberts, 2009), banking (Battiston and Monasterolo, 2018), humans (Matthews et al., 2017) and society (Pindyck, 2013; Nordhaus, 2017).

Estimated damages and losses from global warming and climate change are among the reasons to adjust economic activities to reduce or prevent them. Carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions that cause global warming are currently linked with extensive use of fossil fuels; that is why the proposed path is a transition to a low-carbon economy. This shift should significantly reduce GHG emissions, open new investment opportunities, and help achieve the Paris Agreement's goals. The financial sector has a central role in this transition because significant investments into mitigation and adaptation to climate change are required to ensure this transition and reduce economic losses in the future. According to a Global Commission on Adaptation's (2019) report, $1.8 trillion invested in the adaptation by 2030 could generate $7.1 trillion in net benefits. In addition, mitigation costs for limiting global warming are less than the estimated economic damages (Choudhury, 2020). However, their difference is conditioned on timing; the later mitigation starts, the costlier it will be (Sanderson and O'Neill, 2020). Dietz et al. (2016) estimated that the 99th percentile climate value-at-risk is $24.1 trillion of global financial assets.

As climate refers to long-term weather conditions, all changes in average measures of weather variables come steadily, and thus, observable climate change will happen in the distant future. Climate risk occurs when there is a probability that these changes will be of a magnitude that adversely affects living conditions. However, a set of risks connected to climate change can now be observed. This includes the frequency and the magnitude of extreme weather events, such as storms, floods, and droughts.

This thesis is interested in the economic aspect of climate risk in general and the financial aspect in particular. Although climate change generates several different risks (Buhr, 2017), two sources of risks receive attention: physical and transition (Figure 2.2).

Physical risks are closely related to the actual climate changes and accompanied extreme weather events. They bear the risk that materializes in additional costs for dealing with damages from these events in the short run (real estate damages after storms and floods, lost crops due to droughts) and in the long run (relocation of the primary operations in search of more favorable conditions). Transition climate risks stem from an intended reduction in the severity of the physical risks that are likely to occur during the transition to a low-carbon economy. Political risks (i.e., of implementation of carbon taxes and restrictions) and technology risks (i.e., new technology demands and associated costs for a technological shift) are examples of transition risks.

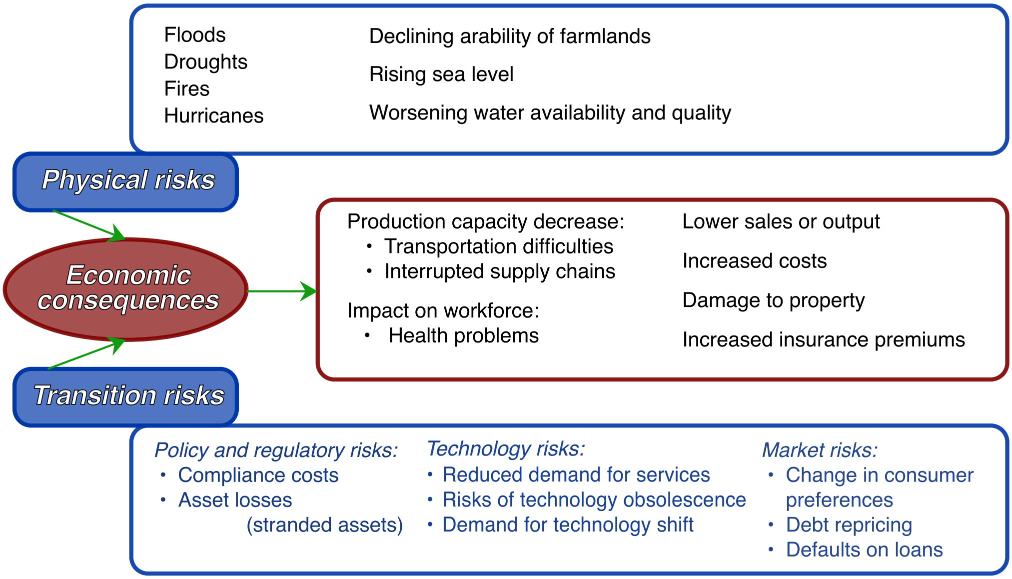

Figure 2.2: Climate risks: type and expected economic consequences (adapted from Allen et al., 2015; Clapp et al., 2017; Choudhury, 2020).

Climate change risk falls into a broader category of environmental risks and, thus, belongs to sustainable finance.

Review of previous research

Scientific studies have investigated different aspects of climate change, from natural disasters in general (Miao and Popp, 2014; Bourdeau-Brien and Kryzanowski, 2020) and separately by their type (Jongman et al., 2014, floods; Lucas et al., 2019, heavy rainfalls; Kruttli et al., 2019, hurricanes) to weather and its components (Dell et al., 2014; Hsiang et al., 2017; Tzouvanas et al., 2019; Tirodkar, 2020; Nagar and Schoenfeld, 2020; Addoum et al., 2020; Choi et al., 2021; Brown et al., 2021). It has been found that natural disasters can temporarily increase risk aversions (Bourdeau-Brien and Kryzanowski, 2020) and lead to more risk-mitigating innovations (Miao and Popp, 2014). Although the mentioned findings have been derived from data within country borders, the impact of natural disasters also spreads across countries, as in the case of floods that call for risk management investment in all territories with basins that have flood-prone main rivers (Jongman et al., 2014).

As showcased by Dell et al. (2014), the effects of weather changes and extreme weather on agriculture, labor productivity, industrial output, health and mortality, political stability, and crime level help in understanding how climate change and weather should be seen as an important macroeconomic risk source. Damages from these impacts can roughly cost 1.2% of the gross domestic product per one-degree increase in temperature (Hsiang et al., 2017, estimated for the United States).

Easterling et al. (2000) show that extreme weather events will occur more frequently with climate change. Sadly, only the occurrence and experience of such events make people believe and pay attention to climate change (Choi et al., 2021).

In summary, this section highlights how climate change affects the economy and society, signifying the contemporary and further importance of the thesis topic.

2.3 Climate change impact on companies

According to Clapp et al. (2017), climate change risks can be described as a function of probability, vulnerability, and exposure. As climate change risk probability is shared globally (for the planet as a whole) and locally (for society, companies, and their assets), vulnerability and exposure are case specific. This makes climate risk systematic in general, but its certain instances can be idiosyncratic.

To answer how companies in the stock market are affected by climate risks, one should look at what defines the stock market price. Stock price is driven by how demand and supply reflect investors' firm valuation. This valuation depends on the earnings, the implied firm's (or earnings') growth in the future, and its capital cost.

Physical climate risk, represented by extreme weather events, interferes with firms' normal operations and directly impacts earnings in the shorter term. Climate change can also lead to relocation, a necessary update, or change in technology, and mitigation costs that can slow down the company's growth.

Even a more nuanced impact should be assigned to transition risks. A low-carbon economy transition requires sustainable consumption. Climate-aware customers can set higher requirements for the product's carbon footprint, its longer life cycle, and proper utilization. They can switch completely to a sustainable alternative or stop buying from the highly emitting producer. This means that demand for certain products can decrease or cease to exist. Any of these scenarios impact the earnings and the corresponding expected growth rate of the firm.

Climate change is on the agenda of governments nationally and internationally. This implies that an adopted agreement to reduce carbon emissions would be implemented through policy measures and regulations. A new or updated policy on cap-and-trade or a carbon tax would mean increased compliance costs for the companies and effectively reduced earnings and future growth.

After considering the channels for earnings changes mentioned above, banks would likely adjust their borrowing rates to account for borrower's long-term debt-paying ability. This would affect firms' cost of capital. Funding can be limited for projects that do not assess climate risks or do not have sustainable goals, meaning that such projects might not become costly but would not be implemented at all.

These are some of the potential impacts of climate risk on the stock price. Including them in valuation could give investors insight into long-term company performance (Figure 2.3) via the detection of climate-related risk and opportunities (Gasbarro et al., 2017). In addition, investors that can distinguish assets by their climate risk (or at least their exposure and vulnerability), can follow an informed climate-aligned strategy that aims at climate change risk reduction.

Review of previous research

To show how climate change affects the cost of debt, researchers rely on different proxy measures for climate risk: carbon footprint (Fernández-Cuesta et al., 2019; Capasso et al., 2020; Palea and Drogo, 2020; Caragnano et al., 2020), carbon intensities (Pizzutilo et al., 2020), carbon risk awareness (Jung et al., 2018), climate vulnerability (Kling et al., 2021), and carbon disclosure (Ramadorai and Zeni, 2019). Regardless of the measure, the conclusion is the same: the higher the risk, the higher the cost of the debt. Environmental concerns alone increase the interest rate for companies with a history of environmental accidents. These findings hold for different markets, for example, Australian (Jung et al., 2018) and European (Palea and Drogo, 2020;

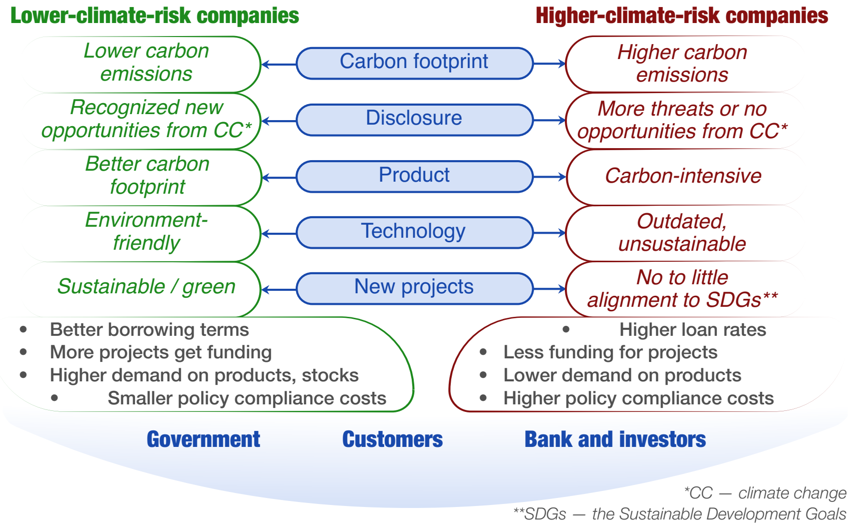

Figure 2.3: Difference between high and low climate risks companies

Caragnano et al., 2020) as well as for weather exposure (Zhang and Zhu, 2020).

Climate vulnerability also restricts access to finance in general (Ginglinger and Moreau, 2019; Kling et al., 2021). High-carbon-footprint companies are perceived as more likely to default (Capasso et al., 2020). Firms with low environmental performance are likely to have lower credit ratings and higher yield spreads (Seltzer et al., 2021). Municipalities with higher exposure to sea-level rise risk face higher issuance costs for longer-term bonds, which suggests that the market can price climate change risk based on the credit quality (Painter, 2019).

Interestingly, in *rich* countries, temperature exposure does not correlate with sales, productivity, and profitability (Addoum et al., 2020). However, firms in countries with higher climate risk have lower and more volatile earnings and cash flows. These firms hold more long-term debt and more cash to remain resilient to climate risk (Huang et al., 2018). Although climate change is usually paired with global warming, extreme winter weather shocks also affect firms' cash needs (Brown et al., 2021).

According to Ceccarelli et al. (2020), mutual funds also experience an increase in assets-under-management after receiving a low-carbon designation.

Thus, it is reasonable to distinguish companies based on their exposure to climate *risk. Because physical and transition climate risks can affect companies' cash flows, these effects should be reflected in asset prices. Two scientific articles included in this thesis study these effects.*

2.4 CLIMATE-ALIGNED INVESTMENTS

A few approaches can be taken to investment decisions based on investors' perceptions of climate change risk. First, they might ignore climate risk completely. This is the case for short-term investors, who believe that climate change will happen in the distant future. Such investors believe they will be able to get returns before unfavorable conditions hit the stock market.

Second, investors can aim to reduce the climate risk of the portfolio, compared to the market, that is, by reducing the total carbon emission of the portfolio. This means that investors recognize climate risks but are not ready to significantly alter the universe of considered assets. Such investments focus on reducing the climate impact of the assets under the management and reducing reputation risk. Additionally, this strategy can lower political risk if new legislation is based on the carbon footprint. This carbon risk awareness does not necessarily mean completely excluding certain sectors. Investors still have access to the same mainstream risk diversification while achieving a lower footprint. This approach corresponds to the mainstream finance premises, namely investing in assets and overlaying the climate risk criteria on top.

Third, investors can *divest* from the specific stocks or sectors associated with high emissions, which are seen as "sin" stocks. Divestment can also be motivated by reduced exposure to stranded asset risks and associated with the carbon bubble hypothesis, which claims that current fossil fuel valuation is inflated by including potentially stranded assets (Ritchie and Dowlatabadi, 2015; Barnett, 2019). Financial literature defines *stranded assets* as

> those investments which have already been made but which, at some time prior to the end of their economic life, are no longer able to earn an economic return as a "result of changes in the market and regulatory

> environment associated with the transition to a low-carbon economy.” (Caldecott, 2017, p.2)

Fourth, value-driven investors can choose only sustainable stocks based on low emissions or carbon neutrality, long-term orientation, and climate mitigation and adaptation. These two approaches are closely related to sustainable finance.

The last three approaches to incorporating climate risk into investment decisions lead to changes in stock pricing.

2.4.1 Risk premium

Investors dislike stocks with high emissions rates. These stocks harm investors’ reputations and are associated with additional costs in the future. Potential new climate policies increase the uncertainty of such companies’ debt repayment ability. Such companies are likely to have higher loan rates, as their cash flows are more sensitive to changes in demand and supply that are conditioned on climate change. Banks can also provide loans at higher rates for companies with higher emissions or projects that do not meet sustainability criteria. Such companies become associated with higher default probability. Altogether, highly emitting companies are seen as riskier or with higher carbon risk.

Therefore, an additional incentive is needed for an investor to hold assets with higher risk. Investors would expect to be compensated for holding riskier assets. This means that a carbon risk premium should exist.

Compensation for the additional risks can also be a consequence of divestment. Shunned stocks become relatively cheaper and hold higher expected returns. Investors holding controversial stocks have lower risk-sharing opportunities (Heinkel et al. 2001, as mentioned in Derwall et al., 2011, p.2138).

2.4.2 Climate alpha

Carbon alpha describes a situation in which low-climate(carbon)-risk stocks have positive abnormal returns after controlling for common risk factors. Theoretically, this happens due to the market’s inefficiency in incorporating information into prices.

If investors want to eliminate or reduce climate risk, they will look for sustainable or low-climate-risk stocks. If there is a shortage of such stocks, increased demand will raise stock prices and improve their returns. However, this abnormal return is unlikely to be sustained.

Another explanation arises from less speculative trading. Value-driven investors care about climate change and prefer companies that incorporate mitigation and adaptation into their strategy. These investors will buy low-climate-risk stocks because they believe that stocks are undervalued in the market. However, such companies have a long-term orientation and are likely to maintain or improve cash flows while creating additional value. If such a prediction is correct, the stock price for these companies will gradually rise until mispricing disappears. Derwall et al. (2011) call this the error-in-expectation hypothesis.

Such a market can also price the climate risk to some extent, but it cannot set its price correctly. In this case, carbon risk will not be fully compensated for. Furthermore, investors could profit from investing in lower-risk stocks and short-selling higher-risk stocks. This leads to a situation where investors are "doing well while doing good".

Lo (2004) introduced the adaptive market hypothesis (AMH), which allows investors to learn from their own experiences and adjust decisions to the market state and personal needs and goals. AMH "can explain how new risks [...] are not yet fully priced in, as not enough investors are examining these new risks" (Schoenmaker and Schramade, 2019).

Review of previous research

Findings by Plantinga and Scholtens (2021) suggest that institutional investors would not have fiduciary issues while a realizing divestment strategy, as nonfossil and fossil fuel portfolios perform similarly. Moreover, fossil fuel divestment leads to higher risk-adjusted returns and lower carbon intensity (Hunt and Weber, 2019). Even announcements about divestment have a significant role in reducing fossil fuel stock prices (Dordi and Weber, 2019).

Brown (2016) stresses that hedging through the new asset classes based on GHG (Andersson et al., 2016) and shorting high-carbon-footprint companies help deal with climate risk. Hedging can also be based on the correlation with the climate change news index (Engle et al., 2020). Lowering the weighting of fossil fuel stocks contributes to lower ex-post transition risks for investors (Benedetti et al., 2019). Similar adjustments work for physical risks. Alok et al. (2020) show that professional money managers underweight stocks located in the areas exposed to hurricanes and earthquakes. Changes in portfolio structure that reflect an alignment with a $2°C$ scenario lead to a better Sharpe ratio, reduced exposure to carbon emissions, and increased exposure to the green sector (Bender et al., 2019).

Bansal et al. (2019) show that positive low-frequency temperature shocks lead to a decrease in the price-dividend ratio. They also argue that climate risk is incorporated into asset prices and carries a positive premium in the United States and globally. Higher monthly temperature shock sensitivity is associated with lower stock returns, making a low-minus-high sensitivity strategy earn 3.6% per year (Kumar et al., 2019). This points out that the market could be inefficient in pricing temperature shocks. Temperature shocks also increase systemic risks, measured as a conditional value-at-risk (for EU stocks, see Tzouvanas et al., 2019). The food industry is more exposed to climate risk; therefore, extreme weather events, such as droughts (Hong et al., 2019) and heavy rainfalls (Lucas et al., 2019), can predict profits or negatively affect stock prices.

Murfin and Spiegel (2020) suggest that the market has a limited understanding and pricing of the sea-level rise risk.[1] The authors found no effect of relative sea-level rise risk and location on housing pricing. However, beliefs about long-term climate change risk might affect the prices; there is a discount for houses that are likely to become under water with sea-level rise in believer neighborhoods (Baldauf et al., 2020) and climate-aware communities (Bernstein et al., 2019). Keys and Mulder (2020) found that market liquidity is also affected and that transaction volumes in coastal Florida declined by 16–20% compared with locations that have low sea-

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[1] Analysis of the housing market is considered complicated because it is hard to find properties that would be different only based on exposure to sea-level rise risk.

level rise risk.

As institutional investors recognize the potential financial implications of climate risks for their portfolio (Krueger et al., 2020) and most companies consider regulatory (transition) risk to impact them sooner (Sakhel, 2017; Kouloukoui et al., 2019), most studies have connected companies to climate change through carbon risks or carbon emissions. The results are mixed. A *low-carbon minus high-carbon* portfolio generates a positive return at 3.5–5.4% annually due to the outperformance of carbon-efficient stocks (In et al., 2019). Bernardini et al. (2021) found a significant low-carbon premium for European electric utilities. Companies that provide carbon disclosure have a higher market value (Jaggi et al., 2017), meaning that GHG disclosure is associated with positive significant abnormal returns (Liesen, 2015; Liesen et al., 2017). At the same time, greener and transparent stocks have a negative premium that investors might accept for climate risk hedging (Alessi et al., 2020). In contrast, companies with higher CO_2 emissions have a positive alpha in long (Bolton and Kacperczyk, 2021) and long-short investments (Hsu et al., 2020; Jiang and Weng, 2020, for agricultural companies).

The impact of climate risk is also reflected in the cost of option protection against downside risks. These costs are higher for more carbon-intensive sectors (Ilhan et al., 2020). According to Kruttli et al. (2019), hurricanes contribute significantly to the implied volatility of options. However, investors tend to underestimate the associated uncertainty.

Thus, investors should account for climate risks' impacts on firms and their stocks. As the literature review shows, significant attention is given to carbon risk. This thesis argues that reducing climate risk to carbon risk only provides a limited understanding of the company's exposure to climate change and proposes another approach in Article 4.

2.5 GREEN INVESTMENTS IN A LOW-CARBON TRANSITION

Divestment in fossil fuels and green bonds (GBs) are two parallel pathways to climate-friendly investment (Glomsrød and Wei, 2018). However, GBs represent a truly climate-focused investment strategy, while others are about portfolio decarbonization (De Jong and Nguyen, 2016). GBs are "any type of bond instrument where the proceeds will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible green projects" (ICMA, 2018).

They can cover a wide range of projects about climate change adaptation, energy efficiency, renewable energy, clean transport, and green buildings, to name a few, if proceedings are used specifically for defined purposes and issuer reports about project realization. GBs' importance for low-carbon transition can be clearly seen since the adoption of the Paris Agreement: Nationally Determined Contributions has led to significant growth of the GB market and specifically to GB allocations to renewable energy (Tolliver et al., 2020a,b).

This predefined but not exhaustive list of goals has enabled the use of a *green* label. Some GBs are self-labeled, while others obtain labels from third parties, sometimes with so-called light, medium, and dark *shades of green* to distinguish GBs by their environmental quality (CICERO, 2015). Although there is no unified certification on the market but rather voluntary guidelines, the green label conveys additional information to the investors about the sustainable strategy of the project and company. For value-driven, sustainable investors, this also means reduced information asymmetry and information costs throughout project implementation. It is worth mentioning that the green label does not necessarily reduce the climate risk of the investment. Corporate GB issuers often belong to the sectors that are more exposed to climate risk and, therefore, try to reduce it with green projects.

Not only do clearly defined GB projects contribute to low-carbon transition but also to their investment horizon. GBs allow investing in the long run, which helps resolve intertemporal conflict of climate finance. GBs from supranational and government agencies can be an alternative to sovereign debt because they are less likely to default, thus attracting investments during market distress (Flaherty et al., 2017).

It has been argued that GBs provide access to capital at lower costs compared with conventional bonds. This hypothesis for the bonds has the same prerequisites as the one for the stocks. Namely, the avoidance of "sin" companies combined with the high demand for green investments makes expected returns on "sinful" investments higher. Thus, conventional bonds will have higher yields to compensate for these implied sustainability-related risks.

Review of previous research

Because GBs are relatively new fixed-income instruments, research covering GB research is just developing, although rather quickly. One strand of the literature is descriptive and theory oriented. It describes how GBs can facilitate the transition to a low-carbon economy (Reichelt, 2010; Wood and Grace, 2011; Gerard, 2019; Maltais and Nykvist, 2020; Sartzetakis, 2021), how the GB market develops (Kochetygova and Jauhari, 2014; Clapp, 2014; Trompeter, 2017; CBI, 2018; Schumacher, 2020), and what factors impede this development (Morel and Bordier, 2012; Banga, 2019; Deschryver and de Mariz, 2020).

Another strand of research is interested in how differently GBs perform from conventional bonds and whether they are related to other asset types. The main question is whether GBs can deliver a lower cost of borrowing for the issuer. Some studies have shown that corporate and municipal GBs have a tighter spread (Baker et al., 2018; Nanayakkara and Colombage, 2019; Zerbib, 2019; Partridge and Medda, 2020; Immel et al., 2021) as well as supranational bonds (Fatica et al., 2021). Findings in others suggest that this was not always the case (Karpf and Mandel, 2018; Hachenberg and Schiereck, 2018; Kanamura, 2020) or that detected *greenium* is negligible (Dorfleitner et al., 2021; Larcker and Watts, 2020). Overall, most studies have found a GB premium on both the primary and secondary markets (MacAskill et al., 2020). The discovered differences in the premium size are attributed to the sample, time horizon, or applied methodology to define matching green and conventional bonds (Liaw, 2020).

Because GB certification is recommended but not unified, only some GBs receive an external certification. Recent studies have documented that certified (or “dark” green) bonds offer a premium compared with nonlabeled/self-labeled GBs (Hyun et al., 2019; Dorfleitner et al., 2021; Li et al., 2020; Hyun et al., 2021). Higher ESG ratings (Immel et al., 2021) or CSR scores (Li et al., 2020) also reduce yield spread. There is also evidence that GBs are more liquid (Wulandari et al., 2018; Bachelet et al., 2019) and riskier in terms of conditional volatility and value-at-risk (Tsoukala and Tsiotas, 2021).

GBs are connected with conventional/corporate bonds (Pham, 2016; Reboredo et al., 2020). This interdependence is expected, as issuers are often the same; thus, credit rating and CSR practices similarly affect bonds. However, this relationship is sensitive to different factors, such as market volatility, policy uncertainty, oil prices, GBs' sentiment on the market (Broadstock and Cheng, 2019), corporate taxes, the issuer's creditworthiness (Agliardi and Agliardi, 2021), and the *shade of green* (Tsoukala and Tsiotas, 2021). Significant connectedness is also found with currencies (Reboredo and Ugolini, 2020) and Bitcoin (Hung, 2021). CO_2 emission prices (Hung, 2021) and carbon futures transmit shocks to the GB market. This means that GBs could be a hedge for the carbon market (Jin et al., 2020).

Weak correlation with commodities (Reboredo, 2018) and asymmetric volatility spillover to commodities (Naeem et al., 2021) suggest that GBs can be used as a risk-reduction instrument for these markets. However, this could also limit the diversification benefits of GB inclusion in portfolios (Nguyen et al., 2020), as they reduce risk and returns (Horsch and Richter, 2017). The connection between GBs and oil prices is found only in the long run (Naeem et al., 2021) and as a Granger causality in lower quantiles (Lee et al., 2021).

Reboredo (2018) shows that the correlation between GBs and stocks is small. Park et al. (2020) found that GBs do not respond to negative but positive shocks from the stock market, while Hung's (2021) findings suggest a bidirectional relationship. Event studies on GB issuance announcements have confirmed positive stock market reactions (Zhou and Cui, 2019; Baulkaran, 2019; Tang and Zhang, 2020). Equity prices also positively respond to the introduction of GB policies (Jakubik and Uguz, 2021, for European insurance companies).

Finally, GBs are cheaper for companies (Gianfrate and Peri, 2019). Their issuance is associated with improved operation and innovative green activities (Flammer, 2021), decreased carbon emissions (Fatica and Panzica, 2021), and improved environmental performance if they are certified by third parties (Yeow and Ng, 2021).

Although GBs are an instrument of climate financing, they are also exposed to cli-

mate risks. The second scientific article assesses how green and conventional bonds differ in response to regulatory climate risk.

2.6 THE CRITIQUE OF CLIMATE RISK ASSESSMENT

Despite the obvious need to assess and include climate risks in investment decisions, this does not happen quickly enough. There is an intertemporal inconsistency with climate risks, as they are expected to materialize in a more distant future than most investment decisions are concerned about (Thomä and Chenet, 2017). The traditional risk model cannot effectively capture transition risks, and there is no proven methodology or practice can yet do this (Christophers, 2019). In line with the discounted cash flow approach, which is often used in firm valuation, losses associated with climate change are highly discounted. This effectively means that long-term risks become too small to be considered in terms of present value. This happens due to a hyperbolic discount function, making long-term components enter the equation with a much lower discount rate (Thomä and Chenet, 2017).

However, another question is what this discount rate should be. In practice, the interest rate of an alternative similar asset is used in the valuation. The pitfall is that no such asset exists for climate risks. None of the government bonds could match the investment horizon with climate change. Therefore, even those few suggestions for a discount rate presented in the scientific literature have been critiqued (Stern, 2008; Gollier, 2013).

Another question is about what can be used as a reliable source of information to measure or approximate asset exposure to climate risks. Previous studies have suggested using ESG, more specifically the environmental factor and carbon emissions defined within it in absolute terms at carbon scope I (emission during production) and scope II (for a company as a unit), and carbon intensity of the revenue (e.g., Bender et al., 2019; Benedetti et al., 2019; Liesen et al., 2017; Liesen, 2015). Nonetheless, there is a concern that by looking at the historical greenhouse gas emissions, researchers operate with backward-looking measures that might not have a predictive advantage for future cash flows (Benedetti et al., 2019).

However, research also depends on *which* ESG rating is applied. Previous studies have shown that rankings provided by different agencies do not converge (Chatterji et al., 2016; Berg et al., 2020; Gyönyörová et al., 2021). This means that the relative placements of the companies depend on the choice of rating providers. Moreover, most of them compare peers within one industry, meaning that the use of rankings for market-wide assessments is not possible (Rekker et al., 2019).

Escrig-Olmedo et al. (2019) show that rating agencies have a strengthened focus on environmental and governmental issues and also argue about the commercial motives of the agencies in providing such services. Berg et al. (2020) discovered that raters' assessments of one category influences which score will be assigned to other categories. De Spiegeleer et al. (2021) conclude that the choice of rating agency significantly affects the performance of the ESG-constrained portfolios. Even though ESG ratings seem to be inconsistent, they include some measures useful for climate risk approximation (Rekker et al., 2019).

There has also been discussion on whether climate risks can be called *risks* per se. Scientists following the Knightian definition of risk might argue that climate risk is likely an uncertainty rather than a risk due to the absence of objective probability distribution for climate risks. Aven (2019) points out which changes to IPCC reports could make climate risks fit better into the risk management domain to resolve the tension.

Another existing discussion point in sustainable finance questions the ethical grounds of companies and investors. A concern about *green-washing* is often raised in studies on the bond market. This refers to environmental wrongdoings (Bryant et al., 2019) or the promotion of green activities when none are present. This activity could arise from rent-seeking behavior when climate finance is attracted only for wealth-adding purposes and not actual climate mitigation and adaptation (Buchholz and Rübbelke, 2020). This underlines that truly sustainable and climate-aligned investments are long-term and value-driven.

This thesis agrees that the choice and availability of ESG rankings present a challenge for an investor who intends to implement a sustainable investment strategy. It is proposed to rely on a more forward-looking valuation of the company's climate *risk exposure, as applied in the fourth scientific article.*

This theoretical and literature overview shows why studying climate risks is important. Despite the rapid development of this research area, there is no consensus on how financial markets price this kind of risk and how investors should incorporate it into investing decisions. Thus, this thesis aims to contribute to this study area by investigating market pricing of climate regulatory risks and profitability of the investing strategies grounded in long-term sustainable considerations.

3 METHODOLOGY AND EMPIRICAL DATA

This chapter addresses the methodological foundation for this thesis and describes the applied research design. It then defines the philosophical positioning that affects the methodology and justifies choices about the data and methods.

This thesis represents causal-comparative quantitative research. Its research design aims to determine how the independent variable (climate risk) affects the dependent variable (returns).

Ardalan (2018) mentions that mainstream financial research is largely based on the functionalist paradigm. This dissertation supports the functionalist idea of providing objective knowledge with explanatory and predictive power. However, this work belongs to *critical realism*, which better reflects sustainable finance concepts.

Mainstream finance research takes a positivist stance in major assumptions and, thus, similar to natural sciences, relies on stable relationships and strict rationality in people's decisions and actions (Peixinho and Coelho, 2005). According to Lagoarde-Segot (2019), this approach explains "company" and not "enterprise,"[1] with which sustainable finance is concerned. *Money* and *value* are synonymous in mainstream finance research. This is a source of possible confusion because practices aimed at social, environmental, and governmental values are seen as a "malfunction," as they reduce "shareholder value maximization" in money equivalent.

Critical realism allows for change and dynamics in an open-world system and, thus, better fits the sustainable finance assumptions (Lagoarde-Segot, 2015, 2019). Research on low-carbon transition (Grubb et al., 2015; Hall et al., 2017) has already used a stratified world structure, as suggested by critical realism. In addition, Lo's (2004) AMH is supported by ontological and epistemological assumptions of critical

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[1] Lagoarde-Segot (2019) mentions that a company is only one of the possible enterprise forms.

realism. AMH allows investors to learn from their own experiences and adjust decisions to the market state and personal needs and goals. According to Schoenmaker and Schramade (2019), the AMH "can explain how new risks [...] are not yet fully priced in, as not enough investors are examining these new risks."

Based on all those arguments mentioned above, critical realist ontology and epistemology are the right choices for research within sustainable finance, and climate risks in particular. It is worth mentioning that critical realism fits studies on climate risks because they combine the sustainable aspect of climate-aligned investments with a required compensation of associated risk, making mainstream and sustainable finance closer. However, a presented amalgam of critical realist philosophical perspectives and mainstream finance methodology may not perform as well for different research within sustainable finance.

The following sections will present a more nuanced description of critical realism.

3.1 ONTOLOGY

Ontology is a philosophical discipline that is concerned with the nature of reality. It asks questions about *what* is real or exists and how things are related (Hofweber, 2021). The ontological position usually falls between objectivity and subjectivity. The former states that reality is mind independent (i.e., it refers to realism), while the latter claims that reality "exists within the mind of subject" (i.e., it presents idealism, Ryan et al., 2002). This research takes a middle ground on the objectivity-subjectivity spectrum. The ontological position of critical realism builds upon the works of Roy Bhaskar, Andrew Sayer, and Steve Fleetwood (Sousa, 2010).

Critical realism describes a world that does not depend on the mind, that is, the world that exists outside one's mind. Entities and events in the world are material and immaterial. Thus, ideas and social entities are as real as material entities, meaning that observability is not required for their existence. Each entity holds a set of "causal powers and liabilities", which defines an entity itself and its relations, exercised or potential, with other entities (Harré and Madden 1975, as mentioned in Sousa, 2010, p.475).

Critical realism suggests that the world is structured, open, and able to change and evolve. Entities can be complex and consist of other entities. Different network levels can exist between entities. Such interconnectedness translates into the stratification of the world. According to Bhaskar (1978, as mentioned in Lagoarde-Segot, 2015, p.4), the world includes three domains:

- the *empirical*, which refers to the observable, and contains the data and facts used in scientific inquiries;
- the *actual*, which contains both the perceivable and unperceivable events generated by real causality mechanisms; [and]
- the *real*, which contains the causal mechanisms and structures that produce the actual.

Causal powers *tend to* bring related outcomes and not cause one because a power exercise depends on the context (i.e., powers of the other entities) due to openness. This tendency means that the world is prone to changes and development.

This research is interested in the stock and bond market, sustainability, climate risks, company stock and its sustainable performance, and returns. The real domain corresponds to the theoretical model and an explanation of the mentioned entities. From a critical realist perspective, a theoretical concept is also real and is an ideal entity. This entity has its structure, which includes money, return, risk, and so on. A financial market, as an entity, has powers that are exercised differently in different countries and periods. This leads to the actual domain where investors and companies are observed. The empirical domain for financial research comprises observable results for investors' decisions, reflected in companies' prices and returns.

3.2 EPISTEMOLOGY

Epistemology, or theory of knowledge, is the "part of philosophy concerned with the nature, sources and justification of knowledge" (Ladyman, 2001, p.265). The middle-ground position of critical realism is also reflected in epistemology. The critical realist research describes and explains the worlds' phenomena. Description and explanation provide knowledge about the world. This knowledge is partly obtained via observation and experimentation (positivist approach), but an even bigger part comes with practical intervention and human communication (postmodernist approach). Knowledge and practice are interdependent and confirm each other.

Unlike postmodernism, critical realism does not support the idea of "anything goes", thus bringing up the importance of the practical adequacy of knowledge in that all theories can be challenged, although they might have uneven fallibility. Researchers develop theories that will be robust but not necessarily ultimate. This is due to each domain's "stable but not static" structure (Sousa, 2010).

Knowledge helps to know the future in a probabilistic way because researchers gain insights assessing the co-occurrence of causal and counteracting powers of entities. Scientific predictions are based on the likelihood of the event occurrence; they may not be completely accurate, but they are never spurious. Empirical research seeks to identify which tendencies in connected events prevail given a certain time and context. Such research results will likely contribute to the initial theory by supporting it or causing its reevaluation and modification. Sousa (2010, p.492) gives the next example on the link between theory and evidence:

> [A]fter postulating the existence of a causal mechanism, scholars and researchers are urged to determine (empirically) if that mechanism acts the way it is supposed to act and does bring about the event that is to be explained.

Such a knowledge generation process describes the modern finance approach in the best way.

3.3 METHODOLOGY AND METHODS

This research also aligns with critical realism methodologically to ensure its relevance for sustainable finance. However, it inherits from mainstream finance research its positivists' interest in and emphasis on modeling.

Critical realism uses abstraction and retroduction as major methodological approaches. Abstraction helps reduce the multidimensionality of the world and create its decomposition with one phenomenon in focus. By doing this, the researcher can detect events' interconnectedness and construct complete knowledge about the world based on several abstractions. The description of the world can be quantitative, but produced knowledge is qualitative. An explanation is based on abductive (retroductive) reasoning, which derives the best prediction from the available observations, and organically fits into critical realist ontology. The abduction results are then used for retrodiction, that is, to communicate to established theory and knowledge (Sousa, 2010).

Criticizing mainstream finance methodology, Lagoarde-Segot (2019) suggests that abductive reasoning will help overcome mainstream finance's inability to understand changes brought about by sustainable finance. This dissertation supports his statement but finds it difficult to neglect the comprehensive methodological base used in mainstream research. Like mainstream finance research, this work relies on statistical inference as a validity criterion. It also uses models in the abstraction approach and as a base for theoretically informed empirical research.

The next subsections briefly describe common models used in asset pricing and methods used to analyze investment performance.

3.3.1 Models

3.3.1.1 The capital asset pricing model

Based on Harry Markowitz's (1952) work on the mean-variance portfolio, the capital asset pricing model (CAPM) was derived by Sharpe (1964), Lintner (1965), and Mossin (1966). It assumes that a rational, mean-variance optimizing investor, which relies on all relevant publicly available information, makes a single-period decision about investment and borrowing/lending on a market where all assets are traded without transaction costs and taxes (Bodie et al., 2018). According to CAPM, all investors will split their investment between a market portfolio M with a return of r_M and risk-free asset r_f, depending on their risk tolerance.

Starting with the contribution of a single stock to the market portfolio risk, an expression for the expected return $E(r)$ for individual security i is derived:

$$E(r_i) = r_f + \beta_i \cdot [E(r_M) - r_f], \tag{3.1}$$

where $\beta_i = \frac{cov(r_i, r_M)}{\sigma_M^2}$ stands for the contribution to total market variance σ_M^2, expressed as the covariance between stock i and the market portfolio. Beta shows the relative risk of investing in stock i compared with the risk of the market portfolio. Thus, $E(r_M) - r_f$ shows a risk premium on the market portfolio.

3.3.1.2 Multifactor models of risk and return

The arbitrage pricing model of Ross (1976, as mentioned in Bodie et al., 2018, p.312) justifies the use of not just single but multiple risk sources. Predictive powers of a firm's size, measured as market capitalization, and its book-to-market ratio laid the groundwork for Fama and French's (1993) model. Small companies tend to have higher returns than large companies, while companies with high book-to-market ratios tend to outperform those with low ratios with the same market risk exposure β_i. Thus, it was suggested that hedge portfolios of small-minus-big (SMB) and high-minus-low (HML) are good candidates for proxies of size and value risk factors, giving the now commonly used Fama-French three-factor model (FF3):

$$R_{it} = \alpha_i + \beta_i \cdot R_{Mt} + \beta_{smb,i} \cdot SMB_t + \beta_{hml,i} \cdot HML_t + \varepsilon_{it}. \tag{3.2}$$

In this model, $R = r - r_f$, an intercept α stands for an excess return; β_{smb} and β_{hml} are exposures to size and value risk factors, respectively; and ε is an error term. Ideally, exposure to these factors should fully explain stock returns so that α should be equal to zero.

Results from empirical studies showed that other characteristics could also have a predictive power, which led to the suggestion of a whole range of other factors, or a so-called "factor zoo" (Feng et al., 2020). These new factors are self-financed hedge portfolios because they suggest going long for (predicted to be) high-return companies and shorting (predicted to be) low-return companies. However, some factors have been proven to be informative and relevant and are therefore used in academic research more often. Some of them are:

- Carhart's (1997) model, which augments the FF3 model with a momentum factor because good performing stocks continue to earn positive returns;
- Pástor and Stambaugh's (2002) model, which shows that lack of liquidity increases stock's risk, suggesting a liquidity factor included in the FF3 model;
- Fama and French's (2015) five-factor model, which adds profitability and investment factors to the FF3 model.

3.3.2 Linear regression: Application for asset pricing models

Asset pricing models, by definition, have the form of a linear regression model, connecting a dependent variable (returns) with some independent variables (risk factors) in a functional form, although they should be slightly rearranged as in the case of the CAPM:

$$R_{it} = \alpha_i + \beta_i \cdot R_{Mt} + \varepsilon_{it}. \tag{3.3}$$

A correctly estimated coefficient and goodness of fit are important from an econometric point of view. That is why linear regression models always account for autocorrelation and normal distribution of residuals so that estimators are adjusted accordingly. Such corrections are needed because stock market data are prone to skewness (i.e., unsymmetric distribution of returns) and/or kurtosis (i.e., extreme returns occur more often than predicted by standard normal distribution).

Much attention goes to the sign of the estimated coefficients (i.e., risk exposure, or risk factor betas, e.g., β_{smb}, β_{hml}) in multifactor models because the sign helps to understand characteristics of studied stocks. For example, a negative beta for the SMB factor suggests that a studied company has a large size. The value of market beta coefficient β_i shows relative asset risk; for example, higher than one means an asset is riskier than the market.

However, the intercept, or alpha, is of high importance for financial analysis. A significant alpha means that the factors suggested in the model do not fully explain the variation in returns. It also presents an opportunity for additional (abnormal) returns or is a sign of a missing risk factor that should be added to the model, which the investor should be compensated for.

3.3.3 Event study

Event studies are based on the efficient market hypothesis (EMH). According to EMH, market changes are connected to information flow; there is no price movement if no new information is available in the market. New information (news or event) is a surprise for investors and randomly drives prices on the stock market. Fama et al. (1969) conducted the first event study to test how this happens on the market and how price adjustment happens. Later, Fama (1970) proposed differentiation of market efficiency into strong (exists when all investors have equal access to any information that could move a price), semi-strong (describes a situation of investors' evaluation of all publicly available information), and weak (efficiency with respect to the information about historical prices).

An event study is a tool to test EMH and proceeds as follows:

1. An event or a set of events is defined for the study, and corresponding historical data are obtained. Usually, daily data are more suitable, but an event study on lower frequencies is also possible, although they might be less indicative (Kothari and Warner, 2007).

2. The time frame is divided into an event window (i.e., a period where an event affects prices) and an estimation window (i.e., a period before the event window).

3. Based on data from the estimation window, a model for expected returns is obtained. Expected returns can be calculated based on the historical mean for the stock, the historical mean for the market, or by application of the asset-pricing model. Usually, the researcher chooses the CAPM, as it can be sufficient for captioning variation in daily observations.

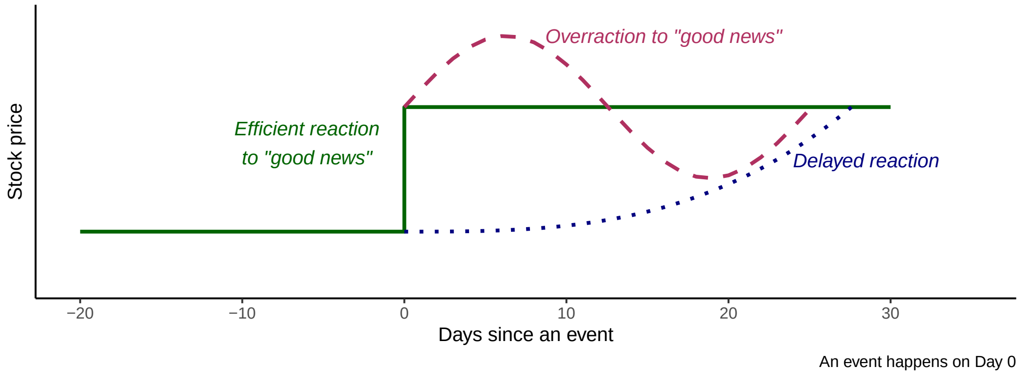

Figure 3.1: Possible stock reactions to an event that carries good news.

4. Abnormal returns are calculated as differences between the historical stock returns and the expected ones for each observation in the event window.
    - There is also a possibility for time series aggregation, which provides cumulative abnormal returns that are useful for detecting whether an event was anticipated and how the market reacted to it (see example in Figure 3.1).
    - Cross-sectional aggregation is also applied to abnormal and cumulative abnormal returns to obtain an average effect of the event.
5. A Student's *t*-test is applied for testing whether abnormal returns are different from zero.
    - Various tests have been suggested to overcome problems with contemporaneous correlation and event-induced volatility (Patell, 1976; Boehmer et al., 1991; Kolari and Pynnönen, 2010).

The obtained results provide insights into whether the studied event carried new information. This is the case when abnormal returns are significantly different from zero.[2] Investors can see whether new information is favorable for a company or not,

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[2] It is worth mentioning that the classical EMH becomes questioned due to observed market overreaction to new information. Nevertheless, it has not been rejected (Fama, 1998) and co-exists with the AMH (Lo, 2004).

and it is reflected in the sign of abnormal returns. Abnormal returns can be used as a dependent variable in linear regression to determine which factors define stock price reaction.

3.3.4 Portfolio performance analysis

One of the modern finance assumptions is the risk aversion of an investor, meaning that the investor will prefer an asset with low risk given the same return. There are two types of risk: systematic and idiosyncratic. The first one cannot be diversified away, as it is inherent in the market. The second can be reduced or even eliminated utilizing portfolio investment. Thus, a portfolio is a combination of a few assets, in that thematic indices and mutual funds are also portfolios.

There are two approaches to combining stocks into a portfolio within empirical finance: equal and value weighting. When portfolios are equally weighted, the same amount is invested in each stock so that the invested amount depends only on the portfolio's number of stocks. According to value weighting, the stock weight in the portfolio depends on the relative share of that stock in the total market capitalization of the chosen stocks. However, these two approaches do not exhaust how stocks can be combined into a portfolio, nor do they identify the optimal combination.

Measures of portfolio performance are used for the evaluation and differentiation of portfolios. Most of them rely on descriptive statistics of historical data on stock prices. An expected return is defined as the annualized average return (R), and risk is calculated as the annualized standard deviation of historical return (σ_R). The next performance measures describe a risk-return relationship:

- The Sharpe ratio (formulated in 1966, as mentioned in Sharpe, 1994, p.49) shows reward-to-variability and is defined as $Sharpe = \frac{R-r_f}{\sigma_R}$, where r_f is a return of the risk-free asset.

- The Treynor ratio, similar to the previous one, shows excess return ($R - r_f$) per unit of systematic risk: $Treynor = \frac{R-r_f}{\beta_R}$.

- The information ratio shows the active return ($R - R_b$) per tracking error

(σ_{R-R_b}): $Information\ ratio = \frac{R-R_b}{\sigma_{R_p-R_B}}$, where R_b is a benchmark's return.

Unfortunately, due to the nonnormality of the stock return distribution, the abovementioned measures do not provide extensive information about portfolio performance. Other measures can account for negative skewness and/or kurtosis of returns:

- The expected shortfall shows an average return for worst N% cases.
- The Sortino ratio (1991) is defined as $Sortino = \frac{R-MAR}{\sigma_d}$. It shows excess return over minimum accepted return ($R - MAR$) per unit of downside risk (σ_d), which is calculated as a deviation for all observations that are less than MAR.

All these measures are constructed so that the investor will prefer one with a higher measure when choosing between two investment opportunities (portfolios).

3.4 RESEARCH DESIGN

This thesis is characterized by a causal-conclusive research design. Hypotheses are made and then tested by applying econometric methods and statistical inference to answer research questions.

As this work is a financial study and is interested in the market-wide effect of climate risks on returns, a relatively large historical data sample is required. Particularly, the analysis is conducted on daily stock and bond prices, combined with interest rates. It includes data on prices for

- share prices for individual companies;
- quotes for indices, which are a combination of stocks or bonds formed on certain criteria(e.g., in this thesis, indices for the global stock market, the Norwegian stock market, the American stock market, the American bond and GB markets, the sustainable Nordic companies are used); and

- quotes for exchange-traded funds—a separate stock-like asset that tracks an index, sector, or other assets.

Due to the needed sample size and data frequency required by methods, the research relies on secondary data from third-party providers, such as the following:

- *TITLON*,[3], which provides financial data for Norwegian academic institutions (Article 3 and 4, Chapters 8 and 9, respectively);
- Wharton Research Data Services (WRDS),[4], which provide access to a collection of security prices, returns, and volume data for the American stock markets (Article 1, Chapter 6, respectively);
- ventures that produce, maintain, license, and market stock market indices (e.g., S&P Dow Jones Indices[5]; used in Article 2, 3, and 4, Chapters 7, 8 and 9, respectively); and
- other public providers of economic data (e.g., Federal Reserve Bank of St. Louis[6]).

Even though data for financial studies are often panel data, meaning that they contain historical observations for different entities (companies or indices), more attention is given to time-series analysis. At the same time, a cross section is used for comparative purposes.

3.5 RESEARCH ETHICS CONSIDERATION

This thesis is an original work done on the grounds of freedom and independence and investigates and describes relationships between sustainability and financial markets. The author's interests and beliefs did not affect the research in any way, and there were no conflicts of interest. The results convey a scientific value and show the

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[3] `https://titlon.uit.no/`

[4] `https://wrds-www.wharton.upenn.edu/`

[5] `https://www.spglobal.com/spdji/`

[6] `https://fred.stlouisfed.org/`

Table 3.1: Summary of some methodological aspects of the thesis

No	*Research method*	*Data source and type*	*Assets*	*Scope*
Article 1 (Ch. 6)	Linear regression, event study	Secondary data from WRDS (price quotes and returns)	exchange-traded funds	the US
Article 2 (Ch. 7)	Linear regression, correlation analysis, event study	Secondary data from S&P Dow Jones Indices (index values)	GB indices	global, the US
Article 3 (Ch. 8)	Linear regression, portfolio analysis	Secondary data from TITLON (price quotes and returns) and S&P Dow Jones Indices (index values)	companies and created portfolios	Norway
Article 4 (Ch. 9)	Linear regression, portfolio analysis	Secondary data from TITLON (price quotes and returns) and CDP (carbon disclosure scores)	companies and created portfolios	Norway

findings as they are. The presented findings are not meant to be used for commercial purposes, the creation of the investment product(s), or investment decisions. These limitations are also taken from the data providers that state these and other restrictions on data usage beforehand.

Applied terms, evidence, and concepts are taken from the scientific community with proper referencing of the sources. The author acknowledges that everyone might not share these views and encourages *scientific* discussion and critique.

The results were presented at international conferences and research seminars and submitted for publication in the appropriate accredited and recognized journals to ensure the openness and dissemination of the research. The co-authors who contributed to article-writing and the organizations and institutions that providede data for academic research are credited appropriately in the versions for journal publications. All journals used for research dissemination provide Open Access publications, making most findings publicly available.

The author does not have permission to store and share data obtained from third-party providers. Although this might restrict possibilities for an exact research replication, the provided data descriptions should suffice for these purposes.

4 SUMMARY AND DISCUSSION OF ARTICLES

This thesis includes four articles, two of which investigate whether financial markets consider climate risks and incorporate them into asset prices. One of the articles studies how sustainability is related to stock market returns, while another looks at a long-term investment strategy based on climate risk exposure. They relate to each other based on the topic and context, despite the evident focus on different assets or investing strategies (Figure 4.1). This chapter summarizes the articles, provides their key findings, and states this thesis's contributions. The last section elaborates on the limitations and makes suggestions for further research.

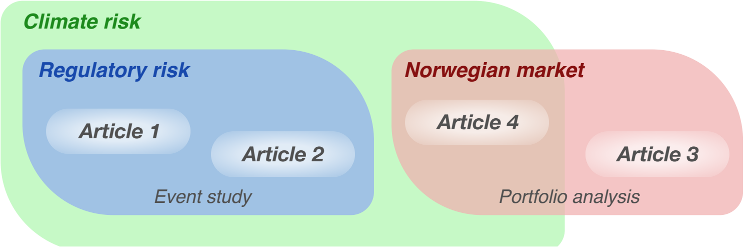

Figure 4.1: The articles' interconnections.

4.1 ARTICLES' SUMMARY

Table 4.1 presents the key findings of each article. These findings can be distinguished into those related to the climate risk discussion in general and those related to sustainable investing in the Norwegian context.

Table 4.1: Overview of the articles and their findings

No	*Title*	*Key finding(s)*
Article 1	”Climate Change Events and Stock Market Returns”	ETFs’ returns react significantly to events, shaping climate policy. The response differs depending on the sector.
Article 2	”Climate Transition Risk and the Impact on Green Bonds”	GBs’ return and volatility changed in connection with events related to climate policy. These events also impacted the relationship with other assets and GBs’ performance.
Article 3	”Sustainable Investments in the Norwegian Stock Market”	High-minus-low ESG exposure portfolios do not offer superior returns. The results suggest no connection between ESG and returns on the Norwegian stock market
Article 4	”The Effect of Climate Disclosure on Stock Market Performance: Evidence from Norway”	The strategy of investing in companies with good climate-related disclosure and shorting ones with weaker disclosure is profitable. The effect comes from the underperformance of the laggards.

Climate change events and stock market returns (Article 1). This article looks at how the US stock market is affected by political events related to the climate change discussion. Results of the event study on a range of exchange-traded funds (ETFs) show that such events indeed carry new, not priced information to the market. Although all sectors included in the study—energy, transport, utilities, energy-intensive, and housing—are meant to be *climate sensitive* in the long run (Battiston and Monasterolo, 2018), some of them react to climate policy changes already. Thus, the first article showcases why transition risks (such as policy introduction and implementation) have a more significant role before irreversible climate change happens.

Climate transition risk and the impact on green bonds (Article 2). Like the first article, this one is also an event study, though focusing on the secondary bond market. The results suggest that climate-related events carry return and volatility shocks to the bond market. This study highlights the differences between green and conventional bonds, which, however, depend on whether bonds are corporate or municipal:

- the Paris Agreement was positively anticipated by the municipal conventional bonds and GBs as well as corporate green bonds, but not conventional corporate ones;
- the results of the 2016 US presidential elections increased bond volatility, especially for municipal bonds, and led to negative price adjustments afterward; and
- in connection to the US pullout from the Paris Agreement, municipal bonds experienced a significant volatility increase and a return decline, while GBs had only the latter.

Climate-change-related events might also be related to the longer-term reaction of the market, as bond indices' performance and correlation with other assets suggest.

The findings show that green corporate bonds might be a better asset for investments as they contribute to sustainability goals and climate change mitigation and are negligibly correlated with other assets, despite changes in the political environment. Thus, they should be considered in hedging strategies. However, due to the negative reaction to the events, they should be used consciously due to climate transition risks that are difficult to price. This additional risk to GBs might cause a time-varying premium for GBs found in previous literature.

Sustainable investments in the Norwegian stock market (Article 3). This article investigates the link between ESG ratings and financial performance in the Norwegian stock market. Norwegian companies' exposure (beta) to ESG factors from 2009 to 2018 was derived as a sensitivity to the Dow Jones Sustainability Nordic Index. The companies were ranked based on exposure and were combined in portfolios. The constructed ESG portfolios did not show any significant return difference based on a high-low strategy, which is robust for market sensitivity, investment style, and industry bias. These results do not suggest any connection between ESG and stock returns in the Norwegian stock market.

The effect of climate disclosure on stock market performance: Evidence from Norway (Article 4). This article explores an investment strategy based on the positive screening of companies that disclose their carbon footprint alongside their strategic plans for adaptation and coping with climate change. Based on the scores from the CDP's Climate Change questionnaire results, companies were categorized as those with high, low, and missing disclosures. It was argued that such disclosure could be used as a proxy for exposure to climate transition risk (low, high, and unknown risk, respectively). The study shows that a portfolio of companies with higher scores performs better than those with low or no scores. Moreover, after controlling for common risk factors, the portfolio with low scores (high climate risk) had negative excess returns. This means that the Norwegian stock market punishes companies for worse climate-related disclosure.

The results of this article suggest that better-disclosing companies have a better performance in terms of Sharpe and information ratios and improve their performance over time. Thus, such a climate-aligned investment strategy is profitable on the Norwegian stock market.

4.2 DISCUSSION AND CONTRIBUTIONS

Climate risks are of a new type that has not been fully priced and has not wholly been studied yet (Daugaard, 2020). This thesis contributes to the understanding of how climate risks are priced on the market. The findings suggest that investors and the overall financial market account for climate risks. Specifically, this research has discovered that stock and bond markets adjust to the climate risk rooted in the transition policy and regulatory risk. By applying event study to climate-policy-related events, the thesis shows that even potential changes in climate policies create price fluctuations on the market. Asset price reaction is sector dependent because not all industries are equally exposed to climate risks. Moreover, the evident sustainable alignment of GBs does not eliminate their exposure to climate risks. This finding highlights the importance of integrating climate risks into investment decisions.

The thesis also has investigated sustainable investment strategies, enriching existing literature and providing evidence from the Norwegian context. The results suggest that investments based on overarching sustainable sensitivity are not profitable on the Norwegian stock market. The thesis thus argues that a climate-aligned strategy would be profitable if investors could distinguish assets by their exposure and/or vulnerability to climate change. It has been shown that climate risk proxied from climate-related disclosure can be used to make long-term investments. Thus, the thesis proposes a forward-looking measure for a company's climate risk exposure and vulnerability and supports the critique of using the ESG rating for these purposes. It has been argued that climate-related disclosure is superior to carbon performance measures, which are deemed backward-looking measures that might not have a predictive advantage for future cash flows (Benedetti et al., 2019). In contrast, climate-related disclosure incorporates strategies and plans for climate change adaptation and highlights new opportunities for their business that climate change brings. This measure aligns better with the long-term value creation principle of sustainable finance.

By studying climate-aligned investment, this thesis presents new unique findings, namely significant negative abnormal returns for the portfolio of companies with higher and unknown climate risks. Thus, this thesis has shown that climate risks are not fully and correctly priced on the market. The exposure to higher climate risks is not appropriately compensated for, as findings for the Norwegian market show. By avoiding climate-risk-exposed companies, investors create a situation on the market when such stocks perform the worst. The performance analysis of the climate-aligned portfolio suggests that this strategy is profitable while offering long-term orientation and lower climate risk exposure for investors.

In summary, this dissertation makes the following contributions:

- discovery of climate transition risk's impact on the stock and bond market, also focusing on a sector-specific response;
- application of the event study for the analysis of climate regulatory risks;
- provision of a new measure of climate risk exposure for companies;

- demonstration of the sustainable portfolio performance on the Norwegian stock market; and
- implementation of the climate-aligned investment strategy and testing it through historical data.

Based on the examples from empirical asset pricing, this thesis provides practical evidence for further developing the theory about climate-aligned investments and pricing of climate and sustainable risks. Described contributions offer nuanced knowledge about the financial impact of climate change, differentiating it from issues related to sustainability and exemplifying this matter in the Norwegian context.

The findings of this empirical research support the hypothesis about climate alpha made in the previous studies. Alongside the changing performance over time of the climate-aligned portfolio, this means that the market adjusts to the available information and learns from it, adapting risk pricing accordingly. The underperformance of the high-climate-risk stocks found in the fourth scientific article significantly contributes to climate alpha magnitude by increasing it. The discovery of climate alpha can be seen as evidence of the shift to a longer-term investment. It also justifies the use of sustainable finance assumptions for climate risk research.

4.3 LIMITATION AND IMPLICATION FOR FURTHER STUDIES

Some of the limitations are closely related to data availability. The data sources at disposal provided mostly trading information, and asset-specific information was scarce (especially for Articles 1 and 2).

The usage of event study helped reveal the market reaction to climate policy-related events. However, its application on the aggregated assets, which ESGs and bond indices are, is not fully utilized. When this method is used on the individual stocks and/or bonds, the estimated abnormal returns could be used to analyze firm-specific characteristics that shape the reaction to an event: size, industry, country, maturity, liquidity, and so on. In addition, the inclusion of carbon performance in abnormal returns modeling could offer a more nuanced understanding of how carbon risk exposure relates to climate regulatory risk from an empirical perspective.

Although previous studies have shown that national context matters in sustainable finance and carbon disclosure (Grauel and Gotthardt, 2016), one may argue that the Norwegian stock market is relatively small. It also affected the sample size and limited the generalization of the findings in Articles 3 and 4. It might be beneficial to extend the sample to the Nordic countries to discover region-specific climate risk pricing. Alternatively, the European market could be investigated similarly in further studies. The European Green Deal, which defines the strategy, objectives, and country-specific targets for greenhouse gas emissions reduction, contributes to a unique context for discovering market pricing of climate risk.

Despite referring to sustainable finance, this research relied on the mainstream finance methodology. By doing so, the thesis appealed to a risk-return relationship common for a contemporary investor, showing that even in this setting, climate risks must be considered. However, it might be interesting to include sustainable finance considerations in decision-making, considering climate risk simultaneously with returns and financial risk criteria.

5 REFERENCES

Addoum, J. M., Ng, D. T., and Ortiz-Bobea, A. (2020). Temperature shocks and establishment sales. *Review of Financial Studies*, 33(3):1331–1366.

Agliardi, E. and Agliardi, R. (2021). Corporate green bonds: Understanding the greenium in a two-factor structural model. *Environmental and Resource Economics*.

Alessi, L., Ossola, E., and Panzica, R. (2020). The greenium matters: Greenhouse gas emissions, environmental disclosures, and stock prices. JRC working papers in economics and finance, Publications Office of the European Union, Luxembourg.

Allen, M., Crawford, K., Théot, J., and Toscani, L. (2015). Climate change and capital markets. Working paper, Graduate School of Stanford Business, Stanford.

Alok, S., Kumar, N., and Wermers, R. (2020). Do fund managers misestimate climatic disaster risk. *Review of Financial Studies*, 33(3):1146–1183.

Andersson, M., Bolton, P., and Samama, F. (2016). Hedging climate risk. *Financial Analysts Journal*, 72(3):1–43.

Andreae, M. O., Jones, C. D., and Cox, P. M. (2005). Strong present-day aerosol cooling implies a hot future. *Nature*, 435(7046):1187–1190.

Ardalan, K. (2018). The “modern” in “modern finance”: A multi-paradigmatic look. *Research in International Business and Finance*, 45:475–487.

Ashwin Kumar, N. C., Smith, C., Badis, L., Wang, N., Ambrosy, P., and Tavares, R. (2016). ESG factors and risk-adjusted performance: A new quantitative model. *Journal of Sustainable Finance and Investment*, 6(4):292–300.

Atz, U., van Holt, T., and Liu, Z. Z. (2020). Do corporate sustainability and sustainable finance generate better financial performance? A review and meta-analysis. *SSRN Electronic Journal*.

Auer, B. R. and Schuhmacher, F. (2016). Do socially (ir)responsible investments pay? New evidence from international ESG data. *Quarterly Review of Economics and Finance*, 59:51–62.

Aven, T. (2019). Climate change risk — what is it and how should it be expressed? *Journal of Risk Research*, pages 1–18.

Bachelet, M. J., Becchetti, L., and Manfredonia, S. (2019). The green bonds premium puzzle: The role of issuer characteristics and third-party verification. *Sustainability*, 11(4):1098.

Baker, M., Bergstresser, D., Serafeim, G., and Wurgler, J. (2018). Financing the response to climate change: The pricing and ownership of U.S. green bonds. NBER Working Paper 25194, National Bureau of Economic Research, Cambridge.

Baldauf, M., Garlappi, L., and Yannelis, C. (2020). Does climate change affect real estate price? Only if you believe in it. *The Review of Financial Studies*, 33(3):1256–1295.

Banga, J. (2019). The green bond market: A potential source of climate finance for developing countries. *Journal of Sustainable Finance and Investment*, 9(1):17–32.

Bansal, R., Kiku, D., and Ochoa, M. (2019). Climate change risk. Working Paper, Duke University's Fuqua School of Business, Durham.

Barnett, M. (2019). A run on oil: Climate policy, stranded assets, and asset prices. Working Paper, University of Chicago, Chicago.

Barnett, M. L. and Salomon, R. M. (2006). Beyond dichotomy: The curvilinear relationship between social responsibility and financial performance. *Strategic Management Journal*, 27(11):1101–1122.

Baron, D. P., Agus Harjoto, M., and Jo, H. (2011). The economics and politics of corporate social performance. *Business and Politics*, 13(2).

Battiston, S. and Monasterolo, I. (2018). The climate target gap is widening. Can we close it by including climate finance in SSPs? *SSRN Electronic Journal*.

Baulkaran, V. (2019). Stock market reaction to green bond issuance. *Journal of Asset Management*, 20:331–340.

Bender, J., Bridges, T. A., and Shah, K. (2019). Reinventing climate investing: Building equity portfolios for climate risk mitigation and adaptation. *Journal of Sustainable Finance and Investment*, 9(3):191–213.

Benedetti, D., Biffis, E., Chatzimichalakis, F., Fedele, L. L., and Simm, I. (2019). Climate change investment risk: Optimal portfolio construction ahead of the transition to a lower-carbon economy. *Annals of Operations Research*.

Bennani, L., Le Guenedal, T., Lepetit, F., Ly, L., Mortier, V., Roncalli, T., and Sekine, T. (2018). How ESG investing has impacted the asset pricing in the equity market. *SSRN Electronic Journal*.

Berg, F., Koelbel, J. F., and Rigobon, R. (2020). Aggregate confusion: the divergence of ESG ratings. Working Paper, MIT Sloan School of Management, Cambridge.

Bernardini, E., Di Giampaolo, J., Faiella, I., and Poli, R. (2021). The impact of carbon risk on stock returns: Evidence from the European electric utilities. *Journal of Sustainable Finance and Investment*, 11(1):1–26.

Bernstein, A., Gustafson, M. T., and Lewis, R. (2019). Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics*, 134(2):253–272.

Bodie, Z., Kane, A., and Marcus, A. (2018). *Investments*. McGraw-Hill Education, New York, NY, eleventh edition.

Boehmer, E., Musumeci, J., and Poulsen, A. B. (1991). Event-study methodology under conditions of event-induced variance. *Journal of Financial Economics*, 30(2):253–272.

Bolton, P. and Kacperczyk, M. T. (2021). Do investors care about carbon risk? *Journal of Financial Econometrics*, 142(2):517–549.

Bourdeau-Brien, M. and Kryzanowski, L. (2020). Natural disasters and risk aversion. *Journal of Economic Behavior and Organization*, 177:818–835.

Boutin-Dufresne, F. and Savaria, P. (2004). Corporate social responsibility and financial risk. *The Journal of Investing*, 13(1):57–66.

Broadstock, D. C. and Cheng, L. T. (2019). Time-varying relation between black and green bond price benchmarks: Macroeconomic determinants for the first decade. *Finance Research Letters*, 29:17–22.

Brøgger, A. and Kronies, A. (2020). Skills and sentiment in sustainable investing. Working Paper, Copenhagen Business School, Copenhagen.

Brown, J. R., Gustafson, M. T., and Ivanov, I. T. (2021). Weathering cash flow shocks. *Journal of Finance*, 76(4):1731–1772.

Brown, S. (2016). Climate risk. *Financial Analysts Journal*, 72(3):2–2.

Bryant, A., Griffin, J. J., and Perry, V. G. (2019). Mitigating climate change: A role for regulations and risk-taking. *Business Strategy and the Environment*, pages bse.2391–bse.2391.

Buchholz, W. and Rübbelke, D. (2020). Overstraining international climate finance: When conflicts of objectives threaten its success. *SSRN Electronic Journal*.

Buhr, B. (2017). Assessing the sources of stranded asset risk: A proposed framework. *Journal of Sustainable Finance and Investment*, 7(1):37–53.

Caldecott, B. (2017). Introduction to special issue: Stranded assets and the environment. *Journal of Sustainable Finance and Investment*, 7(1):1–13.

Capasso, G., Gianfrate, G., and Spinelli, M. (2020). Climate change and credit risk. *Journal of Cleaner Production*, 266:121634.

Caragnano, A., Mariani, M., Pizzutilo, F., and Zito, M. (2020). Is it worth reducing GHG emissions? Exploring the effect on the cost of debt financing. *Journal of Environmental Management*, 270:110860.

Carhart, M. (1997). On persistence in mutual fund performance. *The Journal of Finance*, 52(1):57–82.

Carpentier, C. and Suret, J.-M. (2015). Stock market and deterrence effect: A mid-run analysis of major environmental and non-environmental accidents. *Journal of Environmental Economics and Management*, 71:1–18.

CBI (2018). Green bonds: The state of the market 2018. Technical report, Climate Bonds Initiative.

Ceccarelli, M., Ramelli, S., and Wagner, A. F. (2020). Low-carbon mutual funds. Finance Working Paper 659/2020, European Corporate Governance Institute, Brussels.

Chatterji, A. K., Durand, R., Levine, D. I., and Touboul, S. (2016). Do ratings of firms converge? Implications for managers, investors and strategy researchers. *Strategic Management Journal*, 37(8):1597–1614.

Choi, B., Luo, L., and Shrestha, P. (2021). The value relevance of carbon emissions information from Australian-listed companies. *Australian Journal of Management*, 46(1):3–23.

Choudhury, B. (2020). Climate change as systemic risk. *SSRN Electronic Journal*.

Christophers, B. (2019). Environmental beta or How institutional investors think about climate change and fossil fuel risk. *Annals of the American Association of Geographers*, 109(3):754–774.

CICERO (2015). CICERO Shades of green. https://www.cicero.oslo.no/en/posts/single/cicero-shades-of-green.

Clapp, C. (2014). Climate finance: Capitalising on green investment trends. In de Coninck, H., Lorch, R., and Sagar, A., editors, *The Way Forward in International Climate Policy: Key Issues and New Ideas 2014*, pages 44–48. Climate and Development Knowledge Network and Climate Strategies, London.

Clapp, C., Lund, H. F., Borgar, A., and Lannoo, E. (2017). Shades of climate risk: Categorizing climate risk for investors. Technical Report 2017:1, CICERO Center for International Climate Research, Oslo.

Cohen, M. A., Fenn, S. A., and Konar, S. (1997). Environmental and financial performance: Are they related? Working paper, Investor Responsibility Research Center, New York.

Daugaard, D. (2020). Emerging new themes in environmental, social and governance investing: A systematic literature review. *Accounting & Finance*, 60(2):1501–1530.

De Jong, M. and Nguyen, A. (2016). Weathered for climate risk: A bond investment proposition. *Financial Analysts Journal*, 72(3):34–39.

de Souza Cunha, F. A. F., de Oliveira, E. M., Orsato, R. J., Klotzle, M. C., Cyrino Oliveira, F. L., and Caiado, R. G. G. (2019). Can sustainable investments outperform traditional benchmarks? Evidence from global stock markets. *Business Strategy and the Environment*, 29(2):682–697.

De Spiegeleer, J., Höcht, S., Jakubowski, D., Reyners, S., and Schoutens, W. (2021). ESG: a new dimension in portfolio allocation. *Journal of Sustainable Finance & Investment*, pages 1–41.

Dell, M., Jones, B., and Olken, B. (2014). What do we learn from the weather? The new climate-economy literature. *Journal of Economic Literature*, 52(3):740–798.

Derwall, J., Koedijk, K., and Ter Horst, J. (2011). A tale of values-driven and profit-seeking social investors. *Journal of Banking and Finance*, 35(8):2137–2147.

Deschryver, P. and de Mariz, F. (2020). What future for the green bond market? How can policymakers, companies, and investors unlock the potential of the green bond market? *Journal of Risk and Financial Management*, 13(3):61.

Diaz-Rainey, I., Robertson, B., and Wilson, C. (2017). Stranded research? Leading finance journals are silent on climate change. *Climatic Change*, 143(1-2):243–260.

Dietz, S., Bowen, A., Dixon, C., and Gradwell, P. (2016). ‘Climate value at risk’ of global financial assets. *Nature Climate Change*, 6(7):676–679.

Dordi, T. and Weber, O. (2019). The impact of divestment announcements on the share price of fossil fuel stocks. *Sustainability*, 11(11):3122.

Dorfleitner, G., Utz, S., and Zhang, R. (2021). The pricing of green bonds: External reviews and the shades of green. *Review of Managerial Science*.

Drei, A., Le Guenedal, T., Lepetit, F., Mortier, V., Roncalli, T., and Sekine, T. (2019). ESG investing in recent years: New insights from old challenges. Technical report, Amundi Asset Management, Paris.

Easterling, D., Meehl, G., Parmesan, C., Changnon, S., Karl, T., and Mearns, L. (2000). Climate extremes: observations, modeling, and impacts. *Science*, 289(5487):2068–2074.

Engle, R. F., Giglio, S., Kelly, B., Lee, H., and Stroebel, J. (2020). Hedging climate change news. *Review of Financial Studies*, 33(3):1184–1216.

Escrig-Olmedo, E., ángeles Fernández-Izquierdo, M., Ferrero-Ferrero, I., Rivera-Lirio, J. M., and Muñoz-Torres, M. J. (2019). Rating the raters: Evaluating how ESG rating agencies integrate sustainability principles. *Sustainability*, 11(3).

European Commission (2021). Overview of sustainable finance. https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/what-sustainable-finance_en.

Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. *The Journal of Finance*, 25(2):383–417.

Fama, E. F. (1998). Market efficiency, long-term returns, and behavioral finance. *Journal of Financial Economics*, 49:283–306.

Fama, E. F., Fisher, L., Jensen, M. C., and Roll, R. (1969). The adjustment of stock prices to new information. *International Economic Review*, 10(1):1–1.

Fama, E. F. and French, K. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, 33:3–56.

Fama, E. F. and French, K. R. (2015). A five-factor asset pricing model. *Journal of Financial Economics*, 116(1):1–22.

Fankhauser, S., Sahni, A., Savvas, A., and Ward, J. (2016). Where are the gaps in climate finance? *Climate and Development*, 8(3):203–206.

Fatica, S. and Panzica, R. (2021). Green bonds as a tool against climate change? *Business Strategy and the Environment*, 30(5):2688–2701.

Fatica, S., Panzica, R., and Rancan, M. (2021). The pricing of green bonds: Are financial institutions special? *Journal of Financial Stability*, 54:100873.

Feng, G., Giglio, S., and Xiu, D. (2020). Taming the factor zoo: A test of new factors. *Journal of Finance*, 75(3):1327–1370.

Fernández-Cuesta, C., Castro, P., Tascón, M. T., and Castaño, F. J. (2019). The effect of environmental performance on financial debt. European evidence. *Journal of Cleaner Production*, 207:379–390.

Flaherty, M., Gevorkyan, A., Radpour, S., and Semmler, W. (2017). Financing climate policies through climate bonds — A three stage model and empirics. *Research in International Business and Finance*, 42:468–479.

Flammer, C. (2021). Corporate green bonds. *Journal of Financial Econometrics*.

Friede, G., Busch, T., and Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance and Investment*, 5(4):210–233.

Gasbarro, F., Iraldo, F., and Daddi, T. (2017). The drivers of multinational enterprises' climate change strategies: A quantitative study on climate-related risks and opportunities. *Journal of Cleaner Production*, 160:8–26.

Gerard, B. (2019). ESG and socially responsible investment: A critical review. *Beta*, 33(1):61–83.

Gianfrate, G. and Peri, M. (2019). The green advantage: Exploring the convenience of issuing green bonds. *Journal of Cleaner Production*, 219:127–135.

Giglio, S., Kelly, B., and Stroebel, J. (2021). Climate finance. *Annual Review of Financial Economics*, 13:15–36.

Ginglinger, E. and Moreau, Q. (2019). Climate risk and capital structure. Finance Working Paper 737/2021, European Corporate Governance Institute, Brussels.

Global Commission on Adaptation (2019). Adapt now: A global call for leadership on climate resilience. Technical report, World Resources Institute and the Global Center on Adaptation, Washington.

Glomsrød, S. and Wei, T. (2018). Business as unusual: The implications of fossil divestment and green bonds for financial flows, economic growth and energy market. *Energy for Sustainable Development*, 44:1–10.

Gollier, C. (2013). *Pricing the future: The economics of discounting and sustainable development*. Princeton University Press.

Grauel, J. and Gotthardt, D. (2016). The relevance of national contexts for carbon disclosure decisions of stock-listed companies: A multilevel analysis. *Journal of Cleaner Production*, 133:1204–1217.

Grubb, M., Hourcade, J. C., and Neuhoff, K. (2015). The Three Domains structure of energy-climate transitions. *Technological Forecasting and Social Change*, 98:290–302.

Guerard, J. B. (1997). Is there a cost to being socially responsible in investing? *Journal of Forecasting*, 16(7):475–490.

Gyönyörová, L., Stachoň, M., and Stašek, D. (2021). ESG ratings: Relevant information or misleading clue? Evidence from the S&P Global 1200. *Journal of Sustainable Finance & Investment*, pages 1–35.

Hachenberg, B. and Schiereck, D. (2018). Are green bonds priced differently from conventional bonds? *Journal of Asset Management*, 19(6):371–383.

Hall, S., Foxon, T. J., and Bolton, R. (2017). Investing in low-carbon transitions: Energy finance as an adaptive market. *Climate Policy*, 17(3):280–298.

Hamilton, J. T. (1995). Pollution as news: Media and stock market reactions to the toxics release inventory data. *Journal of Environmental Economics and Management*, 28(1):98–113.

Hartzmark, S. M. and Sussman, A. B. (2019). Do investors value sustainability? A natural experiment examining ranking and fund flows. *Journal of Finance*, 74(6):2789–2837.

Hofweber, T. (2021). Logic and ontology. *Stanford Encyclopedia of Philosophy*.

Hong, H., Karolyi, G. A., and Scheinkman, J. A. (2020). Climate finance. *Review of Financial Studies*, 33(3):1011–1023.

Hong, H., Li, F. W., and Xu, J. (2019). Climate risks and market efficiency. *Journal of Econometrics*, 208(1):265–281.

Horsch, A. and Richter, S. (2017). Climate change driving financial innovation: the case of green bonds. *The Journal of Structured Finance*, 23(1):79–90.

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Rasmussen, D. J., Muir-wood, R., Wilson, P., Oppenheimer, M., Larsen, K., and Houser, T. (2017). Economic damage from climate change in the United States. *Science*, 1369(June):1362–1369.

Hsu, P.-H., Li, K., and Tsou, C.-Y. (2020). The pollution premium. *SSRN Electronic Journal*.

Huang, H. H., Kerstein, J., and Wang, C. (2018). The impact of climate risk on firm performance and financing choices: An international comparison. *Journal of International Business Studies*, 49(5):633–656.

Hübel, B. and Scholz, H. (2020). Integrating sustainability risks in asset management: The role of ESG exposures and ESG ratings. *Journal of Asset Management*, 21:52–69.

Hung, N. T. (2021). Nexus between green bonds, financial, and environmental indicators. *Economics and Business Letters*, 10(3):191–199.

Hunt, C. and Weber, O. (2019). Fossil fuel divestment strategies: Financial and carbon-related consequences. *Organization and Environment*, 32(1):41–61.

Hyun, S., Park, D., and Tian, S. (2019). The price of going green: The role of greenness in green bond markets. *Accounting & Finance*, 60(1):73–95.

Hyun, S., Park, D., and Tian, S. (2021). Pricing of green labeling: A comparison of labeled and unlabeled green bonds. *Finance Research Letters*, 41:101816.

ICMA (2018). Green bond principles: Voluntary process guidelines for issuing green bonds.

Ilhan, E., Sautner, Z., and Vilkov, G. (2020). Carbon tail risk. *The Review of Financial Studies*.

Immel, M., Hachenberg, B., Kiesel, F., and Schiereck, D. (2021). Green bonds: shades of green and brown. *Journal of Asset Management*, 22(2):96–109.

In, S. Y., Park, K. Y., and Monk, A. (2019). Is ”Being Green” rewarded in the market? An empirical investigation of decarbonization risk and stock returns. Working paper, Stanford Global Projects Center, Stanford.

IPCC (2014). Climate Change 2014: Synthesis report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Technical report, Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Jaggi, B., Allini, A., Macchioni, R., and Zampella, A. (2017). Do investors find carbon information useful? Evidence from Italian firms. *Review of Quantitative Finance and Accounting*, 50(1):1031–1056.

Jakubik, P. and Uguz, S. (2021). Impact of green bond policies on insurers: Evidence from the European equity market. *Journal of Economics and Finance*, 45:381–393.

Jiang, R. and Weng, C. (2020). Climate change risk and agriculture-related stocks. *SSRN Electronic Journal*.

Jin, I. (2018). Is ESG a systematic risk factor for US equity mutual funds? *Journal of Sustainable Finance and Investment*, 8(1):72–93.

Jin, J., Han, L., Wu, L., and Zeng, H. (2020). The hedging effect of green bonds on carbon market risk. *International Review of Financial Analysis*, 71:101509.

Jongman, B., Hochrainer-Stigler, S., Feyen, L., Aerts, J. C. J. H., Mechler, R., Botzen, W. J. W., Bouwer, L. M., Pflug, G., Rojas, R., and Ward, P. J. (2014). Increasing stress on disaster-risk finance due to large floods. *Nature Climate Change*, 4(4):264–268.

Jung, J., Herbohn, K., and Clarkson, P. (2018). Carbon risk, carbon risk awareness and the cost of debt financing. *Journal of Business Ethics*, 150(4):1151–1171.

Kanamura, T. (2020). Are green bonds environmentally friendly and good performing assets? *Energy Economics*, 88:104767.

Karpf, A. and Mandel, A. (2018). The changing value of the ’green’ label on the US municipal bond market. *Nature Climate Change*, 8(2):161–165.

Kempf, A. and Osthoff, P. (2007). The effect of socially responsible investing on portfolio performance. *European Financial Management*, 13(5):908–922.

Keys, B. J. and Mulder, P. (2020). Neglected no more: Housing market, mortgage lending and sea level rise. NBER Working Paper 27930, National Bureau of Economic Research, Cambridge.

Kim, S. and Li, Z. (2021). Understanding the impact of ESG practices in corporate finance. *Sustainability*, 13(7):3746.

Kling, G., Volz, U., Murinde, V., and Ayas, S. (2021). The impact of climate vulnerability on firms’ cost of capital and access to finance. *World Development*, 137:105131.

Kochetygova, J. and Jauhari, A. (2014). Climate change, green bonds, and index investing: The new frontier. Technical Report August, S&P Dow Jones Indices, London.

Kolari, J. W. and Pynnönen, S. (2010). Event study testing with cross-sectional correlation of abnormal returns. *Review of Financial Studies*, 23(11):3996–4025.

Kölbel, J. F., Leippold, M., Rillaerts, J., and Wang, Q. (2020). Ask BERT: How regulatory disclosure of transition and physical climate risks affects the CDS term structure. Research paper 21-19, Swiss Finance Institute, Genève.

Kothari, S. and Warner, J. (2007). Econometrics of event studies. In Eckbo, B. E., editor, *Handbook of Empirical Corporate Finance*, pages 3–36. Elsevier.

Kouloukoui, D., Marinho, M. M. d. O., Gomes, S. M. d. S., Kiperstok, A., and Torres, E. A. (2019). Corporate climate risk management and the implementation of climate projects by the world's largest emitters. *Journal of Cleaner Production*, 238:117935.

Krueger, P., Sautner, Z., and Starks, L. T. (2020). The importance of climate risks for institutional investors. *Review of Financial Studies*, 33(3):1067–1111.

Kruttli, M. S., Tran, B. R., and Watugala, S. W. (2019). Pricing Poseidon: Extreme weather uncertainty and firm return dynamics. *SSRN Electronic Journal*.

Kumar, A., Xin, W., and Zhang, C. (2019). Climate sensitivity and predictable returns. *SSRN Electronic Journal*, pages 1–38.

Ladyman, J. (2001). *Understanding philosophy of science*. Routledge, London, first edition.

Lagoarde-Segot, T. (2015). Diversifying finance research: From financialization to sustainability. *International Review of Financial Analysis*, 39:1–6.

Lagoarde-Segot, T. (2019). Sustainable finance. A critical realist perspective. *Research in International Business and Finance*, 47:1–9.

Larcker, D. F. and Watts, E. M. (2020). Where's the greenium? *Journal of Accounting and Economics*, 69(2-3):101312–101312.

Lee, C.-C., Lee, C. C., and Li, Y. Y. (2021). Oil price shocks, geopolitical risks, and green bond market dynamics. *North American Journal of Economics and Finance*, 55:101309.

Lee, D. D. and Faff, R. W. (2009). Corporate sustainability performance and idiosyncratic risk: A global perspective. *Financial Review*, 44(2):213–237.

Levi, M. and Newton, D. (2016). Flash of green: are environmentally driven stock returns sustainable? *Managerial Finance*, 42(11):1091–1109.

Li, M., Dong, L., Luan, J., and Wang, P. (2020). Do environmental regulations affect investors? Evidence from China's action plan for air pollution prevention. *Journal of Cleaner Production*, 244:118817.

Liang, H. and Renneboog, L. (2020). Corporate social responsibility and sustainable finance: A review of the literature. *ECGI Working Paper Series in Finance*.

Liaw, K. T. (2020). Survey of green bond pricing and investment performance. *Journal of Risk and Financial Management*, 13(9):193.

Liesen, A. (2015). Climate change and financial market efficiency. *Business & Society*, 54(4):511–539.

Liesen, A., Figge, F., Hoepner, A., and Patten, D. M. (2017). Climate change and asset prices: Are corporate carbon disclosure and performance priced appropriately? *Journal of Business Finance and Accounting*, 44(1-2):35–62.

Lintner, J. (1965). The valuation of risky assets and the selection of risky investments in stock portfolio and capital budgets. *Review of Economics and Statistics*, 47(1):13–27.

Lo, A. (2004). The adaptive market hypothesis: market efficiency from an evolutionary perspective. *The Journal of Portfolio Management*, 30(5):15–29.

Lucas, E. C., Mendes-Da-Silva, W., and Araujo, G. S. (2019). Does extreme rainfall lead to heavy losses in the food industry? *Academia Revista Latinoamericana de Administracion*, 32(2):244–266.

MacAskill, S., Roca, E. D., Liu, B., Stewart, R. A., and Sahin, O. (2020). Is there a green premium in the green bond market? Systematic literature review revealing premium determinants. *Journal of Cleaner Production*, 280(2):124491.

Maltais, A. and Nykvist, B. (2020). Understanding the role of green bonds in advancing sustainability. *Journal of Sustainable Finance and Investment*.

Margolis, J. D., Elfenbein, H. A., and Walsh, J. P. (2012). Does it pay to be good... and does it matter? A meta-analysis of the relationship between corporate social and financial performance. *SSRN Electronic Journal*.

Markowitz, H. M. (1952). Mean-variance analysis in portfolio choice and capital markets. *Journal of Finance*, 7:77–91.

Matthews, D., Gillett, N., Stott, P., and Zickfeld, K. (2009). The proportionality of global warming to cumulative carbon emissions. *Nature*, 459(7248):829–832.

Matthews, T., Wilby, R. L., and Murphy, C. (2017). Communicating the deadly consequences of global warming for human heat stress. *Proceedings of the National Academy of Sciences*, 114(15):3861–3866.

McWilliams, A. and Siegel, D. (2000). Corporate social responsibility and financial performance: Correlation or misspecification? *Strategic Management Journal*, 21(5):603–609.

Mendelsohn, R., Nordhaus, W., and Shaw, D. (1994). The impact of global warming on agriculture: A Ricardian analysis. *American Economic Review*, 84(4):753–771.

Miao, Q. and Popp, D. (2014). Necessity as the mother of invention: Innovative responses to natural disasters. *Journal of Environmental Economics and Management*, 68(2):280–295.

Morel, R. and Bordier, C. (2012). Financing the transition to a green economy: Their word is their (green) bond? (Climate Brief N°14).

Mossin, J. (1966). Equilibrium in a capital asset market. *Econometrica*, 34(4):768–768.

Murfin, J. and Spiegel, M. (2020). Is the risk of sea level rise capitalized in residential real estate? *Review of Financial Studies*, 33(3):1217–1255.

Naeem, M. A., Adekoya, O. B., and Oliyide, J. A. (2021). Asymmetric spillovers between green bonds and commodities. *Journal of Cleaner Production*, 314:128100.

Nagar, V. and Schoenfeld, J. (2020). Is weather a systematic risk? Evidence from annual reports. Working paper 3438428, Tuck School of Business, Hanover.

Nanayakkara, M. and Colombage, S. (2019). Do investors in green bond market pay a premium? Global evidence. *Applied Economics*, 51(40):4425–4437.

NASA (2021). The causes of climate change. https://climate.nasa.gov/resources/global-warming-vs-climate-change/.

Nguyen, T. T. H., Naeem, M. A., Balli, F., Balli, H. O., and Vo, X. V. (2020). Time-frequency comovement among green bonds, stocks, commodities, clean energy, and conventional bonds. *Finance Research Letters*, 40:101739.

Nordhaus, W. (2017). Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences of the United States of America*, 114(7):1518–1523.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review*, 109(6):1991–2014.

Oberndorfer, U., Schmidt, P., Wagner, M., and Ziegler, A. (2013). Does the stock market value the inclusion in a sustainability stock index? An event study analysis for German firms. *Journal of Environmental Economics and Management*, 66(3):497–509.

Painter, M. (2019). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*, 135(2):468–482.

Palea, V. and Drogo, F. (2020). Carbon emissions and the cost of debt in the eurozone: The role of public policies, climate-related disclosure and corporate governance. *Business Strategy and the Environment*.

Park, D., Park, J., and Ryu, D. (2020). Volatility spillovers between equity and green bond markets. *Sustainability*, 12(9):3722.

Partridge, C. and Medda, F. R. (2020). The evolution of pricing performance of green municipal bonds. *Journal of Sustainable Finance and Investment*, 10(1):44–64.

Pástor, Ľ. and Stambaugh, R. F. (2002). Mutual fund performance and seemingly unrelated assets. *Journal of Financial Economics*, 63(3):315–349.

Patell, J. M. (1976). Corporate forecasts of earnings per share and stock price behavior: Empirical test. *Journal of Accounting Research*, 14(2):246–246.

Peixinho, R. M. and Coelho, L. M. (2005). Philosophy of research in accounting and finance — A critical reflexion. In *Estudos II*, pages 571–587. Faculty of Economics at University of Algarve.

Pham, L. (2016). Is it risky to go green? A volatility analysis of the green bond market. *Journal of Sustainable Finance and Investment*, 6(4):263–291.

Phillips, P. C., Leirvik, T., and Storelvmo, T. (2020). Econometric estimates of Earth's transient climate sensitivity. *Journal of Econometrics*, 214(1):6–32.

Pindyck, R. S. (2013). Climate change policy: What do the models tell us? *Journal of Economic Literature*, 51(3):1–23.

Pizzutilo, F., Mariani, M., Caragnano, A., and Zito, M. (2020). Dealing with carbon risk and the cost of debt: Evidence from the European market. *International Journal of Financial Studies*, 8(4):1–10.

Plantinga, A. and Scholtens, B. (2021). The financial impact of fossil fuel divestment. *Climate Policy*, 21(1):107–119.

Ramadorai, T. and Zeni, F. (2019). Climate regulation and emissions abatement: Theory and evidence from firms' disclosures. *SSRN Electronic Journal*, page 60.

Reboredo, J. C. (2018). Green bond and financial markets: Co-movement, diversification and price spillover effects. *Energy Economics*, 74:38–50.

Reboredo, J. C. and Ugolini, A. (2020). Price connectedness between green bond and financial markets. *Economic Modelling*, 88:25–38.

Reboredo, J. C., Ugolini, A., and Aiube, F. A. L. (2020). Network connectedness of green bonds and asset classes. *Energy Economics*, 86:104629.

Rehman, M. U. and Vo, X. V. (2020). Is a portfolio of socially responsible firms profitable for investors? *Journal of Sustainable Finance and Investment*, 10(2):191–212.

Reichelt, H. (2010). Green bonds: A model to mobilise private capital to fund climate change mitigation and adaptation projects. In *Environmental finance handbook*, Euromoney handbooks, pages 1–7. The Euromoney, Washington, DC.

Rekker, S. A. C., Humphrey, J. E., and O'Brien, K. R. (2019). Do sustainability rating schemes capture climate goals? *Business & Society*, 60(1):000765031982576.

Renneboog, L., Ter Horst, J., and Zhang, C. (2008). The price of ethics and stakeholder governance: The performance of socially responsible mutual funds. *Journal of Corporate Finance*, 14(3):302–322.

Ritchie, J. and Dowlatabadi, H. (2015). Divest from the carbon bubble? Reviewing the implications and limitations of fossil fuel divestment for institutional investors. *Review of Economics & Finance*, 5(2):59–80.

Ryan, B., Scapens, R. W., and Theobold, M. (2002). Research methods and methodology in finance and accounting. *Research Methods in Finance and Accounting*, pages Chapter 1–Chapter 1.

Sakhel, A. (2017). Corporate climate risk management: Are European companies prepared? *Journal of Cleaner Production*, 165:103–118.

Sanderson, B. M. and O'Neill, B. C. (2020). Assessing the costs of historical inaction on climate change. *Scientific Reports*, 10(1):1–12.

Sartzetakis, E. S. (2021). Green bonds as an instrument to finance low carbon transition. *Economic Change and Restructuring*, 54:755–779.

Schaeffer, R., Borba, B. S., Rathmann, R., Szklo, A., and Castelo Branco, D. A. (2012). Dow Jones sustainability index transmission to oil stock market returns: A GARCH approach. *Energy*, 45(1):933–943.

Schlenker, W. and Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proceedings of the National Academy of Sciences*, 106(37):15594–15598.

Schoenmaker, D. and Schramade, W. (2019). Investing for long-term value creation. *Journal of Sustainable Finance and Investment*, 9(4):356–377.

Schumacher, K. (2020). Green bonds: The shape of green fixed-income investing to come. *The Journal of Environmental Investing*, 10(1):5–29.

Secinaro, S., Brescia, V., Calandra, D., and Saiti, B. (2020). Impact of climate change mitigation policies on corporate financial performance: Evidence-based on European publicly listed firms. *Corporate Social Responsibility and Environmental Management*, 27(6):2491–2501.

Seltzer, L., Starks, L., and Zhu, Q. (2021). Climate regulatory risks and corporate bonds. Research Paper 20-05, Nanyang Business School, Singapore.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *The Journal of Finance*, 19(3):425–442.

Sharpe, W. F. (1994). The Sharpe ratio. *The Journal of Portfolio Management*, 21(1):49–58.

Sortino, F. A. and van der Meer, R. (1991). Downside risk. *Journal of Portfolio Management*, 17(4):27–31.

Sousa, F. J. (2010). Chapter 9: Metatheories in research: Positivism, postmodernism, and critical realism. *Advances in Business Marketing and Purchasing*, 16:455–503.

Statman, M. and Glushkov, D. (2009). The wages of social responsibility. *Financial Analysts Journal*, 65(4):33–46.

Stern, N. (2008). The economics of climate change. *The American Economic Review*, 98(2):1–37.

Storelvmo, T., Leirvik, T., Lohmann, U., Phillips, P. C., and Wild, M. (2016). Disentangling greenhouse warming and aerosol cooling to reveal Earth's climate sensitivity. *Nature Geoscience*, 9(4):286–289.

Stroebel, J. and Wurgler, J. (2021). What do you think about climate finance? *Journal of Financial Economics*, 142(2):487–498.

Tang, D. Y. and Zhang, Y. (2020). Do shareholders benefit from green bonds? *Journal of Corporate Finance*, 61:101427.

Thomä, J. and Chenet, H. (2017). Transition risks and market failure: A theoretical discourse on why financial models and economic agents may misprice risk related to the transition to a low-carbon economy. *Journal of Sustainable Finance and Investment*, 7(1):82–98.

Tirodkar, M. (2020). Global warming asset pricing: Estimating a temperature risk. Working paper, University of Auckland Business School, Auckland.

Tolliver, C., Keeley, A. R., and Managi, S. (2020a). Drivers of green bond market growth: The importance of Nationally Determined Contributions to the Paris Agreement and implications for sustainability. *Journal of Cleaner Production*, 244:118643.

Tolliver, C., Keeley, A. R., and Managi, S. (2020b). Policy targets behind green bonds for renewable energy: Do climate commitments matter? *Technological Forecasting and Social Change*, 157:120051.

Trompeter, L. (2017). Green is good: How green bonds cultivated into Wall Street's environmental paradox. *Sustainable Development Law & Policy*, 17(2):3.

Trumpp, C. and Guenther, T. (2017). Too little or too much? Exploring U-shaped relationships between corporate environmental performance and corporate financial performance. *Business Strategy and the Environment*, 26(1):49–68.

Tsoukala, A. and Tsiotas, G. (2021). Assessing green bond risk: An empirical investigation. *Green Finance*, 3(2):222–252.

Tzouvanas, P., Kizys, R., Chatziantoniou, I., and Sagitova, R. (2019). Can variations in temperature explain the systemic risk of european firms? *Environmental and Resource Economics*, 74(4):1723–1759.

Van Stekelenburg, A., Georgakopoulos, G., Sotiropoulou, V., Vasileiou, K. Z., and Vlachos, I. (2015). The relation between sustainability performance and stock market returns: An empirical analysis of the Dow Jones Sustainability Index Europe. *International Journal of Economics and Finance*, 7(7):74–88.

Warren, P. (2020). Blind spots in climate finance for innovation. *Advances in Climate Change Research*, 11(1):60–64.

Widyawati, L. (2019). A systematic literature review of socially responsible investment and environmental social governance metrics. *Business Strategy and the Environment*, pages 1–19.

Wood, D. and Grace, K. (2011). A brief note on the global green bond market. IRI Working Paper, Harvard University, Initiative for Responsible Investment.

Wulandari, F., Schäfer, D., Stephan, A., and Sun, C. (2018). The impact of liquidity risk on the yield spread of green bonds. *Finance Research Letters*, 27:53–59.

Yadav, P. L., Han, S. H., and Rho, J. J. (2016). Impact of environmental performance on firm value for sustainable investment: Evidence from large US firms. *Business Strategy and the Environment*, 25(6):402–420.

Yeow, K. E. and Ng, S. H. (2021). The impact of green bonds on corporate environmental and financial performance. *Managerial Finance*, aop.

Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking and Finance*, 98:39–60.

Zhang, L. and Zhu, M. (2020). Does corporate exposure to weather affect bond yield spread? *SSRN Electronic Journal*.

Zhou, X. and Cui, Y. (2019). Green bonds, corporate performance, and corporate social responsibility. *Sustainability*, 11(23):6881.

PART II

ARTICLES

To get to know, to discover, to publish—this is the destiny of a scientist.

François Arago

From ’De L’Utiliteé des Pensions’, Œuvres complètes de François Arago (1855), Vol. 3, 621. Translation as given in Alan L. MacKay in A Harvest of a Quiet Eye (1977), 10.

6 CLIMATE CHANGE EVENTS AND STOCK MARKET RETURNS

Abstract

Using an event study methodology, we investigate how unexpected political events affect climate-sensitive sectors. We find that events related to climate change policy have significantly impacted returns. The clean energy sector benefitted from the Paris Agreement, Climategate, and Fukushima since these events increased climate change awareness and favor toward policies related to reducing the impact of climate change. For the utilities, energy-intensive, and transport sectors, these events imply increased transition-related political and market risks, which should be compensated. Events weakening climate change policy are associated with positive abnormal returns for the fossil energy sector. We further find that stock market investors are quick to adapt to new information related to climate change. Policymakers should be aware of such events' impact on the stock market because the investors are likely to price in both climate risk and expectation about sectors' growth.

6.1 INTRODUCTION

Climate change is receiving a great deal of attention today from both policymakers and the public. During the last three decades, there has been a dramatic improvement in humanity's understanding of the drivers of Earth's climate (Hansen et al., 2005; Andreae et al., 2005; Matthews et al., 2009; Storelvmo et al., 2016; Phillips et al., 2020). The economic consequences and societal impact of climate change have also received much attention (Alley, 2003; Nordhaus and Yang, 1996; Easterling et al., 2000; Hayhoe et al., 2004; Matthews et al., 2017; He and Liu, 2018). The projected changes in temperature over the next century range from $1\,^{\circ}$C to more than $4\,^{\circ}$C, which will have devastating effects for many firms. Climate change and how society can and should adapt to it are severe challenges. Nordhaus (2019) discusses three possible paths and concludes that the only viable path is the one where humans reduce their emissions significantly over time.

While the effects of climate change are not observed overnight and are often neglected, investors are increasingly interested in understanding how the shift to a greener and cleaner economy affects firms; see for example He and Liu (2018), Teng and He (2020), Li et al. (2020), Alsaifi et al. (2020), Sarkodie et al. (2020a), Sarkodie et al. (2020b), Qian et al. (2020). In particular, Alsaifi et al. (2020) applied an event study method to determine how voluntary carbon disclosure affects firms in the UK. The authors found that firms operating in carbon-intensive industries experience a more pronounced negative reaction to voluntary carbon disclosure. Qian et al. (2020) have specifically analyzed climate policy changes for Australia. The authors also applied an event study methodology and found that better carbon performance has led to significantly higher market returns during the Australian carbon tax repeal.

These studies highlight the current focus on climate risk that according to Nordhaus and Yang (1996) is a systematic risk, meaning that it affects the whole economy, not just a specific firm. Furthermore, climate risks can be broken down into *i)* physical risk and *ii)* transition risk (Clapp et al., 2017). The former is related to extreme weather events and their consequences, whereas the latter is related to attributes of transition to a low-carbon economy: technological shifts, policy and regulation introduction, production-level changes, and consumer behavior. Transition risk is likely to be realized in the near future; therefore, the market needs to account for it.

In this paper, we study the transition risk that stems from climate change policy and awareness. We apply an event study methodology and analyze how unexpected events related to climate change affect the stock market. We focus on the following set of events:

1. The Climatic Research Unit email controversy (17.11.2009), also known as Climategate, which began after the leaking of the thousands of emails written by employees at the Climatic Research Unit at the University of East Anglia. The leaked information was widely used by climate change deniers who claim that climate change facts are fabricated.

2. The Fukushima Daiichi nuclear disaster (11.03.2011; Ōkuma, Japan): The ruination of the nuclear plant's reactors after the Tōhoku earthquake and the ensuing tsunami triggered their shutdown. This accident led to revision of energy policies in Japan and other countries. Before the accident, nuclear energy, like clean energy, was an essential part of the transition to a low-carbon economy.
3. The UN Climate Change Conference (12.12.2015; Paris, France): The adoption of the Paris Agreement (PA) that governs climate change reduction measures from 2020 onward. Given that previous negotiation at the Copenhagen Climate Change Conference in 2009 did not result in an agreement, the climate meeting in Paris was a surprise in that parties agreed on and signed a bill to reduce CO_2 emissions.
4. The US presidential election (08.11.2016; USA): The outcome of the election (USPE) was a surprise because the winning candidate lagged behind his opponent by a large margin in poll results. The winner of the election, Donald Trump, had clear intentions to change the climate policy legislation, limit climate policy cooperation, and revive the coal industry in the US. Such policy changes are expected to affect clean energy stocks as well as oil and fossil fuel stocks.

We hypothesize that the stock market can efficiently price in new information that these events carry. We assume that the stock market reaction to this systematic risk depends on the industry, similarly to Pham et al. (2019) and Birindelli and Chiappini (2021). However, we follow the definition of climate policy-relevant sectors provided by Battiston and Monasterolo (2018) to study the response of sector-specific exchange-traded fund (ETF) to the events relevant to the climate change discussion and climate policy.

Previous event studies on climate policies looked at the European companies' response to the Paris Agreement (Pham et al., 2019; Birindelli and Chiappini, 2021), and reaction of energy stocks from Germany (Betzer et al., 2013; Sen and von Schickfus, 2020), the US (Diaz-Rainey et al., 2021), and in worldwide comparison (Ferstl et al., 2012; Mukanjari and Sterner, 2018) to Fukushima and the American election.

Thus, this work differs from the previous research by focusing on a sector-specific response of the US ETFs to a set of events that includes Climategate, which has not been considered before in the financial studies.

Climate change policies aim to reduce carbon emissions; thus, carbon risk should be included in investment decision making. Recent studies show that investors recognize climate risk (Krueger et al., 2020), and they require higher returns from firms with higher emission levels (Bolton and Kacperczyk, 2021). Additionally, the cost of debt for climate-aware firms is lower compared to firms without carbon disclosure (Jung et al., 2018). These findings suggest that investors require compensation for holding stocks with higher climate risks. We propose that risk premiums and changes in expectations can explain the sectors' reaction to the events. Understanding the mechanism of how individual firms and the stock market as a whole react to changes in climate policy is critical for policymakers to create the best solution possible for all parts of an economy.

6.2 HYPOTHESIS

In connection with an event, the stock market could have a negative reaction, a positive reaction, or no reaction. If there is no reaction, a chosen event does not impact stocks. This can mean that the event is not relevant to the specific company or market or does not convey new information that should be priced in. Alternatively, an event-related change in price is significant but could have a different impact on price development. In the case of the market overreacting or underreacting, an initial price adjustment to the newly arrived information is too large or small, meaning that the market must correct for that later to trade on fair prices. The reaction can be efficient, and stock prices after incorporating an information shock remain at the new level.

Considering transition climate risks, we hypothesize that all sectors except for clean energy react negatively to climate policy-positive events, or events that take the further discussion and policy on climate change mitigation. Clean energy is supposed to benefit from such positive events since a more favorable environment for clean and renewable energy development is created alongside promoting a low-carbon economy. Because these positive events will hamper fossil fuel energy development, other sectors, which are dependent on the fossil fuel sector's energy supply (e.g., energy-intensive, transport, and, to some degree, utility sectors), will have increased uncertainty and risks. These risks would be caused by the shift and adaptation to a new sustainable energy source, which means switching to new technologies to reduce companies' carbon footprint and increase energy efficiency. The latter is also the case for the housing sector. Hypothetically, the opposite is true for climate policy-negative events. We hypothesize that climate policy-related events cause a change in investors' preferences, which affects demand for stocks and thus their prices.

We suggest two events—Climategate and USPE—to be climate policy negative, and another two—Fukushima and PA—to be climate policy positive. Below we explain this categorization.

Climategate. The email leakage that occurred at the end of November 2009 began a discussion on the credibility of scientific research and climate change evidence. Public perception of climate change and its risks translates into expectations about the development of the market. The distributed information from the leaked emails affected public beliefs about global warming since more people began to question whether it is happening (Leiserowitz et al., 2013).

Fukushima. There is an ongoing debate about nuclear energy and whether it can be considered clean and renewable. The casualties and environmental harm caused by the Fukushima disaster made a shift toward other energy sources more urgent. The need for change was obvious for Japan, which suffered from the accident directly, but also for the rest of the world, which witnessed its consequences (Lei and Shcherbakova, 2015). This event could be seen as a good point from which to reshape energy source structures to be more sustainable.

PA. There was a need for an agreement to frame climate change and emission targets after 2020 when the Kyoto Protocol would end. The Copenhagen meeting's failure to draft such an agreement led to a different negotiation approach: states were asked to send determined national contributions before the Paris meeting. Even though the meeting date was set in advance and market actors knew about it, its outcome was highly unanticipated. The polarization of the opinions of developed and developing countries made the possibility of reaching the agreement and its form (i.e., whether it would be legally binding) questionable. Thus, the written agreement stating a $1.5\,^{\circ}$C warming ceiling was "a real positive surprise" (Christoff, 2016).

USPE. For this event as well as for the previous one, the date was known in advance. However, the outcome was unexpected. According to the pre-election polls, another candidate had a higher chance to win and a higher share of electoral and popular votes according to *538 Project*. The election outcome was expected to affect climate change strategy for the US and other parties in the UN. Trump mentioned his intention to remove the US from the Paris Agreement and revive the coal industry. As such, his decisions were expected to increase the emission reduction burden on other countries while the US accounted for 15% of total global emissions as of 2014 (Christoff, 2016).

6.3 DATA AND METHOD

For the analysis, we used daily price data of exchange-traded funds (ETFs) from July 2009 to December 2016. An ETF is a collection of stocks (i.e., a portfolio) that invests in assets in a specific market segment (e.g., stocks in companies in the clean energy sector or companies in the fossil fuel industry exclusively). As such, the ETF price can be an approximate indicator of the industry's future growth. Moreover, when including many stocks in a portfolio, the firm-specific risk is reduced, making systematic risks the main price drivers. This implies that a significant change in the price of an ETF is likely caused by a change in a systematic risk factor, such as news

Table 6.1: Sample statistics for sectorwise daily returns for 2009 to 2016. Returns are given in percentages. Columns (1) to (6) report covariance among sectors

Type	*Mean*	*St.Dev*	*Min*	*Q1*	*Median*	*Q3*	*Max*	*Skew*	*Kurt*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Market (1)	.049	1.27	-7.7	0.5	.084	.67	7.57	0.23	4.35						
Transport (2)	.039	1.51	-9.1	0.66	.117	.82	8.88	0.22	4.19	.76					
Utility (3)	.02	.85	-5.55	0.42	.058	.5	3.91	0.37	3.07	.58	.48				
Energy Intensive (4)	.04	.86	-5.63	0.39	.07	.51	3.81	0.42	3.04	.66	.58	.48			
Housing (5)	.053	1.56	-9.09	0.57	.067	.7	12.24	.34	8.96	.62	.55	.47	.5		
Fossil fuels (6)	.034	1.76	-8.99	0.85	.044	.93	7.62	0.19	2.24	.71	.63	.5	.52	.45	
Clean energy (7)	.008	1.71	-8.78	0.81	.048	.96	8.85	0.17	3.04	.77	.7	.5	.57	.54	.69
SP500	.061	1.12	-6.97	0.41	.09	.59	6.89	0.2	4.29						
SMB	.008	.56	-2.08	0.34	.01	.34	3.58	.22	1.61						
HML	.003	.64	-4.22	0.31	0.02	.29	4.34	.3	7.93						

related to climate change.

The stock data for the study was obtained from the Center for Research in Securities Prices. We focused on equity ETFs launched in 2015 or earlier. Most of these ETFs invest in companies worldwide, though companies from the US have a large share due to the size of the US economy, financial markets, and the companies listed in the US. We then limited ETFs to trade within the following five industries: energy (separated in this paper into fossil fuel and clean energy sectors), energy-intensive industries, housing, transport, and utilities. This focus is based on Battiston and Monasterolo's (2018) work, which identified the former as climate-sensitive industries. The data for size and value risk factors was obtained from Kenneth R. French's data library. Returns of the S&P 500 Index were a proxy for market returns.

Besides the wide range of sector-specific ETFs, we also have a set of ETFs that track the market as a whole. The list of ETFs is available in Appendix 6.A, see Table 6.1 for some descriptive statistics. Note that the energy sectors are interconnected since the covariance between fossil fuel-based and clean energy is high (0.69). Both also highly covariate with the transport sector (0.63 and 0.71, respectively).

6.3.1 *Event study*

The event study aims to define and distinguish each event's effect from exposure to a general market. The underlying idea is to test whether abnormal (excess) returns around the event dates are different from the expected returns. If the event does not carry new information for the market, there is no surprise, and thus there should be no excess returns for the event. A traditional way of testing abnormal returns (Kothari and Warner, 2007) is presented below.

Abnormal returns (*AR*) are calculated as the difference between realized (historical) and expected returns. Expected returns can be obtained from different models: mean return, the market model, or different factor models. In this paper, we focus on the capital asset pricing model (CAPM, introduced by Sharpe, 1964; and Lintner, 1965). This model relates expected returns to how the overall market behaves and is provided in Eq. (6.1):

$$R_{it} - r_{ft} = \alpha + \beta_M (R_{Mt} - r_{ft}) + \varepsilon_t \tag{6.1}$$

where R_M is the return to the market portfolio, r_{ft} is a risk-free rate, and β_M measures the sensitivity for the asset i to the market. To analyze any excess returns in the event window, we computed realized abnormal returns for each observation within the event window. The cumulative abnormal returns (*CAR*) are a rolling sum of abnormal returns over the event window. The CAR is calculated as follows:

$$CAR^i_{\tau_1,\tau_2} = \sum_{\tau=\tau_1}^{\tau_2} (R^i_\tau - E[R^i_\tau]). \tag{6.2}$$

In Eq. (6.2), i corresponds to each ETF, R_τ is the return of the ETF at the time τ, and $E[R^i_\tau]$ denotes an expected return of the ETF, given by Eq. (6.1). τ_1, τ_2 stand for the beginning and the end of the event window, respectively.

We then added the cumulative returns for all ETFs, and computed the cross-sectional average, denote *CAAR*. It is used as an estimate for average industry cumulative return and it is defined as follows:

$$CAAR_{\tau_1,\tau_2} = \frac{1}{N} \sum_{k=1}^{N} CAR^k_{\tau_1,\tau_2}. \tag{6.3}$$

In Eq. (6.3), *N* denotes the total number of ETFs within a sector.We calculated CAAR separately for each sector. Based on similar event studies (e.g., Oberndorfer et al., 2013; Sorokina et al., 2013; Qian et al., 2020; Alsaifi et al., 2020), we defined the event window as 1, 3, or 5 days before and after the event. We compare the results for all event window sizes. Our chosen model is estimated based on approximately 200 observations beginning 230 trading days before the event.

Traditional testing of abnormal and cumulative abnormal returns is done based on the t-statistics for a single event and one company. For this paper, a test on standardized returns are applied to ensure that AR can be compared between companies:

$$A_{it} = \frac{AR_{it}}{s_i\sqrt{1+d_t}} \tag{6.4}$$

In Eq. (6.4), AR_{it} is the estimated abnormal return for the ETF *i* on day *t*, and A_{it} is the scaled abnormal returns. s_i is the regression residual standard deviation; d_t is the correction term of the form $x_t'(X'X)^{-1}x_t$ where x_t and X represent vectors of explanatory variables in the event and the estimation window, respectively.

We chose Patell's (1976) methodology for testing, which includes the number of observations in the estimation window (m) and the number of explanatory variables (p):

$$t_{Patell} = \bar{A}\sqrt{\frac{n \times (m-p-3)}{m-p-1}}. \tag{6.5}$$

On top of this test, we apply an adjustment, suggested in Kolari and Pynnönen (2010): $\sqrt{\frac{1-\bar{\rho}}{1+(n-1)\bar{\rho}}}$, where $\bar{\rho}$ is the average of the sample cross-correlations of the estimation period residuals. After multiplying Eq. (6.5) by this factor, we obtained a new test statistics $t_{aPatell}$ that is adjusted for cross-correlation. We need to address cross-correlation, because in our case ETFs track global indices and include some of the same companies. There is also an overlap in event windows because events took place simultaneously for every ETF.

Robustness We additionally compared our results against a more sophisticated model derived by Fama and French (1993). This model is called the three-factor model (FF3) and is as follows:

$$R_{it} - r_{ft} = \alpha + \beta_M (R_{Mt} - r_{ft}) + \beta_{smb} SMB_t + \beta_{hml} HML_t + \varepsilon_t \quad (6.6)$$

In Eq. (6.6), *SMB* is the returns of small firms less returns on large firms (i.e., small-minus big-cap factor), and *HML* is the returns of firms with a high book-to-market value over returns of firms with a low book-to-market value; thus, it is called the high-minus-low book-to-market-ratio factor.

According to Corrado (2011), the estimated abnormal returns in the event study are subject to cross-sectional correlation but also event-induced volatility. To address this issue, we used a scaled test statistic called BPM (t_{BMP}; see Boehmer et al., 1991), based on the *t*-test that accounts for event-induced volatility. The BPM test statistic is calculated as follows:

$$t_{BMP} = \frac{\bar{A_{it}}\sqrt{n}}{s}, \quad (6.7)$$

where s is the (cross-sectional) standard deviation of the event-day-scaled abnormal returns. While accounting for event-induced volatility, t_{BMP} is still prone to cross-sectional correlation. We used the method suggested in Kolari and Pynnönen (2010) to adjust also this test statistic for cross-correlation. A new measure is denoted as t_{aBMP}. We used BMP test for the abnormal and cumulative abnormal returns and its adjusted version for check.

6.4 EMPIRICAL RESULTS

We analyzed each ETF's reaction to climate-related events by running a regression (6.1) for each ETF accounting for each event. We made a prediction based on the regression analysis to produce abnormal returns for further testing. We then obtained abnormal returns averaged for each ETF type and calculated CAR from 10 days before the event to 20 days afterward (Figure 6.1).

This figure aids in understanding the ETFs' reaction to the events. As one can see, the various ETFs reacted differently in terms of both scale and direction. In the next section, we explore each event in more detail.

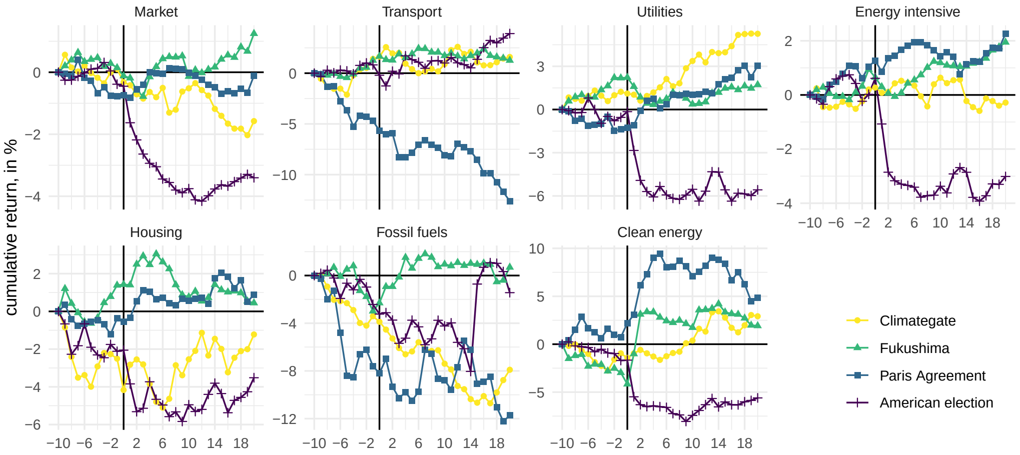

Figure 6.1: Cumulative abnormal returns from the capital asset pricing model calculated from 10 days before the event until 20 days after the event.

6.4.1 Climategate

The housing sector experienced statistically significant abnormal negative returns of 1.66% on the day of the event followed by a 1.34% rebound the next day (Table 6.2). This can be explained by a correction for the overreaction to the event. The market ETFs also reacted negatively with $-40\,bps$ (**b**asis **p**oint**s**) on day one and down to $-84\,bps$ over three days. However, at the end of 2009, the real estate market was in distress after the financial crisis, so negative abnormal returns were rather expected and could be explained by factors other than Climategate.

The transport ETFs did not react to Climategate since neither abnormal nor cumulative abnormal returns are significantly different from 0. A highly significant abnormal return on the fourth day of the event even after correction for cross-correlation based on the adjusted BMP statistic (*aBMP*) is not likely connected to the event.

The energy-intensive and fossil fuel ETFs' results are controversial in terms of the BMP testing: while the fossil fuel sector experienced statistically significant negative abnormal returns, the energy-intensive sector received an additional $69\,bps$

Table 6.2: Stock market reaction to Climategate.

Day(s)	-3	-2	-1	0	1	2	3	4	5	-1, 1	-1, 3	-1, 5	-3, 3
Market (R^2=0.903)													
AR	0.11	0.35	-0.18	-0.42	-0.1	-0.29	-0.14	0.21	-0.17	-0.41	-0.84	-0.8	-0.67
BMP	0.58	0.09	0.41	**<.01**	0.9	0.05	0.24	0.46	0.73	0.15	**0.03**	0.14	**0.02**
aBMP	0.74	0.27	0.61	**0.03**	0.94	0.2	0.45	0.65	0.83	0.35	0.14	0.35	0.1
Patell	0.77	0.34	0.65	0.12	0.96	0.29	0.6	0.7	0.76	0.44	0.21	0.4	0.37
aPatell	0.85	0.51	0.76	0.27	0.97	0.46	0.73	0.79	0.84	0.6	0.38	0.56	0.54
Transport (R^2=0.714)													
AR	0.89	0.15	0.57	0.22	0.94	-0.62	0.05	-1.07	-0.53	2.05	1.48	-0.12	2.2
BMP	0.35	0.65	0.38	0.24	0.69	0.54	0.75	**0.02**	0.12	0.53	0.41	0.79	0.42
aBMP	0.44	0.74	0.48	0.32	0.76	0.64	0.81	**0.03**	0.17	0.62	0.51	0.84	0.52
Patell	0.62	0.94	0.74	0.89	0.67	0.74	0.94	0.52	0.71	0.56	0.71	0.93	0.65
aPatell	0.66	0.95	0.77	0.9	0.7	0.77	0.94	0.57	0.74	0.6	0.74	0.94	0.68
Utilities (R^2=0.59)													
AR	0.24	0.41	-0.38	-0.12	-0.08	-0.41	0.32	0.25	0.35	0.04	-0.05	0.54	-0.02
BMP	0.09	**0.01**	**0.02**	0.19	0.49	**0.01**	0.06	0.08	**0.02**	0.58	0.89	0.06	0.94
aBMP	0.46	0.21	0.26	0.58	0.77	0.24	0.4	0.44	0.29	0.82	0.96	0.41	0.97
Patell	0.39	0.16	0.19	0.7	0.8	0.2	0.31	0.36	0.22	0.89	0.98	0.42	0.99
aPatell	0.67	0.47	0.51	0.85	0.9	0.52	0.62	0.65	0.53	0.95	0.99	0.69	0.99
Energy intensive (R^2=0.671)													
AR	0.44	0.28	-0.16	0.07	-0.19	0.03	0.32	0.09	-0.07	0.32	0.67	0.69	0.78
BMP	0.08	**0.02**	0.12	0.45	0.08	0.26	**0.01**	0.08	0.82	0.53	**0.03**	**0.01**	**0.01**
aBMP	0.5	0.33	0.57	0.79	0.5	0.68	0.27	0.51	0.94	0.83	0.4	0.31	0.28
Patell	0.35	0.26	0.6	0.86	0.48	0.83	0.34	0.46	0.94	0.8	0.47	0.39	0.4
aPatell	0.65	0.59	0.8	0.93	0.74	0.92	0.65	0.73	0.97	0.91	0.73	0.69	0.69
Housing (R^2=0.736)													
AR	-0.24	-0.06	0.71	-1.66	1.34	0.28	-0.26	-1.03	-0.95	-0.56	-0.54	-2.53	0.11
BMP	0.56	0.8	0.05	**<.01**	**0.01**	0.57	0.26	**<.01**	**<.01**	**0.04**	0.16	**<.01**	0.65
aBMP	0.82	0.92	0.42	**0.01**	0.21	0.83	0.66	**0.02**	**<.01**	0.39	0.57	0.08	0.86
Patell	0.82	0.92	0.36	**0.02**	0.1	0.82	0.63	0.14	0.14	0.47	0.5	0.1	0.79
aPatell	0.92	0.96	0.66	0.2	0.4	0.91	0.82	0.47	0.46	0.73	0.75	0.42	0.9
Clean energy (R^2=0.722)													
AR	0.79	-0.21	-1.09	-0.47	-0.65	-0.75	-0.8	-0.52	0.24	-0.33	-1.88	-2.17	-3.19
BMP	**<.01**	0.14	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**0.01**	0.05	0.21	**<.01**	**<.01**	**<.01**
aBMP	0.24	0.77	0.07	0.53	0.32	0.52	0.29	0.57	0.7	0.81	0.38	0.36	0.24
Patell	0.08	0.7	**0.03**	0.25	0.15	0.13	0.08	0.35	0.39	0.65	0.07	0.12	**0.02**
aPatell	0.54	0.9	0.42	0.7	0.63	0.6	0.53	0.75	0.77	0.88	0.53	0.59	0.38
Market (R^2=0.714)													
AR	0.64	1.16	-0.5	-0.48	0.47	0.36	-0.35	-0.33	-0.35	0.63	0.64	-0.04	1.31
BMP	0.09	**<.01**	**<.01**	**0.02**	0.14	0.17	0.09	0.27	**0.04**	0.32	0.69	0.51	0.41
aBMP	0.59	0.3	0.24	0.45	0.65	0.68	0.6	0.74	0.51	0.77	0.91	0.85	0.81
Patell	0.3	0.08	0.3	0.36	0.58	0.65	0.46	0.56	0.53	0.69	0.86	0.76	0.64
aPatell	0.66	0.45	0.67	0.7	0.82	0.85	0.76	0.81	0.8	0.87	0.94	0.9	0.85

The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (row *AR*), given in percentages. The abnormal returns were calculated based on the CAPM and tested by the parametric Boehmer et al. (1991) test (row *BMP*) and Patell's test (1976; row *Patell*). Rows *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The underlined *p*-values are significant at the 10% level, and those in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.

Table 6.3: Stock market reaction to Fukushima.

Day(s)	-3	-2	-1	0	1	2	3	4	5	-1, 1	-1, 3	-1, 5	-3, 3
Market (R^2=0.876)													
AR	-0.14	0.1	-0.28	-0.26	-0.07	-0.4	-0.19	0.63	0.33	-0.47	-1.06	-0.1	-1.25
BMP	0.07	0.14	0.06	0.12	0.62	**0.04**	0.67	0.2	0.16	0.16	0.15	0.51	0.12
aBMP	0.24	0.34	0.21	0.31	0.76	0.17	0.79	0.42	0.37	0.37	0.36	0.69	0.32
Patell	0.5	0.64	0.09	0.23	0.54	0.06	0.5	**0.02**	0.16	0.17	**0.04**	0.73	**0.03**
aPatell	0.65	0.75	0.23	0.41	0.68	0.17	0.65	0.07	0.33	0.33	0.13	0.81	0.11
Transport (R^2=0.755)													
AR	0.69	0.09	0.56	0.4	-0.33	-0.05	0.61	-0.36	0.37	0.76	1.32	1.33	1.98
BMP	0.35	0.66	0.65	0.27	0.65	0.94	0.15	0.68	0.34	0.34	0.3	0.39	0.48
aBMP	0.37	0.68	0.67	0.29	0.67	0.94	0.16	0.69	0.36	0.36	0.32	0.41	0.5
Patell	0.37	0.85	0.37	0.59	0.54	0.87	0.42	0.67	0.62	0.57	0.42	0.46	0.33
aPatell	0.38	0.85	0.38	0.6	0.55	0.88	0.43	0.68	0.62	0.58	0.43	0.47	0.34
Utilities (R^2=0.695)													
AR	-0.02	0.57	0.27	0.04	-0.63	-0.73	-0.43	-0.09	0.23	-0.62	-1.78	-1.64	-0.94
BMP	0.87	**<.01**	0.09	0.87	**0.02**	**<.01**	**0.01**	0.46	0.22	**0.02**	**<.01**	**0.01**	0.06
aBMP	0.95	0.14	0.44	0.94	0.29	0.1	0.18	0.75	0.59	0.29	0.15	0.2	0.38
Patell	0.94	**<.01**	0.15	0.93	**<.01**	**<.01**	**0.02**	0.54	0.22	**0.04**	**<.01**	**<.01**	**0.04**
aPatell	0.97	0.09	0.46	0.97	0.08	**0.04**	0.23	0.76	0.53	0.27	**0.03**	0.07	0.28
Energy intensive (R^2=0.718)													
AR	0.62	0.22	0.28	-0.29	-0.35	-0.24	-0.12	0.13	0.36	-0.02	-0.38	0.11	0.12
BMP	**<.01**	**0.04**	**0.01**	**<.01**	**<.01**	0.09	0.22	0.67	**0.02**	0.26	0.08	0.42	0.48
aBMP	0.1	0.38	0.21	0.14	0.18	0.49	0.63	0.87	0.29	0.66	0.47	0.76	0.79
Patell	**0.01**	**0.02**	0.05	0.1	**0.02**	0.23	0.27	0.64	**0.04**	0.48	0.13	0.53	0.59
aPatell	0.12	0.2	0.29	0.39	0.19	0.55	0.58	0.82	0.26	0.73	0.44	0.76	0.79
Housing (R^2=0.74)													
AR	0.6	0.33	0.8	0.04	-0.02	1.1	0.44	-0.46	0.57	0.62	2.15	2.26	3.28
BMP	**<.01**	**0.02**	**0.01**	0.6	0.98	**<.01**	**0.02**	0.08	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**
aBMP	0.13	0.42	0.34	0.87	0.99	0.21	0.41	0.55	0.24	0.28	**0.04**	**<.01**	0.08
Patell	**0.03**	0.23	**0.01**	0.82	0.99	**<.01**	0.1	0.11	**0.04**	0.15	**<.01**	**0.01**	**<.01**
aPatell	0.33	0.6	0.24	0.93	0.99	0.11	0.47	0.49	0.35	0.53	0.13	0.17	0.07
Clean energy (R^2=0.738)													
AR	-1.22	-0.49	-2.08	0.68	1.37	0.01	0.79	1.65	-0.91	0.83	1.63	2.37	-0.94
BMP	**<.01**	**<.01**	**<.01**	**0.01**	**<.01**	0.58	**0.01**	**<.01**	**<.01**	**0.01**	**0.01**	**<.01**	0.08
aBMP	0.1	0.33	0.05	0.47	0.1	0.9	0.5	0.05	0.22	0.52	0.52	0.22	0.68
Patell	**<.01**	0.06	**<.01**	**0.01**	**<.01**	0.65	**0.02**	**<.01**	**<.01**	0.07	**0.01**	**<.01**	0.13
aPatell	0.08	0.48	**0.01**	0.28	0.08	0.87	0.35	**0.03**	0.21	0.5	0.32	0.22	0.58
Market (R^2=0.755)													
AR	-0.45	0.28	-0.67	-1.19	3.15	4.13	0.26	-0.02	-0.55	1.51	5.9	5.33	5.51
BMP	0.06	0.2	**0.01**	**<.01**	**<.01**	**<.01**	0.14	0.73	0.41	**0.03**	**<.01**	**<.01**	**<.01**
aBMP	0.51	0.68	0.32	0.08	0.16	0.09	0.62	0.91	0.79	0.46	0.08	0.17	0.14
Patell	0.25	0.3	0.05	**<.01**	**<.01**	**<.01**	0.1	0.72	0.3	**0.02**	**<.01**	**<.01**	**<.01**
aPatell	0.61	0.65	0.36	0.12	**<.01**	**<.01**	0.46	0.88	0.65	0.27	**<.01**	**0.01**	**0.01**

The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (row *AR*), given in percentages. The abnormal returns were calculated based on the CAPM and tested by the parametric Boehmer et al. (1991) test (row *BMP*) and Patell's test (1976; row *Patell*). Rows *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The underlined *p*-values are significant at the 10% level, and those in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.

within five days. However, these results do not hold after the correction for the cross-sectional correlation. The energy-intensive ETFs' performance in late 2009 is likely related to the continuous rise of the oil prices since mid-2008. The clean energy ETFs' loss in returns is significant only for $48\,bps$ on the event day and before the test statistics adjustment. Figure 6.1 shows that later the clean energy ETFs actually gained positive CAR as the Copenhagen meeting drew nearer.

6.4.2 Fukushima

As mentioned earlier, we expected a positive reaction of the energy stocks in connection with the Fukushima disaster. However, we also expected clean energy to be preferred as a source with a minimal negative environmental production effect. This type of reaction is exactly what is apparent for the clean energy and fossil fuel ETFs (Table 6.3). Their CAR reached 5.33% and 2.37%, respectively, within five days, with the greatest abnormal returns on the second and third days.

The Fukushima event is associated with a negative return of 29 to $35\,bps$ on the event day and the day after it for the Energy intensive sector. The Utility sector also has negative returns of 43 to $73\,bps$ on the first three days after the event. However, the statistical significance for both sectors disappeared after the adjustment for cross-sectional correlation.

Although market abnormal returns were negative, they were not statistically significant for most days for the BMP test, while the Patell test shows that $CAR_{(-1,3)} = -1.06\%$ is statistically different from 0. Transport ETFs' abnormal returns were not affected by the event. The housing sector's positive significant cumulative returns were found for three and five days after the event.

6.4.3 The Paris Agreement

The PA was positive news for the clean energy ETFs, and a series of significant abnormal returns in the days following the announcement added up to 8.43% within five days. This result remains highly significant irrespective of the test applied.

The market ETFs also had a positive and statistically significant reaction to the news, though of 10 times smaller magnitude ($73\,bps$), which disappears for both adjusted and Patell's tests.

The energy-intensive sector also had a positive return of less than 1% on the days after the event, which cumulatively reached 1.2% on the fifth day. However, their statistical significance declines after the adjustment for cross-sectional correlation.

Unlike the clean energy ETFs, the fossil fuel ETFs lost up to 4.2% in returns in connection to the PA. However, a negative reaction to the event could also be seen five days before the event. This indicates that the fossil fuel sector anticipated negative news due to the Paris meeting long before the agreement took place.

The transport ETFs did not have statistically significant returns in connection with the event. At the same time, utilities and housing ETFs experienced some positive movements in the returns, which cumulatively reached 1.59 and 1.86%, respectively.

6.4.4 The American election

The results of the USPE 2016 led to highly significant negative abnormal returns in all sectors in the study except for transport, which showed some negative returns at the 10% significance level. Since most sectors had significant negative CAR according to one test or both, we can conclude that the USPE was taken as news that increased uncertainty. However, the magnitude of the reaction differed across sectors. Within five days, market ETFs lost 3.09% in returns. If we consider this result to represent a general reaction pattern, energy-intensive and housing sectors were just in line with the negative market reaction. They had -3.11 and -2.91% in abnormal returns, respectively.

However, the results for the energy sectors stand out. The comparison of the reaction based on $CAR_{(-1,\,5)}$ shows that although fossil fuel ETFs had a negative abnormal return of -2.78%, this is $40\,bps$ better than the average market ETFs loss. Moreover, after a period of some abnormal return fluctuations, fossil fuel cumulative returns rebounded after two weeks (Figure 6.1). In contrast, the clean energy sector cumulatively lost 5.55% in abnormal returns.

The magnitude and sign of the estimated abnormal returns from the CAPM and

Table 6.4: Stock market reaction to the Paris Agreement.

Day(s)	-3	-2	-1	0	1	2	3	4	5	-1, 1	-1, 3	-1, 5	-3, 3
Market (R^2=0.781)													
AR	-0.02	-0.27	0.19	0.04	-0.09	0.28	0.14	0.42	-0.03	-0.07	0.35	0.73	0.27
BMP	0.2	**0.01**	0.29	0.54	0.48	0.18	0.63	0.08	0.76	0.46	**0.04**	**0.02**	0.16
aBMP	0.46	0.11	0.55	0.73	0.7	0.44	0.79	0.3	0.86	0.68	0.22	0.13	0.41
Patell	0.31	0.12	0.46	0.38	0.59	0.36	0.8	0.13	0.85	0.43	0.27	0.13	0.53
aPatell	0.52	0.31	0.64	0.57	0.74	0.56	0.87	0.32	0.91	0.61	0.47	0.32	0.69
Transport (R^2=0.582)													
AR	-0.4	-0.12	1.08	-0.96	-0.35	0.08	-2.38	0	0.49	-1.71	-4.01	-3.52	-3.05
BMP	0.29	0.94	0.23	0.08	0.29	0.73	0.37	0.94	0.27	0.14	0.33	0.17	0.46
aBMP	0.5	0.97	0.43	0.2	0.49	0.84	0.57	0.96	0.48	0.3	0.53	0.35	0.65
Patell	0.51	0.91	0.15	0.17	0.52	0.81	**0.04**	0.86	0.41	0.17	0.07	0.11	0.15
aPatell	0.61	0.93	0.23	0.26	0.62	0.86	0.07	0.9	0.53	0.26	0.11	0.17	0.23
Utilities (R^2=0.364)													
AR	0.11	-0.97	0.47	0.09	0.19	1.01	0.68	0.14	-0.64	0.39	2.09	1.59	1.59
BMP	0.45	**<.01**	**0.01**	1	**0.04**	**<.01**	**<.01**	0.63	**0.01**	0.1	**<.01**	**0.01**	**<.01**
aBMP	0.81	0.14	0.34	1	0.48	0.14	0.3	0.88	0.34	0.58	0.21	0.36	0.18
Patell	0.56	**<.01**	**0.01**	1	0.31	**<.01**	**0.01**	0.68	**<.01**	0.36	**<.01**	**0.02**	**0.01**
aPatell	0.82	0.09	0.26	1	0.69	0.07	0.26	0.87	0.2	0.72	0.11	0.34	0.25
Energy intensive (R^2=0.706)													
AR	0.43	-0.44	-0.02	0.22	-0.41	0.49	0.09	0.22	0.15	0.24	0.83	1.2	0.37
BMP	**0.02**	**<.01**	0.19	0.08	0.06	**<.01**	0.55	0.46	0.34	0.08	**<.01**	**<.01**	0.07
aBMP	0.34	0.14	0.61	0.49	0.45	0.1	0.82	0.78	0.72	0.48	0.16	0.2	0.47
Patell	**0.03**	**0.02**	0.35	0.06	0.14	**<.01**	0.66	0.24	0.35	0.12	**0.01**	**0.02**	0.22
aPatell	0.3	0.26	0.67	0.38	0.5	0.11	0.84	0.59	0.67	0.48	0.18	0.27	0.57
Housing (R^2=0.441)													
AR	0.85	-0.52	-0.22	-0.18	0.22	0.87	0.58	-0.07	-0.41	0.89	2.34	1.86	1.59
BMP	**<.01**	**<.01**	0.17	0.3	0.09	**<.01**	**<.01**	0.67	**0.02**	**0.04**	**<.01**	**<.01**	**0.01**
aBMP	0.28	0.35	0.73	0.79	0.66	0.19	0.41	0.91	0.54	0.57	0.2	0.36	0.45
Patell	**<.01**	**0.02**	0.23	0.18	0.24	**<.01**	**0.01**	0.77	0.06	**0.03**	**<.01**	**<.01**	**0.01**
aPatell	0.16	0.38	0.68	0.64	0.68	0.14	0.33	0.92	0.5	0.43	0.1	0.25	0.34
Clean energy (R^2=0.512)													
AR	-1.37	0.36	1.94	-0.59	1.19	-2.33	-0.95	0.5	-0.72	-0.77	-4.05	-4.27	-1.76
BMP	**<.01**	0.1	**<.01**	0.05	**<.01**	**<.01**	**<.01**	**0.03**	**0.01**	0.15	**<.01**	**<.01**	**0.03**
aBMP	0.15	0.8	0.33	0.75	0.49	0.45	0.26	0.71	0.67	0.82	0.21	0.4	0.71
Patell	**<.01**	0.34	**<.01**	0.19	**0.01**	**<.01**	**0.04**	0.17	0.09	0.27	**<.01**	**<.01**	0.21
aPatell	0.27	0.76	0.12	0.68	0.36	0.11	0.48	0.66	0.58	0.73	0.19	0.25	0.69
Market (R^2=0.582)													
AR	-0.27	-0.64	1.02	1.49	0.87	3.09	1.11	1.77	0.38	2.09	6.28	8.43	6.67
BMP	0.28	**0.02**	**<.01**	0.07	**0.02**	**<.01**	**<.01**	**<.01**	0.43	0.09	**<.01**	**<.01**	**<.01**
aBMP	0.71	0.36	0.09	0.52	0.37	0.05	0.07	0.08	0.79	0.54	0.17	0.16	0.13
Patell	0.29	**0.04**	**0.01**	**0.01**	**0.04**	**<.01**	**0.01**	**<.01**	0.57	**0.02**	**<.01**	**<.01**	**<.01**
aPatell	0.64	0.33	0.17	0.15	0.33	**<.01**	0.15	0.05	0.8	0.26	**0.01**	**<.01**	**0.01**

The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (row *AR*), given in percentages. The abnormal returns were calculated based on the CAPM and tested by the parametric Boehmer et al. (1991) test (row *BMP*) and Patell's test (1976; row *Patell*). Rows *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The underlined *p*-values are significant at the 10% level, and those in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.

Table 6.5: Stock market reaction to the American election.

Day(s)	-3	-2	-1	0	1	2	3	4	5	-1, 1	-1, 3	-1, 5	-3, 3
Market (R^2=0.814)													
AR	-0.43	-0.27	0.19	-0.07	-1.18	-0.55	-0.46	-0.3	-0.11	-1.67	-2.68	-3.09	-2.77
BMP	0.16	0.97	0.66	0.52	**0.04**	0.31	0.23	0.77	0.26	**0.01**	0.06	0.07	0.1
aBMP	0.41	0.98	0.81	0.71	0.19	0.56	0.49	0.87	0.51	0.09	0.26	0.26	0.32
Patell	0.1	0.96	0.78	0.71	**<.01**	0.06	**0.01**	0.64	0.34	**<.01**	**<.01**	**<.01**	**<.01**
aPatell	0.27	0.98	0.86	0.81	**<.01**	0.2	0.05	0.77	0.54	**0.01**	**<.01**	**0.01**	**0.01**
Transport (R^2=0.685)													
AR	-0.19	0.24	0.83	-1.02	-1.05	1.45	-0.26	1.78	-0.37	-2.26	-1.08	0.33	-0.01
BMP	0.91	0.39	0.07	0.07	0.1	0.06	0.87	0.07	**0.01**	0.25	0.91	0.64	0.73
aBMP	0.96	0.63	0.2	0.21	0.27	0.19	0.93	0.2	**0.02**	0.5	0.95	0.81	0.86
Patell	0.9	0.55	0.21	0.22	0.21	0.09	0.88	0.06	0.54	0.18	0.84	0.42	0.52
aPatell	0.93	0.66	0.33	0.33	0.32	0.15	0.91	0.11	0.65	0.29	0.89	0.55	0.64
Utilities (R^2=0.251)													
AR	0.23	-0.3	0.47	0.4	-2.7	-2.08	-0.77	-0.37	0.73	-2.06	-4.92	-4.56	-4.74
BMP	0.16	**0.03**	**<.01**	**0.01**	**<.01**	**<.01**	**0.03**	**0.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**
aBMP	0.68	0.49	0.36	0.37	0.09	0.12	0.5	0.42	0.33	0.13	0.13	0.16	0.2
Patell	0.22	0.16	**0.03**	**0.04**	**<.01**	**<.01**	**<.01**	0.07	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**
aPatell	0.65	0.6	0.41	0.44	**<.01**	**<.01**	0.16	0.49	0.18	**0.04**	**<.01**	**<.01**	**<.01**
Energy intensive (R^2=0.476)													
AR	0.26	-0.66	-0.32	0.59	-1.69	-1.78	-0.32	-0.12	-0.05	-0.84	-2.94	-3.11	-3.91
BMP	**0.03**	**<.01**	**0.03**	**<.01**	**<.01**	**<.01**	0.34	0.42	0.61	**0.02**	**<.01**	**<.01**	**<.01**
aBMP	0.37	**0.04**	0.37	0.14	0.12	0.11	0.72	0.76	0.84	0.34	0.17	0.17	0.13
Patell	0.14	**<.01**	**0.03**	**0.01**	**<.01**	**<.01**	0.18	0.4	0.71	**<.01**	**<.01**	**<.01**	**<.01**
aPatell	0.49	0.06	0.29	0.18	**<.01**	**<.01**	0.54	0.7	0.87	0.08	**<.01**	**<.01**	**<.01**
Housing (R^2=0.384)													
AR	-0.36	0.7	-0.15	0.06	-1.79	-1.47	0.18	1.4	-0.93	-2.09	-3.38	-2.91	-2.83
BMP	**0.01**	**<.01**	0.07	0.53	**<.01**	**<.01**	0.27	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**
aBMP	0.54	0.26	0.68	0.89	0.36	0.46	0.8	0.13	0.19	0.2	0.33	0.43	0.46
Patell	**0.03**	**<.01**	0.34	0.72	**<.01**	**<.01**	0.19	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**
aPatell	0.5	0.2	0.77	0.91	**0.01**	**0.04**	0.68	**0.02**	0.11	0.05	**0.03**	0.1	0.12
Clean energy (R^2=0.615)													
AR	-1.46	-0.65	0.88	-0.81	0.12	-0.62	-1.95	0.43	1.51	-2.15	-4.72	-2.78	-4.49
BMP	**<.01**	**<.01**	**<.01**	**<.01**	0.91	**0.02**	**<.01**	0.2	**0.01**	**<.01**	**<.01**	**<.01**	**<.01**
aBMP	0.23	0.08	0.52	0.23	0.99	0.71	0.19	0.85	0.63	0.19	0.18	0.61	0.31
Patell	**0.01**	0.16	0.05	0.1	0.94	0.18	**<.01**	0.48	**<.01**	**0.01**	**<.01**	**0.02**	**<.01**
aPatell	0.32	0.65	0.51	0.59	0.98	0.67	0.16	0.83	0.29	0.37	0.14	0.42	0.23
Market (R^2=0.685)													
AR	-0.73	-0.06	-0.38	0.04	-3.83	-0.82	-0.2	0.08	-0.08	-4.51	-5.54	-5.55	-5.98
BMP	**<.01**	0.84	0.42	0.7	**<.01**	0.12	0.92	0.93	0.88	**<.01**	**0.01**	**0.02**	**0.01**
aBMP	0.19	0.94	0.77	0.89	0.13	0.56	0.97	0.97	0.96	0.1	0.24	0.33	0.27
Patell	**0.04**	0.89	0.43	0.76	**<.01**	**0.02**	0.89	0.94	0.92	**<.01**	**<.01**	**<.01**	**<.01**
aPatell	0.32	0.95	0.72	0.89	**<.01**	0.23	0.95	0.97	0.96	**<.01**	**<.01**	**0.01**	**0.01**

The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (row *AR*), given in percentages. The abnormal returns were calculated based on the CAPM and tested by the parametric Boehmer et al. (1991) test (row *BMP*) and Patell's test (1976; row *Patell*). Rows *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The underlined *p*-values are significant at the 10% level, and those in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.

FF3 model (Table 6.B1) are similar. The same applies to the test results based on the BMP and Patell tests for these models. However, the adjustment for cross-sectional correlation reveals that the significance of the reaction holds for fossil fuel (positive), clean energy (positive), and utilities (negative) ETFs for the Fukushima event; clean energy (positive) ETFs for the Paris Agreement; and all (negative) ETFs for the USPE. These results suggest that climate change-related events have a prominent effect on the energy sector.

6.5 DISCUSSION

Based on the analysis results, accompanied by figures 6.2 and 6.1, we can summarize the overall impact of the climate-related events on the stock market.

Climategate seems to have brought a negative news shock to all sectors in our study (Figure 6.2). However, it is associated with a temporary shock that was compensated for within a few days. The evidence is illustrated in Figure 6.1, which shows that cumulative returns were approximately zero (energy-intensive, transport, and clean energy sectors) or maintained the same level and dynamic as before the event (market, utilities, housing, and fossil fuel sectors). This reaction was concentrated within the first 10 days after the event. Later price development is likely to have been affected by the anticipation of the Copenhagen meeting. A negative reaction to Climategate suggests that the market accounts for the climate change discussion and prices its risks. Since climate change evidence was questioned, the market tried to adjust prices so as not to overcompensate for climate risks.

The stock market reaction to the Fukushima accident was similar. All sectors except fossil fuels had an initial negative reaction since abnormal returns on the event day (day 0 on Figure 6.2) were below zero on average. Even though negative returns were present a few days afterward in the history of the energy-intensive and utilities sectors and the market in general, prices reverted later. This means that Fukushima caused some uncertainty in the market, but as more information about the event and its scope and handling became available, prices stabilized. However, the clean energy, fossil fuel, and transport sectors experienced a qualitative shift in

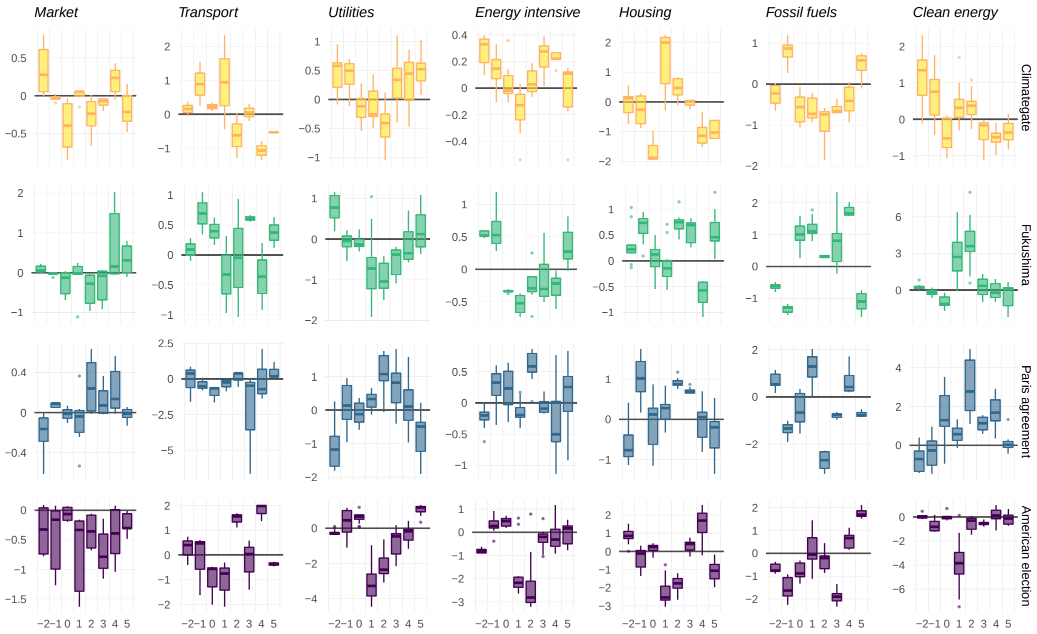

Figure 6.2: Distribution of the abnormal returns from the capital asset pricing model calculated from two days before the event until five days after event. Y-axis – estimated abnormal returns (in percentages), x-axis – days.

the price level since after the initial drop they recovered and began to perform better than before the event. Our results for the ETFs are similar to those obtained by Lei and Shcherbakova (2015) for stocks: they capture an expected behavior on the market because other energy sources would benefit from nuclear energy being compromised. These benefits could be associated with greater future growth in other sectors of the energy industry. However, contrary to Ferstl et al. (2012), who used bootstrapping for the inference, our analysis shows a significant positive impact on the clean energy ETFs with the FF3 specification.

The PA caused a positive price development in the market. The market in general and the utilities, energy-intensive, and housing sectors in particular also remained optimistic after the event. The PA created a positive long-term change for the clean energy sector since its CAR increased dramatically. However, this sector likely overreacted since CAR declined after 11 trading days. Such results suggest that better market conditions for clean energy development are anticipated.

Because the PA was not a one-day event, it appears that the sectors analyzed here anticipated some changes in climate change policy since the CAR of the fossil fuel and transport sectors also decreased before the agreement announcement, corroborating the results of Pham et al. (2019) for Germany and Diaz-Rainey et al. (2021) for the US oil and gas companies. However, new information about the agreement reached further reduced asset values in the US as was the case for the EU (Birindelli and Chiappini, 2021). The expectation about different restrictive measures against fossil fuels (i.e., extraction limits, required carbon compensation) and transport (i.e., emission control) affected these sectors' growth estimation.

The results show that the USPE was a major surprise for the stock market in general. Increased uncertainty about the future of the economy and policies of the new president reduced all returns. Only transport recovered shortly after the price drop, meaning its negative overreaction to USPE results had a temporary effect; later, CAR became positive and stable, which is likely due to the agenda featuring policies favorable for this sector. If we increase the period after the event to 20 days, the USPE had a similar effect for fossil fuel ETFs since CAR reverted to 0 (see Figure 6.2 for a graphical illustration). This finding is similar to the results of Diaz-Rainey et al. (2021) for stocks. A dramatic CAR recovery occurred when Trump announced his new team on 29 November (day 15). For other sectors, the USPE had a significant permanent effect: their CAR dropped with no subsequent recovery. One could argue that such a reaction could simply be a response to the election itself and not connected to climate change risks. However, our results contrast with those of Blau et al. (2019), who found a positive reaction of pharmaceutical and healthcare companies to the USPE. This means that the reaction is indeed sector specific and can be connected to the candidate's political program concerning climate-related issues.

Considering sector-specific responses, the ETFs' reaction to the events has a systematic character. In terms of the climate change risks for each type of ETF, clean energy ETFs have lower transition risks since the firms in such ETFs have smaller carbon footprints. We argue that expectations about clean energy development are among the major factors that drive stock prices in this sector and others. Renewable energy prices has the potential to be lower than those of fossil fuels. If climate change policy supports the transition to a low-carbon economy and thus creates favorable conditions for clean energy, its prices are likely to decrease in the future. The utilities, energy-intensive, and housing sectors will benefit from lower energy prices. The International Renewable Energy Agency (IRENA) statistics also show that solar energy costs became comparable to those generated by fossil fuels in 2016 and that renewable energy costs decreased later[1].

In contrast, transportation is strongly dependent on fossil fuels and is among the most significantly emitting sectors, accounting for 28% of total greenhouse gas emissions in the US and 14% worldwide (see US EPA, 2019a,b). Thus, this sector will be negatively affected by a transition to a low-carbon economy. This might imply an increase in fossil energy costs and a challenging change for most of the current vehicles in this sector.

Our findings suggest that sector-specific climate sensitivity, discussed in Battiston and Monasterolo (2018) via climate stress testing of the financial system in five-year intervals up to 2050, is also present in the stock market for a shorter horizon. The stock market and ETF stocks in particular experience price adjustments in connection to climate change-related events. Namely, these events are associated with lowering of transition political risks (PA) and transition market risks (Climategate, Fukushima) since they motivate the shift to and development of cleaner energy sources based on current climatic issues. One possible explanation of changes in the non-energy ETFs' return could be the transition climate risk premium. Since climate transition risks become better recognized after climate-related events, investors adjust prices to account for the potential risk premium. Climate change policy addresses the reduction of carbon emissions. It makes sectors dependent on energy, especially fossil fuel energy, sensitive to the policy-related decisions. The more restrictive the climate policy expected, the higher the transition climate risks implied and the higher the compensation for the accompanying risks and vice versa. This is exactly what happened in case of the PA, for instance, since the utilities, energy-intensive, and housing sectors' returns increased. In contrast, these sectors' returns decreased when less focus on

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[1] IRENA (2020). How Falling Costs Make Renewables a Cost-effective Investment [web]

climate change was expected after the USPE.

In summary, we investigated how investors in financial markets account for climate change risk by performing an event study of 118 ETFs from six different industry sectors. In most cases, the effects of the selected events were significant for the sectors we studied. Not surprisingly, we found that the energy industry has the highest magnitude of abnormal returns related to the events for both the fossil fuel and clean or renewable energy sectors. Other sectors' dependence on energy shaped their reaction to the events. The sectors' responses to the events have a systematic character that is reflected in the directions of the abnormal price changes around similar events: the response pattern is the same for events that similarly contribute to the discussion of climate change consequences and policies. We argue that the stock market recognizes events that carry new information about transition climate risks, and investors in the market are quick to adjust prices accordingly. This implies that policymakers should be aware of the market reactions to climate change policy since investors price the accompanying changes in terms of both risk and growth expectations.

REFERENCES

Alley, R. B. (2003). Abrupt climate change. *Science*, 299(5615):2005–2010.

Alsaifi, K., Elnahass, M., and Salama, A. (2020). Market responses to firms' voluntary carbon disclosure: Empirical evidence from the United Kingdom. *Journal of Cleaner Production*, 262:121377.

Andreae, M. O., Jones, C. D., and Cox, P. M. (2005). Strong present-day aerosol cooling implies a hot future. *Nature*, 435(7046):1187–1190.

Battiston, S. and Monasterolo, I. (2018). The climate target gap is widening. Can we close it by including climate finance in SSPs? *SSRN Electronic Journal*.

Betzer, A., Doumet, M., and Rinne, U. (2013). How policy changes affect shareholder wealth: The case of the Fukushima Dai-ichi nuclear disaster. *Applied Economics Letters*, 20(8):799–803.

Birindelli, G. and Chiappini, H. (2021). Climate change policies: Good news or bad news for firms in the European Union? *Corporate Social Responsibility and Environmental Management*, 28(2):831–848.

Blau, B. M., Griffith, T. G., and Whitby, R. J. (2019). Information in stock prices: the case of the 2016 U.S. presidential election. *Applied Economics*, 51(40):4385–4396.

Boehmer, E., Musumeci, J., and Poulsen, A. B. (1991). Event-study methodology under conditions of event-induced variance. *Journal of Financial Economics*, 30(2):253–272.

Bolton, P. and Kacperczyk, M. T. (2021). Do investors care about carbon risk? *Journal of Financial Econometrics*, 142(2):517–549.

Christoff, P. (2016). The promissory note: COP 21 and the Paris Climate Agreement. *Environmental Politics*, 25(5):765–787.

Clapp, C., Lund, H. F., Borgar, A., and Lannoo, E. (2017). Shades of climate risk: Categorizing climate risk for investors. Technical Report 2017:1, CICERO Center for International Climate Research, Oslo.

Corrado, C. J. (2011). Event studies: A methodology review. *Accounting and Finance*, 51(1):207–234.

Diaz-Rainey, I., Gehricke, S. A., Roberts, H., and Zhang, R. (2021). Trump vs. Paris: The impact of climate policy on U.S. listed oil and gas firm returns and volatility. *International Review of Financial Analysis*, 76:101746.

Easterling, D., Meehl, G., Parmesan, C., Changnon, S., Karl, T., and Mearns, L. (2000). Climate extremes: observations, modeling, and impacts. *Science*, 289(5487):2068–2074.

Fama, E. F. and French, K. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, 33:3–56.

Ferstl, R., Utz, S., and Wimmer, M. (2012). The effect of the Japan 2011 disaster on nuclear and alternative energy stocks worldwide: An event study. *Business Research*, 5(1):25–41.

Hansen, J., Nazarenko, L., Ruedy, R., Sato, M., Willis, J., Del Genio, A., Koch, D., Lacis, A., Lo, K., Menon, S., Novakov, T., Perlwitz, J., Russell, G., Schmidt, G. A., and Tausnev, N. (2005). Earth's energy imbalance: confirmation and implications. *Science*, 308(November):1431–1435.

Hayhoe, K., Cayan, D., Field, C., Frumhoff, P., Maurer, E., Miller, N. L., Moser, S., Schneider, S., Cahill, K. N., Cleland, E., Dale, L., Drapek, R., Hanemann, R. M., Kalkstein, L., Lenihan, J., Lunch, C., Neilson, R., Sheridan, S., and Verville, J. (2004). Emissions pathways, climate change, and impacts on California. *Proceedings of the National Academy of Sciences*, 101(34):12422–12427.

He, X. and Liu, Y. (2018). The public environmental awareness and the air pollution effect in Chinese stock market. *Journal of Cleaner Production*, 185:446–454.

Jung, J., Herbohn, K., and Clarkson, P. (2018). Carbon risk, carbon risk awareness and the cost of debt financing. *Journal of Business Ethics*, 150(4):1151–1171.

Kolari, J. W. and Pynnönen, S. (2010). Event study testing with cross-sectional correlation of abnormal returns. *Review of Financial Studies*, 23(11):3996–4025.

Kothari, S. and Warner, J. (2007). Econometrics of event studies. In Eckbo, B. E., editor, *Handbook of Empirical Corporate Finance*, pages 3–36. Elsevier.

Krueger, P., Sautner, Z., and Starks, L. T. (2020). The importance of climate risks for institutional investors. *Review of Financial Studies*, 33(3):1067–1111.

Lei, Z. and Shcherbakova, A. V. (2015). Revealing climate change opinions through investment behavior: Evidence from Fukushima. *Journal of Environmental Economics and Management*, 70:92–108.

Leiserowitz, A. A., Maibach, E. W., Roser-Renouf, C., Smith, N., and Dawson, E. (2013). Climategate, public opinion, and the loss of trust. *American Behavioral Scientist*, 57(6):818–837.

Li, M., Dong, L., Luan, J., and Wang, P. (2020). Do environmental regulations affect investors? Evidence from China's action plan for air pollution prevention. *Journal of Cleaner Production*, 244:118817.

Lintner, J. (1965). The valuation of risky assets and the selection of risky investments in stock portfolio and capital budgets. *Review of Economics and Statistics*, 47(1):13–27.

Matthews, D., Gillett, N., Stott, P., and Zickfeld, K. (2009). The proportionality of global warming to cumulative carbon emissions. *Nature*, 459(7248):829–832.

Matthews, T., Wilby, R. L., and Murphy, C. (2017). Communicating the deadly consequences of global warming for human heat stress. *Proceedings of the National Academy of Sciences*, 114(15):3861–3866.

Mukanjari, S. and Sterner, T. (2018). Do markets trump politics? Evidence from fossil market reactions to the Paris Agreement and the US election. Technical Report 18-24, Resources for the Future, Washington, DC.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review*, 109(6):1991–2014.

Nordhaus, W. and Yang, Z. (1996). A regional dynamic general-equilibrium model of alternative climate-change strategies. *American Economic Review*, 86(17):741–765.

Oberndorfer, U., Schmidt, P., Wagner, M., and Ziegler, A. (2013). Does the stock market value the inclusion in a sustainability stock index? An event study analysis for German firms. *Journal of Environmental Economics and Management*, 66(3):497–509.

Patell, J. M. (1976). Corporate forecasts of earnings per share and stock price behavior: Empirical test. *Journal of Accounting Research*, 14(2):246–246.

Pham, H., Nguyen, V., Ramiah, V., Saleem, K., and Moosa, N. (2019). The effects of the Paris climate agreement on stock markets: Evidence from the German stock market. *Applied Economics*, 51(57):6068–6075.

Phillips, P. C., Leirvik, T., and Storelvmo, T. (2020). Econometric estimates of Earth's transient climate sensitivity. *Journal of Econometrics*, 214(1):6–32.

Qian, W., Suryani, A. W., and Xing, K. (2020). Does carbon performance matter to market returns during climate policy changes? Evidence from Australia. *Journal of Cleaner Production*, 259:121040.

Sarkodie, S. A., Adams, S., and Leirvik, T. (2020a). Foreign direct investment and renewable energy in climate change mitigation: Does governance matter? *Journal of Cleaner Production*, 263:121262.

Sarkodie, S. A., Adams, S., Owusu, P. A., Leirvik, T., and Ozturk, I. (2020b). Mitigating degradation and emissions in China: The role of environmental sustainability, human capital and renewable energy. *Science of the Total Environment*, 719:137530–137530.

Sen, S. and von Schickfus, M. T. (2020). Climate policy, stranded assets, and investors' expectations. *Journal of Environmental Economics and Management*, 100:102277.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *The Journal of Finance*, 19(3):425–442.

Sorokina, N., Booth, D. E., and Thornton, J. H. (2013). Robust methods in event studies: Empirical evidence and theoretical implications. *Journal of Data Science*, 11:575–606.

Storelvmo, T., Leirvik, T., Lohmann, U., Phillips, P. C., and Wild, M. (2016). Disentangling greenhouse warming and aerosol cooling to reveal Earth's climate sensitivity. *Nature Geoscience*, 9(4):286–289.

Teng, M. and He, X. (2020). Air quality levels, environmental awareness and investor trading behavior: Evidence from stock market in China. *Journal of Cleaner Production*, 244:118663.

US EPA (2019a). Global greenhouse gas emissions data | Greenhouse gas (GHG) emissions. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

US EPA (2019b). Sources of greenhouse gas emissions | Greenhouse gas (GHG) emissions. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

6.A DATA

Fossil fuels ETFs:

USO	United States Oil
XOP	SPDR S&P Oil & Gas Explor & Prodtn ETF
XLE	Energy Select Sector SPDR ETF
VDE	Vanguard Energy ETF
IYE	VanEck Vectors Environmental Svcs ETF
OIH	VanEck Vectors Oil Services ETF
FXN	First Trust Energy AlphaDEX ETF
IXC	iShares Global Energy
IEO	iShares US Oil & Gas Explor&Prodtn
XES	SPDR S&P Oil & Gas Equipment & Svcs ETF
RYE	Guggenheim S&P 500 Equal Wt Energy ETF
KOL	VanEck Vectors Coal ETF
IPW	SPDR S&P International Energy Sect ETF

Clean energy ETFs:

TAN	Guggenheim Solar ETF
QCLN	First Trust NASDAQ Clean Edge Green Energy Index Fund
KWT	VanEck Vectors Solar Energy ETF
GEX	VanEck Vectors Global Alternative Energy ETF
ICLN	iShares Global Clean Energy ETF
PBW	PowerShares WilderHill Clean Energy Portfolio ETF
FAN	First Trust ISE Global Wind Energy Index Fund
URA	Global X Uranium ETF
PUW	PowerShares WilderHill Progressive Energy Portfolio ETF
PBD	PowerShares Global Clean Energy Portfolio ETF
PZD	PowerShares Cleantech Portfolio ETF
EVX	VanEck Vectors Environmental Svcs ETF

Market ETFs:

SPY	SPDR S&P 500 ETF
EEM	iShares MSCI Emerging Markets
IWM	iShares Russell 2000
VTI	Vanguard Total Stock Market ETF
EFA	iShares MSCI EAFE
VEA	Vanguard FTSE Developed Markets ETF
VGK	Vanguard FTSE Europe ETF
IWV	iShares Russell 3000

Energy intensive ETFs:

DBB	PowerShares DB Base Metals Fund
JJC	iPath Dow Jones-UBS Copper ETN
JJN	iPath Dow Jones-UBS Nickel ETN
JJM	iPath Dow Jones-UBS Industrial Metals ETN
CPER	United States Copper Index Fund
RJZ	RICI-Metals ETN
JJU	iPath Dow Jones-UBS Aluminum ETN
JJT	iPath Dow Jones-UBS Tin ETN
UBM	E-TRACS UBS Bloomberg CMCI Industrial Metals ETN
NINI	iPath Pure Beta Nickel ETN
CUPM	iPath Pure Beta Copper ETN
HEVY	iPath Pure Beta Industrial Metals ETN
LEDD	iPath Pure Beta Lead ETN
LD	iPath Dow Jones-UBS Lead ETN
FOIL	iPath Pure Beta Aluminum ETN
SOIL	Global X Fertilizers/Potash ETF
XLP	Consumer Staples Select Sector SPDR Fund
VDC	Vanguard Consumer Staples ETF
ECON	Columbia Emerging Markets Consumer ETF
KXI	iShares Global Consumer Staples ETF
IYK	iShares U.S. Consumer Goods ETF
RHS	Guggenheim S&P Equal Weight Consumer Staples
FXG	First Trust Consumer Staples AlphaDEX Fund
FSTA	Fidelity MSCI Consumer Staples Index ETF
PBJ	PowerShares Dynamic Food and Beverage
PSL	PowerShares DWA Consumer Staples Momentum Portfolio
PSCC	PowerShares S&P SmallCap Consumer Staples Portfolio
JHMS	John Hancock Multifactor Consumer Staples ETF
CNSF	iShares Edge MSCI Multifactor Consumer Staples ETF
BFIT	Global X Health & Wellness Thematic ETF
FTXG	First Trust Nasdaq Food & Beverage ETF
CARZ	First Trust NASDAQ Global Auto Index Fund

Housing ETFs:

ITB iShares U.S. Home Construction ETF

XHB SPDR S&P Homebuilders ETF

PKB PowerShares Dynamic Building & Construction

PAVE US Infrastructure Development ETF

FLM First Trust ISE Global Engineering and Construction ETF

VNQ Vanguard REIT ETF

IYR iShares U.S. Real Estate ETF

SCHH Schwab US REIT ETF

ICF iShares Cohen & Steers REIT ETF

RWR SPDR Dow Jones REIT ETF

XLRE Real Estate Select Sector SPDR Fund

REM iShares Mortgage Real Estate Capped ETF

FREL Fidelity MSCI Real Estate Index ETF

KBWY PowerShares KBW Premium Yield Equity REIT Portfolio

REZ iShares Residential Real Estate Capped ETF

USRT iShares Core U.S. REIT ETF

FRI First Trust S&P REIT Index Fund

MORT VanEck Vectors Mortgage REIT Income ETF

ROOF IQ US Real Estate Small Cap ETF

SRET Global X SuperDividend REIT ETF

EWRE Guggenheim S&P 500 Equal Weight Real Estate ETF

PSR PowerShares Active U.S. Real Estate Fund

WREI Wilshire US REIT ETF

OLD Long-Term Care ETF

RORE Hartford Multifactor REIT ETF

MRRL ETRACS Monthly Pay 2xLeveraged Mortgage REIT ETN

NURE NuShares Short-Term REIT ETF

LARE Tierra XP Latin America Real Estate ETF

DXJR WisdomTree Japan Hedged Real Estate Fund

PRME First Trust Heitman Global Prime Real Estate ETF

Transport ETFs:

IYT iShares Transportation Average ETF

XTN SPDR S&P Transportation ETF

SEA Guggenheim Shipping ETF

Utilities ETFs:

XLU Utilities Select Sector SPDR Fund

VPU Vanguard Utilities ETF

IGF iShares Global Infrastructure ETF

FXU First Trust Utilities AlphaDEX Fund

IDU iShares U.S. Utilities ETF

FUTY Fidelity MSCI Utilities Index ETF

GII SPDR S&P Global Infrastructure ETF

RYU Guggenheim S&P Equal Weight Utilities

JXI iShares Global Utilities ETF

PUI PowerShares DWA Utilities Momentum Portfolio

PSCU PowerShares S&P SmallCap Utilities Portfolio

INXX Columbia India Infrastructure Index Fund

EMIF iShares Emerging Markets Infrastructure ETF

TOLZ ProShares DJ Brookfield Global Infrastructure ETF

GHII Guggenheim S&P High Income Infrastructure ETF

UPW ProShares Ultra Utilities

JHMU John Hancock Multi-Factor Utilities ETF

PXR PowerShares Emerging Markets Infrastructure ETF

UTES Reaves Utilities ETF

SDP ProShares Ultra Short Utilities

UTLF iShares Edge MSCI Multifactor Utilities ETF

6.B ANALYSIS RESULTS

This section presents the regression results for the ETFs returns for the Fama-French three-factor model (FF3), for details see subsection 6.3.1. Figure 6.B1 shows the dynamic of cumulative abnormal returns, starting ten days before each event.

In Table 6.B1 each event is tested separately, i.e., for each event abnormal returns for the event window estimated, and tested as well as cumulative abnormal returns.

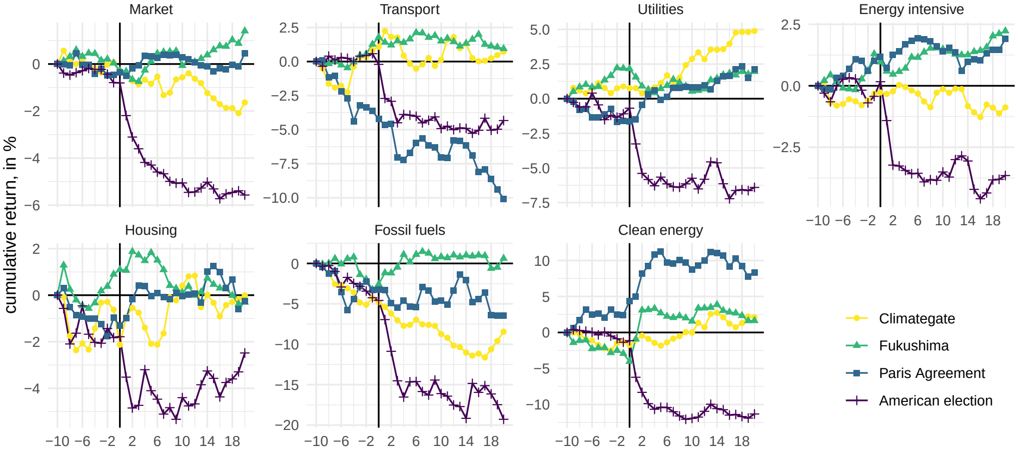

Figure 6.B1: Cumulative abnormal returns from Fama-French three-factor model calculated from 10 days before the event to 20 days after event.

Table 6.B1: Stock market reaction to selected events

The table reports estimated abnormal returns separately for three days before the event and five days after and CAR for various event windows (column *AR*), given in %. The abnormal returns were calculated based on the Fama-French three-factor model (Fama and French, 1991), and tested by the parametric Boehmer et al. (1991) test (column *BMP*) and Patell's test (1976; column *Patell*). Columns *aBMP* and *aPatell* report the tests mentioned above, but adjusted for the cross-sectional correlation by Kolari and Pynnönen (2010). The table reports test results as *p*-values (since *t*-values are not directly comparable between samples due to different degrees of freedom). The underlined *p*-values are significant at the 10% level, and those in **bold** are significant at the 5% level. R^2 shows a median coefficient of determination within each type.

Day(s)	-3	-2	-1	0	1	2	3	4	5	-1, 1	-1, 3	-1, 5	-3, 3
Climategate													
Market ($R^2 = 0.931$)													
AR	0.09	0.34	-0.17	-0.42	-0.09	-0.28	-0.15	0.2	-0.17	-0.42	-0.84	-0.82	-0.68
BMP	0.27	0.08	0.48	**0.01**	0.68	**0.01**	0.32	0.44	0.79	0.17	**0.04**	0.18	0.08
aBMP	0.51	0.28	0.68	0.07	0.81	0.07	0.56	0.65	0.88	0.41	0.19	0.42	0.27
Patell	0.77	0.33	0.7	0.12	0.85	0.24	0.66	0.69	0.81	0.49	0.22	0.4	0.4
aPatell	0.85	0.52	0.8	0.29	0.9	0.43	0.78	0.79	0.88	0.65	0.41	0.58	0.58
Transport ($R^2 = 0.729$)													
AR	0.52	0.01	0.68	0.24	1.16	-0.44	-0.04	-1.33	-0.6	1.92	1.44	-0.49	2.13
BMP	0.78	0.86	0.07	**0.03**	0.56	0.81	0.97	0.05	0.1	0.59	0.42	0.62	0.4
aBMP	0.83	0.9	0.1	**0.04**	0.65	0.86	0.98	0.07	0.14	0.68	0.52	0.71	0.5
Patell	0.83	0.96	0.66	0.87	0.57	0.86	0.99	0.44	0.68	0.59	0.71	0.84	0.65
aPatell	0.85	0.97	0.7	0.89	0.61	0.88	1	0.48	0.71	0.63	0.75	0.86	0.69
Utilities ($R^2 = 0.609$)													
AR	0.14	0.36	-0.38	-0.13	0	-0.37	0.29	0.13	0.31	0.01	-0.07	0.37	-0.09
BMP	0.18	**0.01**	**0.02**	0.18	0.92	**0.01**	0.08	0.22	**0.03**	0.74	0.79	0.12	0.7
aBMP	0.56	0.24	0.25	0.56	0.97	0.24	0.43	0.6	0.32	0.89	0.91	0.49	0.87
Patell	0.6	0.21	0.19	0.68	0.97	0.25	0.37	0.59	0.27	0.94	0.95	0.56	0.94
aPatell	0.8	0.53	0.5	0.84	0.99	0.56	0.65	0.79	0.58	0.97	0.98	0.77	0.97
Energy intensive ($R^2 = 0.717$)													
AR	0.27	0.19	-0.16	0.06	-0.06	0.11	0.26	-0.09	-0.14	0.27	0.63	0.41	0.67
BMP	0.62	0.07	0.22	0.56	0.56	0.05	**0.02**	0.95	0.28	0.79	**0.04**	0.15	**0.03**
aBMP	0.86	0.47	0.64	0.83	0.83	0.44	0.33	0.98	0.69	0.92	0.42	0.59	0.36
Patell	0.78	0.39	0.6	0.9	0.84	0.59	0.43	0.98	0.72	0.91	0.49	0.65	0.48
aPatell	0.89	0.68	0.8	0.95	0.92	0.8	0.7	0.99	0.86	0.96	0.74	0.83	0.73
Housing ($R^2 = 0.774$)													
AR	-0.34	0.04	1.11	-1.51	1.18	0.41	-0.21	-0.64	-0.7	-0.67	-0.47	-1.81	0.68
BMP	0.1	0.98	**<.01**	**<.01**	**<.01**	0.11	0.33	**<.01**	**<.01**	0.05	0.19	**0.01**	0.89
aBMP	0.48	0.99	**0.04**	**0.02**	0.1	0.49	0.69	**0.01**	**0.01**	0.38	0.58	0.21	0.96
Patell	0.53	0.99	0.11	**0.02**	0.11	0.56	0.63	0.28	0.23	0.35	0.5	0.16	0.94
aPatell	0.75	1	0.41	0.2	0.41	0.77	0.81	0.59	0.54	0.64	0.74	0.47	0.97
Fossil fuel ($R^2 = 0.722$)													
AR	0.84	-0.26	-1.28	-0.54	-0.58	-0.81	-0.82	-0.7	0.12	-0.28	-1.92	-2.49	-3.45
BMP	**<.01**	0.09	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	0.15	0.33	**<.01**	**<.01**	**<.01**
aBMP	0.28	0.74	0.06	0.47	0.37	0.45	0.27	0.44	0.78	0.85	0.36	0.25	0.18
Patell	0.06	0.64	**0.01**	0.19	0.19	0.09	0.07	0.19	0.54	0.71	0.07	0.07	**0.01**
aPatell	0.5	0.87	0.34	0.65	0.66	0.55	0.52	0.65	0.84	0.9	0.52	0.52	0.33
Clean energy ($R^2 = 0.743$)													
AR	0.21	1.01	-0.3	-0.43	0.69	0.6	-0.45	-0.57	-0.39	0.46	0.61	-0.35	1.32
BMP	0.81	**0.01**	**0.02**	**0.04**	**0.01**	**<.01**	**0.04**	0.06	**0.03**	0.64	0.76	0.27	0.4
aBMP	0.94	0.38	0.44	0.5	0.36	0.25	0.5	0.54	0.45	0.89	0.93	0.74	0.8
Patell	0.89	0.14	0.54	0.41	0.32	0.35	0.34	0.3	0.48	0.85	0.89	0.58	0.63
aPatell	0.96	0.52	0.8	0.73	0.67	0.69	0.69	0.66	0.77	0.94	0.95	0.82	0.84
AR	-0.17	0.05	-0.29	-0.32	-0.03	-0.34	-0.09	0.49	0.37	-0.52	-0.96	-0.1	-1.19
Fukushima													
Market ($R^2 = 0.928$)													
BMP	0.07	0.95	0.08	**0.02**	0.8	**<.01**	0.57	0.4	0.06	0.1	0.14	0.48	0.1

Table 6.B1: Stock market reaction to selected events

Day(s)	-3	-2	-1	0	1	2	3	4	5	-1, 1	-1, 3	-1, 5	-3, 3
aBMP	0.28	0.97	0.3	0.13	0.89	**0.04**	0.75	0.64	0.25	0.32	0.38	0.69	0.32
Patell	0.38	0.99	0.11	0.06	0.75	0.07	0.56	0.13	**0.04**	0.08	0.06	0.76	**0.04**
aPatell	0.57	0.99	0.28	0.2	0.84	0.23	0.71	0.32	0.16	0.24	0.2	0.85	0.15
Transport ($R^2 = 0.764$)													
AR	0.71	0.11	0.48	0.52	-0.38	-0.2	0.31	-0.12	0.26	0.85	0.96	1.1	1.55
BMP	0.38	0.68	0.68	0.1	0.63	0.97	0.05	1	0.55	0.25	0.34	0.45	0.54
aBMP	0.4	0.7	0.7	0.11	0.66	0.97	0.06	1	0.58	0.27	0.37	0.48	0.57
Patell	0.35	0.81	0.39	0.49	0.49	0.95	0.64	1	0.73	0.52	0.51	0.5	0.38
aPatell	0.36	0.81	0.4	0.5	0.5	0.95	0.65	1	0.74	0.53	0.52	0.52	0.39
Utilities ($R^2 = 0.697$)													
AR	-0.03	0.56	0.32	-0.04	-0.6	-0.64	-0.25	-0.23	0.3	-0.67	-1.57	-1.5	-0.69
BMP	0.76	**<.01**	0.06	0.39	**0.03**	**<.01**	**0.02**	0.08	0.12	**0.02**	**<.01**	**0.01**	0.1
aBMP	0.9	0.14	0.39	0.71	0.3	0.1	0.27	0.43	0.48	0.27	0.15	0.2	0.46
Patell	0.88	**<.01**	0.09	0.57	**<.01**	**<.01**	0.17	0.14	0.1	**0.02**	**<.01**	**<.01**	0.11
aPatell	0.94	0.09	0.38	0.78	0.09	0.06	0.48	0.44	0.39	0.22	**0.04**	0.09	0.41
Energy intensive ($R^2 = 0.757$)													
AR	0.69	0.33	0.44	-0.33	-0.37	-0.12	0.11	0.13	0.45	-0.02	-0.03	0.56	0.74
BMP	**<.01**	**0.02**	**<.01**	**<.01**	**<.01**	0.34	0.64	0.65	**<.01**	0.25	0.35	0.49	**0.02**
aBMP	0.07	0.27	0.1	0.08	0.15	0.71	0.86	0.86	0.16	0.64	0.71	0.79	0.29
Patell	**<.01**	**<.01**	**0.01**	0.06	**0.01**	0.57	0.74	0.66	**0.01**	0.46	0.49	0.66	0.06
aPatell	0.07	0.09	0.11	0.3	0.14	0.78	0.87	0.83	0.15	0.71	0.73	0.83	0.31
Housing ($R^2 = 0.762$)													
AR	0.52	0.19	0.52	0.2	-0.04	0.81	-0.15	-0.24	0.35	0.69	1.35	1.45	2.06
BMP	**<.01**	0.19	0.06	**0.03**	0.95	**0.01**	0.36	0.26	0.05	**<.01**	**<.01**	**<.01**	**<.01**
aBMP	0.12	0.65	0.5	0.43	0.98	0.28	0.75	0.7	0.46	0.2	0.05	**0.03**	0.13
Patell	0.05	0.43	0.07	0.39	0.97	**0.01**	0.59	0.37	0.17	0.1	**0.03**	**0.04**	**0.01**
aPatell	0.36	0.73	0.41	0.71	0.99	0.19	0.81	0.69	0.54	0.46	0.29	0.32	0.19
Fossil fuel ($R^2 = 0.718$)													
AR	-1.28	-0.58	-2.17	0.67	1.4	-0.03	0.72	1.57	-0.94	0.8	1.49	2.13	-1.25
BMP	**<.01**	**<.01**	**<.01**	**0.01**	**<.01**	0.62	**0.01**	**<.01**	**<.01**	**0.02**	**0.01**	**<.01**	**0.03**
aBMP	0.1	0.3	**0.04**	0.49	0.1	0.91	0.47	**0.03**	0.22	0.56	0.54	0.26	0.59
Patell	**<.01**	**0.03**	**<.01**	**0.01**	**<.01**	0.66	**0.02**	**<.01**	**<.01**	0.08	**0.01**	**0.01**	0.07
aPatell	0.07	0.41	**0.01**	0.3	0.07	0.88	0.37	**0.04**	0.2	0.52	0.34	0.26	0.5
Clean energy ($R^2 = 0.762$)													
AR	-0.43	0.31	-0.71	-1.1	3.11	4.03	0.05	0.18	-0.63	1.58	5.66	5.21	5.26
BMP	0.09	0.12	**0.01**	**<.01**	**<.01**	**<.01**	0.32	0.16	0.29	**0.02**	**<.01**	**<.01**	**<.01**
aBMP	0.57	0.61	0.31	0.13	0.19	0.11	0.75	0.64	0.73	0.41	0.13	0.2	0.2
Patell	0.3	0.24	**0.03**	**<.01**	**<.01**	**<.01**	0.38	0.22	0.17	**0.02**	**<.01**	**<.01**	**<.01**
aPatell	0.65	0.61	0.32	0.16	**<.01**	**<.01**	0.71	0.59	0.54	0.24	**<.01**	**0.01**	**0.02**
AR	0.01	-0.27	0.2	0.12	-0.15	0.3	0.14	0.4	-0.03	-0.01	0.43	0.8	0.35
Paris Agreement													
Market ($R^2 = 0.86$)													
BMP	0.09	**<.01**	0.3	0.5	0.88	0.17	0.3	0.51	0.44	0.26	**0.01**	**0.01**	**0.04**
aBMP	0.37	0.08	0.61	0.74	0.94	0.48	0.61	0.75	0.71	0.57	0.14	0.1	0.26
Patell	0.27	0.1	0.54	0.54	0.87	0.3	0.6	0.3	0.56	0.37	0.18	0.1	0.46
aPatell	0.51	0.32	0.73	0.73	0.92	0.55	0.77	0.54	0.74	0.6	0.42	0.31	0.67
Transport ($R^2 = 0.61$)													
AR	-0.29	-0.15	1.18	-0.59	-0.44	0.09	-2.46	-0.2	0.54	-1.32	-3.69	-3.34	-2.66
BMP	0.36	0.9	0.2	0.14	0.34	0.68	0.36	0.82	0.26	0.2	0.35	0.17	0.5
aBMP	0.56	0.94	0.38	0.29	0.54	0.81	0.55	0.89	0.45	0.38	0.55	0.34	0.67
Patell	0.62	0.84	0.12	0.31	0.43	0.8	**0.03**	0.61	0.37	0.24	0.07	0.11	0.17
aPatell	0.71	0.88	0.19	0.42	0.54	0.85	0.06	0.7	0.47	0.34	0.12	0.17	0.26
Utilities ($R^2 = 0.373$)													
AR	0.08	-0.94	0.39	-0.04	0.14	1.06	0.75	0.27	-0.66	0.17	1.98	1.59	1.44
BMP	0.54	**<.01**	**0.01**	0.31	0.16	**<.01**	**<.01**	0.19	**0.01**	0.55	**<.01**	**0.01**	**<.01**
aBMP	0.84	0.15	0.38	0.74	0.64	0.12	0.27	0.67	0.33	0.85	0.18	0.33	0.15

Table 6.B1: Stock market reaction to selected events

Day(s)	-3	-2	-1	0	1	2	3	4	5	-1, 1	-1, 3	-1, 5	-3, 3
Patell	0.67	<**.01**	**0.02**	0.46	0.44	<**.01**	<**.01**	0.28	<**.01**	0.79	<**.01**	**0.02**	**0.01**
aPatell	0.87	0.1	0.32	0.77	0.76	0.05	0.21	0.67	0.18	0.92	0.13	0.34	0.3
Energy intensive ($R^2 = 0.727$)													
AR	0.42	-0.42	-0.07	0.16	-0.46	0.53	0.14	0.3	0.14	0.12	0.79	1.23	0.31
BMP	**0.02**	<**.01**	0.09	0.17	0.08	<**.01**	0.31	0.64	0.39	0.15	<**.01**	<**.01**	0.08
aBMP	0.37	0.17	0.52	0.6	0.5	0.11	0.71	0.87	0.75	0.58	0.14	0.2	0.51
Patell	0.05	**0.02**	0.19	0.24	0.13	<**.01**	0.47	0.48	0.39	0.31	**0.01**	**0.02**	0.34
aPatell	0.35	0.28	0.55	0.6	0.5	0.1	0.75	0.75	0.7	0.65	0.22	0.28	0.67
Housing ($R^2 = 0.475$)													
AR	0.79	-0.53	-0.23	-0.33	0.32	0.82	0.59	-0.03	-0.43	0.77	2.18	1.73	1.42
BMP	<**.01**	<**.01**	0.13	0.06	0.05	<**.01**	**0.01**	0.83	**0.02**	**0.02**	<**.01**	<**.01**	**0.01**
aBMP	0.29	0.36	0.71	0.63	0.62	0.21	0.46	0.96	0.54	0.55	0.16	0.37	0.45
Patell	<**.01**	**0.01**	0.2	0.05	0.1	<**.01**	**0.01**	0.88	0.05	**0.04**	<**.01**	<**.01**	**0.02**
aPatell	0.18	0.37	0.66	0.49	0.57	0.16	0.34	0.96	0.48	0.48	0.12	0.28	0.39
Fossil fuel ($R^2 = 0.54$)													
AR	-1.04	0.54	1.59	0.07	-0.07	-1.64	-0.56	0.87	-0.69	-1.04	-3.24	-3.05	-1.11
BMP	<**.01**	**0.02**	<**.01**	0.74	1	<**.01**	<**.01**	<**.01**	**0.01**	**0.04**	<**.01**	<**.01**	0.16
aBMP	0.21	0.66	0.33	0.96	1	0.5	0.41	0.46	0.63	0.7	0.24	0.47	0.81
Patell	**0.01**	0.11	<**.01**	0.84	1	<**.01**	0.14	**0.02**	0.06	0.11	<**.01**	**0.01**	0.42
aPatell	0.31	0.59	0.12	0.95	1	0.17	0.62	0.4	0.52	0.58	0.22	0.32	0.79
Clean energy ($R^2 = 0.572$)													
AR	-0.1	-0.66	1.11	1.98	0.64	3.17	1.05	1.57	0.44	2.52	6.74	8.75	7.19
BMP	0.62	**0.02**	<**.01**	**0.01**	0.11	<**.01**	<**.01**	<**.01**	0.29	**0.04**	<**.01**	<**.01**	<**.01**
aBMP	0.86	0.34	0.09	0.33	0.56	**0.04**	0.06	0.08	0.71	0.44	0.13	0.14	0.11
Patell	0.61	**0.04**	<**.01**	<**.01**	0.16	<**.01**	**0.01**	<**.01**	0.42	**0.01**	<**.01**	<**.01**	<**.01**
aPatell	0.82	0.31	0.12	**0.04**	0.52	<**.01**	0.15	0.06	0.72	0.14	<**.01**	<**.01**	**0.01**
AR	-0.36	-0.2	0	-0.01	-1.39	-0.91	-0.5	-0.58	-0.11	-1.76	-3.17	-3.86	-3.37
American election													
Market ($R^2 = 0.884$)													
BMP	0.17	0.48	0.8	0.42	**0.01**	0.39	**0.01**	0.93	0.08	<**.01**	**0.03**	**0.04**	0.06
aBMP	0.48	0.72	0.9	0.69	0.12	0.67	0.16	0.97	0.34	0.08	0.22	0.26	0.31
Patell	0.1	0.38	0.78	0.68	<**.01**	0.05	**0.02**	0.84	0.13	<**.01**	<**.01**	<**.01**	<**.01**
aPatell	0.31	0.61	0.87	0.81	<**.01**	0.2	0.12	0.9	0.36	**0.02**	**0.01**	**0.01**	**0.02**
Transport ($R^2 = 0.738$)													
AR	0.13	0.05	0.4	-0.78	-2.5	-0.21	-1.57	0.61	-0.05	-3.15	-4.94	-4.38	-4.49
BMP	0.6	0.63	0.28	0.11	**0.02**	1	0.06	0.31	0.28	0.14	0.18	0.34	0.32
aBMP	0.75	0.77	0.47	0.25	0.05	1	0.15	0.51	0.47	0.3	0.36	0.54	0.52
Patell	0.52	0.79	0.38	0.28	**0.04**	1	0.09	0.21	0.93	0.08	0.06	0.12	0.12
aPatell	0.62	0.84	0.48	0.38	0.06	1	0.15	0.3	0.95	0.14	0.1	0.19	0.18
Utilities ($R^2 = 0.27$)													
AR	0.24	-0.13	0.31	0.41	-2.58	-2.13	-0.44	-0.45	0.63	-1.93	-4.5	-4.32	-4.32
BMP	0.13	0.27	0.08	<**.01**	<**.01**	<**.01**	0.22	**0.02**	<**.01**	<**.01**	<**.01**	<**.01**	<**.01**
aBMP	0.65	0.75	0.61	0.34	0.07	0.11	0.72	0.46	0.37	0.14	0.17	0.23	0.25
Patell	0.21	0.54	0.13	**0.04**	<**.01**	<**.01**	**0.03**	**0.04**	<**.01**	<**.01**	<**.01**	<**.01**	<**.01**
aPatell	0.64	0.82	0.58	0.44	<**.01**	<**.01**	0.42	0.44	0.24	0.06	<**.01**	**0.01**	**0.01**
Energy intensive ($R^2 = 0.55$)													
AR	0.27	-0.52	-0.45	0.59	-1.58	-1.81	-0.03	-0.18	-0.13	-0.72	-2.57	-2.88	-3.54
BMP	**0.04**	<**.01**	<**.01**	<**.01**	<**.01**	<**.01**	0.47	0.86	0.5	**0.04**	<**.01**	<**.01**	<**.01**
aBMP	0.43	0.09	0.24	0.15	0.11	0.06	0.79	0.95	0.81	0.42	0.21	0.22	0.13
Patell	0.18	<**.01**	**0.01**	**0.01**	<**.01**	<**.01**	0.18	0.83	0.68	**0.01**	<**.01**	<**.01**	<**.01**
aPatell	0.55	0.13	0.22	0.2	<**.01**	<**.01**	0.55	0.92	0.86	0.18	**0.01**	**0.01**	<**.01**
Housing ($R^2 = 0.41$)													
AR	-0.39	0.63	-0.04	0.04	-1.74	-1.33	0.11	1.53	-0.9	-2.09	-3.3	-2.67	-2.7
BMP	<**.01**	<**.01**	0.51	0.64	<**.01**	<**.01**	0.66	<**.01**	<**.01**	<**.01**	<**.01**	<**.01**	<**.01**
aBMP	0.48	0.23	0.89	0.92	0.3	0.49	0.92	0.23	0.26	0.18	0.3	0.46	0.42
Patell	**0.02**	<**.01**	0.82	0.8	<**.01**	<**.01**	0.51	<**.01**	<**.01**	<**.01**	<**.01**	<**.01**	<**.01**

Table 6.B1: Stock market reaction to selected events

Day(s)	-3	-2	-1	0	1	2	3	4	5	-1, 1	-1, 3	-1, 5	-3, 3
aPatell	0.46	0.25	0.95	0.94	**0.01**	0.06	0.84	**0.01**	0.12	0.06	**0.03**	0.14	0.14
Fossil fuel ($R^2 = 0.641$)													
AR	-0.82	-0.59	-0.36	-0.34	-2.37	-3.93	-3.65	-2.01	1.88	-3.52	-11.1	-11.23	-12.06
BMP	**<.01**	**<.01**	0.13	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**
aBMP	0.37	0.25	0.78	0.54	**0.01**	**<.01**	**<.01**	**0.04**	0.45	**0.01**	**<.01**	**<.01**	**<.01**
Patell	**0.04**	0.16	0.44	0.43	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**	**<.01**
aPatell	0.48	0.64	0.8	0.8	0.06	**0.01**	**0.01**	0.09	0.12	0.11	**<.01**	**<.01**	**<.01**
Clean energy ($R^2 = 0.67$)													
AR	-0.49	-0.38	-0.57	0.22	-5.09	-2.1	-1.56	-0.78	0.27	-5.35	-9.01	-9.52	-9.96
BMP	**0.02**	0.15	0.22	0.65	**<.01**	**<.01**	**<.01**	**0.01**	0.16	**<.01**	**<.01**	**<.01**	**<.01**
aBMP	0.32	0.56	0.62	0.86	**0.02**	0.1	0.09	0.2	0.56	**0.03**	**0.02**	**0.04**	**0.02**
Patell	0.14	0.31	0.18	0.71	**<.01**	**<.01**	**<.01**	**0.01**	0.21	**<.01**	**<.01**	**<.01**	**<.01**
aPatell	0.46	0.62	0.51	0.86	**<.01**	**<.01**	**0.03**	0.18	0.54	**<.01**	**<.01**	**<.01**	**<.01**

7 CLIMATE TRANSITION RISK AND THE IMPACT ON GREEN BONDS

Abstract

The green bond market develops rapidly and aims to contribute to climate mitigation and adaptation significantly. Green bonds as any asset are subject to transition climate risk, namely regulatory risk. This paper investigates the impact of unexpected political events on the risk and returns of green bonds and their correlation with other asset. We apply a traditional and regression-based event study and find that events related to climate change policy impact green bonds indices. Green bonds indices anticipated the 2015 Paris Agreement on climate change as a favorable event, whereas the 2016 US Presidential Election had a significant negative impact. The negative impact of the US withdrawal from the Paris Agreement is more prominent for municipal but not corporate green bonds. All three events also have a similar effect on green bonds performance in the long term. The results imply that, despite the benefits of issuing green bonds, there are substantial risks that are difficult to hedge. This additional risk to green bonds might cause a time-varying premium for green bonds found in previous literature.

7.1 INTRODUCTION

This paper investigates how green bonds are affected by unexpected political events related to climate change. We find that over the period July 2014 and November 2021, green bonds significantly outperform conventional bonds in terms of returns. We further find that the 2016 US presidential election (USPE) has a significant negative impact on bonds in general and green bonds in particular. Other unexpected political events, such as the 2015 Paris Agreement (PA), have a positive and significant impact on green bonds and no significant impact on conventional bonds.

Green bonds (GB) were introduced by the European Investment Bank in 2007 as an instrument with a purpose to finance projects with an environmentally friendly profile, see, for example, Horsch and Richter (2017), Zhang et al. (2019) and Nguyen et al. (2020). A GB is a fixed-income instrument specifically earmarked to raise money in the debt markets for climate and environmentally friendly projects. These bonds are typically asset-linked and backed by the issuing entity's balance sheet, so they usually carry the same credit rating as their issuers' other debt obligations. GBs are designated bonds intended to encourage sustainability and to support climate adaptation and mitigation.

The green bond market has grown in popularity, and not without reason: according to Chambwera et al. (2014), mitigation and adaptation to climate change require significant investments of $70–100 billion per year to ensure sufficient adaptation in major sectors until 2050. Bonds are suitable financial vehicles for these purposes because they have an intertemporal basis and let the issuer pay back the raised capital over time. This is one reason why climate finance researchers suggested an introduction of a climate bond in the first place. According to Flaherty et al. (2017), easing the investment burden for the current generation while implementing climate-change policy can be more easily carried out using GB. It means that GB has an important role in the transition to a low-carbon economy.

Long- and short-term climatic trends include changes in the distribution of temperature, precipitation, cloudiness, and more. Observational studies have found that temperature increases over time, with an increase in all regions on Earth and with an increase in the level, variability, and drivers of the level of temperature, see, for example, Storelvmo et al. (2016), Yuan et al. (2021), and Kotz et al. (2021).

Precipitation, on the other hand, shows more heterogeneous trends, with dry areas getting dryer and wet areas getting wetter; see Gulev et al. (2021) for a thorough treatment of the matter. The change in climatic trends has, in general, a profound impact on economies and financial markets around the world, see Burke et al. (2015), Campiglio et al. (2018), Sarkodie et al. (2020), and Bartram et al. (2021), and on the banking sector in particular, see Duqi et al. (2021). Moreover, Bolton and Kacperczyk (2021) find that investors are already demanding compensation for carbon emissions. Exposure to climate risk restricts access to finance in general (Ginglinger and Moreau, 2019). Higher exposure to such risk leads to higher cost of debt (Kling et al., 2021), lower credit ratings and higher yield spreads (Seltzer et al., 2021) because such companies are perceived as more likely to default (Capasso et al., 2020). In our paper, we investigate how unexpected political events related to transitioning countries and economies towards lower carbon emissions affect the green bond market.

Low-carbon transition is seen as a way to reduce climate change's impact on the economy and planet. This process is expected to induce *transition* risks in addition to physical ones stemming from the climate change itself. Although both are important, this paper's focus is on the former. The reason is that firms feel less exposed to physical risk, which is expected to materialize in the more distant future (Sakhel, 2017). Transition climate risks include a regulatory risk that comes with an introduction of and adjustments to climate policy, either global or local. Companies are more concerned about regulatory risk because its impact could lead to additional expenses or changes in expected growth that should be priced.

With a strong link that GB has to climate and the environment, we hypothesize that GB's price is affected by events related to environmentally sensitive issues, such as climate change and political legislation and regulations on the matter. Mitigation and adaption to climate change have been on the political agenda for a few years, though there are few globally recognized regulations and limitations to, for example, greenhouse gas emissions. Often, regulatory changes are long processes with lengthy negotiations. According to the efficient market hypothesis (see Fama, 1970; Tran and Leirvik, 2019), any regulations that impact a firm or industry are reflected in the asset prices. For this reason, we investigate how abrupt and *unexpected* political events affect the prices, as such events are hard to account for before the event. Building on the previous literature, we focus on three events—the Paris Agreement, the 2016 US presidential election, and the US withdrawal from the Paris agreement, and find that all three significantly affect the bond markets.

The green label attracts investors interested in or focused on socially responsible investments (SRI) and investors who want to diversify portfolios, as highlighted in Nguyen et al. (2020). Green bonds widen the choice for SRI investors since they can invest in a project and not in the company itself (Shishlov et al., 2016). The demand for green bonds is high, increases every year, and continues to rise, according to Banga (2019). Thus, green bond investors must understand the risks inherent in the prices.

We argue that green bonds might have an uncompensated advantage since they offer higher returns with lower volatility. However, as we show, there is significant political risk tied up in the prices of GBs, which might be the reason why the premiums found by Zerbib (2019) changes over time.

So far, the impact of climate risk was mostly studied on the stock market with an emphasis on carbon risks (Kumar et al., 2019; In et al., 2019; Bolton and Kacperczyk, 2021) and attention to climate-related policies events (Koch et al., 2016; Ramadorai and Zeni, 2019; Monasterolo and de Angelis, 2020; Birindelli and Chiappini, 2021; Diaz-Rainey et al., 2021; Antoniuk and Leirvik, 2021). This paper is among the first to apply an event study on green bonds. This work is complementary to Seltzer et al. (2021), which looked at the effect of climate regulatory risk on conventional corporate bonds, while ours investigates green corporate bonds and extends the analysis to municipal bonds and the secondary bond market.

7.2 LITERATURE REVIEW

We consider two strands of literature that are related to our research. The first covers green bonds, and another is related to studies on climate regulation.

7.2.1 Green bonds

Earlier studies looked at the definition of green bonds, general market trends (Kochetygova and Jauhari, 2014), and barriers for its further development (Clapp, 2014). Later, research focused on GB performance, how GBs are different from conventional bonds, and how they are related to other assets

The differences between green and conventional bonds have received much attention. The research interest is a green premium, or *greenium*, a negative yield difference between green and conventional bonds, which causes GBs to have a higher price. Zerbib (2019) finds that GBs have a negative premium compared with conventional synthetic bonds of the same issuer in USD (Euro). This implies that they trade on a discount compared to comparable bonds. This discount, however, is different for bonds with a credit rating lower than AAA. Zerbib (2019) shows that this premium of -2 bp is *neither a risk premium nor a market premium*, and thus it could be related specifically to green bonds. A negative premium was also found by Immel et al. (2021). Partridge and Medda (2020) show that greenium exists for municipal bonds, while Fatica et al. (2021) conclude that financial issuers have a higher GB yield. Larcker and Watts (2020) suggest that green and non-green municipal bonds are seen as substitutes when risk and payoff are held constant. Overall, according to MacAskill et al. (2020), a green premium is found within 56% of primary and 70% of secondary market research papers.

Wulandari et al. (2018) find that GBs are more liquid, and Nanayakkara and Colombage (2019) find that the yield spread is tighter for bonds issued in local currency. Karpf and Mandel (2018) argue that the liquidity premium for green bonds is time-varying and that the premium was negative only until 2015 and positive later. Bachelet et al. (2019) find that the GB premium is positive and about 2.09–5.9 bp but claims that correction for liquidity and issue type solves the premium puzzle. Tsoukala and Tsiotas (2021) find that GBs are riskier than conventional bonds in terms of value-at-risk and conditional value-at-risk.

GBs are correlated with corporate bonds (Horsch and Richter, 2017); moreover, this co-movement has a time-varying character: Broadstock and Cheng (2019) find that it was negative before 2014 and became positive after. Green bonds correlate negatively with VIX and the US dollar index (Horsch and Richter, 2017; Reboredo and Ugolini, 2020), making them a good tool for diversification (Ehlers and Packer, 2017), i.e., by reducing the total risk of a portfolio. GB is also connected and dependent on corporate and treasury bonds (Reboredo et al., 2020), commodities (Naeem et al., 2021a; and especially oil by Kanamura, 2020), clean energy (Nguyen et al., 2020), carbon futures (Jin et al., 2020; Hung, 2021). Recent studies look at the impact of COVID-19 on this connectedness and find that it has become more prominent (Naeem et al., 2021c; Arif et al., 2021; Bouri et al., 2021). COVID-19 has also affected bond market efficiency, but the green bond market is more efficient than the conventional one (Naeem et al., 2021b).

7.2.2 Climate regulation

The impact of the climate-related policies was mostly studied for the stock market. The overall conclusion is that these policies affect market prices. Not only does the introduction of new policy cause reaction on the market, but also its timing. Adopted earlier climate policies help avoid shocks in asset pricing (Battiston et al., 2017), while introducing policies during low market sentiment or attention can lead to price decrease and volatility increase on the emission market (Deeney et al., 2016).

Some studies look closer at specific events related to climate change. Birindelli and Chiappini (2021) find that only EU high-score firms reacted positively to the Paris Agreement, but all companies had an extensive negative wealth effect after it. After this event, the correlation between low-carbon and carbon-intensive indices became lower, and investors started to consider an opportunity to invest in low-carbon assets (Monasterolo and de Angelis, 2020).

The 2016 US Presidential election's impact on the stock market was evaluated for fossil and oil companies (Diaz-Rainey et al., 2021), for different types of energy companies (Mukanjari and Sterner, 2018); for other sectors that are climate-sensitive (Antoniuk and Leirvik, 2021). All of them found a non-positive reaction to the election results. The only companies with gain in returns are those with large deferred tax liabilities (Wagner et al., 2018).

These events were only touched in a few studies on the bond market. Seltzer et al. (2021) studied corporate bonds and found that differences in credit ranking and the yield spread between companies with poor and rich environmental profiles are more prominent after the Paris Agreement, with some reversal after the US pullout from the agreement. The Paris Agreement also played an important role for the green bond market in general by significantly affecting its growth (Tolliver et al., 2020a) and increasing green bond allocation to renewable energy (Tolliver et al., 2020b).

7.3 DATA AND METHOD

In this paper, we apply daily prices for July 2014 – November 2021 for a sample of green bond indices available from S&P. They include:

GB: S&P Green Bond Index, which tracks the global green bond market and includes only bonds whose proceeds are used to finance environmentally friendly projects.

GB S: S&P Green Bond Select Index that is a market value-weighted subset of the GB bonds issued globally, subject to stringent financial and extra-financial eligibility criteria.

Muni GB: S&P Municipal Green Bond Index that tracks the US green municipal bond market.

Additionally, we consider the S&P International Corporate Bond Index (***Corp B***) and the S&P Municipal Bond Index (***Muni B***) for comparative purposes. The S&P 500 (***SP500***) is used as a reference for the stock market, and the S&P US Treasury Bond Index (***T-BondI***) is a factor that affects the bond market in general.

Previous research finds a connection between green bonds and other assets; therefore, we also include data on:

Dollar: US dollar index is obtained from the St. Louis Federal Reserve[1]

Commodity: S&P GSCI Index, which is a benchmark for investment in the commodity markets and a measure of commodity performance over time.

Brent: daily Brent Crude Oil price.

Clean energy: S&P Global Clean Energy Index that tracks the performance of companies in global clean energy-related businesses from both developed and emerging markets.

CO2: CO_2 European Emission Allowance, which prices climate credits used in the EU Emission Trading Scheme.

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[1] St. Louis Federal Reserve: stlouisfed.org

Table 7.1: Summary statistics. The numbers in this table are given in percentages using daily data over the period we investigate. The Green Bond Index (GB) has the lowest mean daily return at 0.42 bp (0.0042%), and the Municipal Bond Index (Muni B) has the lowest daily volatility at 0.191% among bond indices.

	Mean	Std.Dev	Min	Median	Max	Skewness	Kurtosis	N.Valid
GB	0.0042	0.312	-2.386	0.003	2.033	-0.526	5.794	1825
GB S	0.0047	0.355	-2.913	0.008	2.292	-0.523	6.004	1825
Corp B	0.0043	0.495	-4.547	0.010	2.990	-0.858	9.661	1825
Muni GB	0.0153	0.267	-3.330	0.019	4.221	-0.899	86.031	1825
Muni B	0.0143	0.191	-2.592	0.019	3.394	-0.379	124.893	1825
T-BondI	0.0095	0.216	-1.674	0.012	1.805	0.239	8.160	1825
SP500	0.0466	1.124	-12.765	0.066	8.968	-1.039	21.247	1825
Brent	-0.0144	2.647	-27.976	0.040	27.419	-0.521	21.982	1825
Clean Energy	0.0484	1.456	-11.748	0.083	11.666	-0.480	10.315	1825
CO2	0.1230	2.773	-18.969	0.132	12.497	-0.438	4.497	1825
Dollar	0.0111	0.317	-2.089	-0.004	1.925	0.165	3.949	1825
Commodity	0.0074	1.404	-11.770	0.074	7.986	-0.629	7.914	1825
VIX	-0.0034	8.348	-29.983	-0.723	76.825	1.261	6.897	1825

VIX: CBOE Market Volatility Index that measures 30-day expected volatility of the stock market.

Our sample starts in July 2014, although a more extended time series for the S&P green bond indices is available. Since most of the green bond indices from S&P were launched in 2014, we argue that only after that would index prices reflect the events' impact. Table 7.1 shows the summary statistics of the assets we investigate in this study. The *GB* has the lowest mean return at 0.42 bp (0.0042%), and *Muni B* had the lowest risk, as measured by the standard deviation of the returns.

We apply a standard event study methodology, which has been widely applied in financial research to investigate how significant news (the event) affects stock prices and returns, see, for example, Bessembinder and Zhang (2013), Duarte-Silva and Tripolski Kimel (2014), Buigut and Kapar (2019), Heyden and Heyden (2020). We have identified three events relevant for our study: the Paris Agreement (*PA*), the 2016 US presidential election (*USPE*), and the announcement of the US pull-

Table 7.2: Set of the events for analysis

	Date	Event	Description
PA	12 December 2015	Paris agreement	UN Climate Change Conference, which adopted the Paris Agreement that governs climate change reduction measures from 2020.
USPE	08 November 2016	US election	The 58th quadrennial US presidential election had an outcome that differed from the results of the poll.
USPO	01 June 2017	US pull out	US President announced that the US would cease all participation in the 2015 Paris Agreement on climate change mitigation.
COVID	13 March 2020	COVID-19 Lockdown	A national emergency was declared in the US in order to reduce the spread of SARS-CoV-2.

out from PA (*USPO*; Table 7.2). PA and USPE are of particular interest, as both were highly unanticipated political events carrying significant consequences for climate-relevant policies. PA initiated an adoption and gradual implementation of national plans about coping with climate change, in which investment instruments as green bonds play a significant role. Another two events were seen as an inhibitor to climate adaptation and mitigation. We hypothesize that PA will benefit green bonds, whereas other events will affect it negatively. Our results largely confirm these hypotheses.

The underlying idea is to test whether realized returns around the event dates are different from the expected ones derived from the model. For each model, the estimation is done based on 200 observations ten days before the event, meaning that if the event day is denoted as $t = 0$, the estimation of the relevant parameters is based on observations $t \in [-210, -11]$. Suppose the event does not carry new information for the market. In that case, there is no surprise, and thus excess (abnormal) return, which is the difference between realized and expected returns, for the event should be zero.

We calculate abnormal returns (AR) based on three expected returns models (Warner and Brown, 1985):

- mean adjusted model: the expected return is equal to the mean return in the estimation period;
- market adjusted model: the expected return is equal to the [stock] market return;
- market model: the expected returns follow a one-factor [stock] market model.

The event window is then defined to include the three trading days before and three days after the event, or $t \in [-3;3]$. For this window, both abnormal and cumulative abnormal returns (CAR) are calculated.

$$CAR_{i_{T_0,T_1}} = \sum_{t=T_0}^{T} AR_{it}, \tag{7.1}$$

where T_0 indicates the number of days before the event included in the computation, and T_1 indicates how many days after the event are included. We tested $CAR_{-3,-1}$, $CAR_{-1,1}$, and $CAR_{1,3}$, which means that we tested event windows of three days, though with a varying number of days before and after the event.

Because events tend to affect not only returns but also volatility, we check for this simultaneously by applying exponential generalized autoregressive conditional heteroscedasticity model, EGARCH(m, s), which also includes S&P 500 as an external regressor that affects returns model with an autoregressive moving average process ARMA(p, q):

$$\begin{aligned} R_t &= \mu + cX_t + \textstyle\sum_{i=1}^{p} \phi_i R_{t-i} + a_t - \sum_{j=1}^{q} \theta_j a_{t-j}, \\ a_t &= \sigma_t \epsilon_t \\ ln(\sigma_t^2) &= \omega + \textstyle\sum_{i=1}^{s} \alpha_i \frac{|a_{t-i}| + \gamma_i a_{t-i}}{\sigma_{t-i}} + \sum_{j=1}^{m} \beta_j \, ln(\sigma_{t-j}^2) \end{aligned} \tag{7.2}$$

where R is daily index return, X is an explanatory variable, ϵ is an iid standard normal error, a is an innovation. σ^2 is a volatility of the returns. A set of dummy variables D_i is introduced in the mean and variance models to capture the event effect. D_i equals one if t corresponds to event day and zero otherwise. A detailed specification of distribution and order for ARMA and EGARCH models is given in Appendix 7.A.

The advantage of this model is two-fold: firstly, we can additionally account for event-induced changes in volatility, and secondly, we do not need to divide our sample into testing and event window because events enter the model as dummy variables (Pynnönen, 2005).

We also calculate correlation and different performance measures (risk, return, value-at-risk, and Sharpe (1994) ratio) for bond indices to assess a longer-term impact of four events: the Paris Agreement, the 2016 US presidential election, the announcement of the US pullout from PA, and US lockdown in 2020. Recent research shows that the COVID-19 pandemic and lockdown impact the financial markets and thus should also be considered.

7.4 EMPIRICAL RESULTS

As discussed previously, this study aims to investigate the impact of unexpected political events related to environmentally sensitive issues on the returns of assets related to the green bond market. The reason we choose political events, and not physical events, such as a natural disaster creating destruction to plants and infrastructure, is that political events, in contrast to physical events, does not carry a direct cost for which it is possible to compute changes in cash flows to the firm.

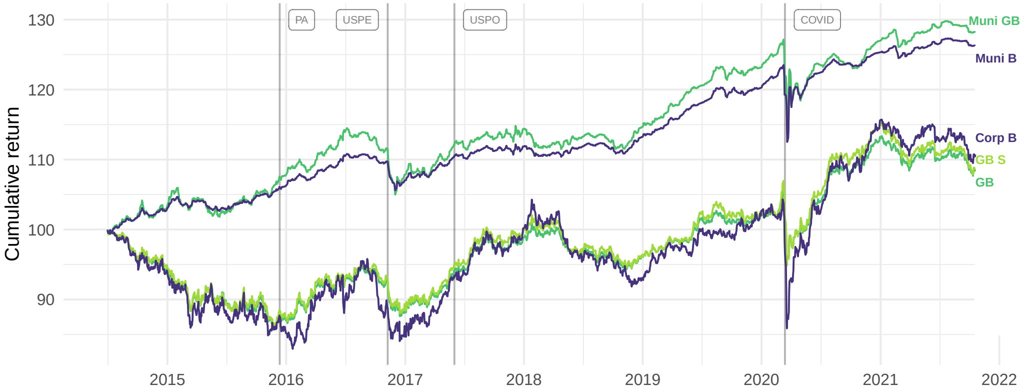

Figure 7.1: Historical prices of the green bond indices

The indices history shows that some of the selected events are associated with changes in returns, and others not so much; see Figure 7.1 for an illustration. Note that the green bond indices are highly correlated with corresponding conventional bond indices. However, for both municipal and corporate bonds, green bonds slightly outperform conventional ones: for both groups, darker lines for conventional bond indices in Figure 7.1 are mostly below. The municipal bond indices do not seem to be affected by the events, whereas corporate bonds, to a higher extent, increase or decrease after the events. The lockdown is associated with a bond market decline, during which corporate green bonds outperformed the conventional ones until late 2020 when this relationship reversed. In contrast, municipal green bonds continued to outperform conventional municipal bonds also after the US lockdown. We test the impact of the events on the returns statistically and find their significant effect on both green and conventional bonds (Table 7.3).

7.4.1 The Paris Agreement

According to traditional event study methodology results, bonds do not significantly react to the news on the event day itself. However, all bond indices have positive cumulative returns three days prior to the event. According to the mean adjusted model, *GB* and *GB S* gain 95 and 112 bp (basis points) before the event (significant at the 10% level). Municipal bond return increased by 29 bp, and municipal green bond gained twice more, 56 bp.

Only conventional corporate bonds adjusted prices after the announcement of the Paris Agreement. Depending on the model applied, they lost 1.7-2.9% of the value three days after the event. Regression-based analysis shows that PA was associated with negative shock to return for all bond types. *GB* and *GB S* lost 13 bp on the event day; *Muni GB* and *Muni B* lost 3-9 bps, while *Corp B*'s return dropped by 31 bp.

The marginally significant effect of the PA event on volatility depends on the type of bond: corporate bonds experienced a decrease in volatility, which varies from 0.55 pp (percentage point) for conventional ones to 0.8-1.16 pp for green bonds. On the other hand, municipal green bond volatility slightly increased by 0.01-0.06 pp.

7.4.2 The US Presidential election

Similarly, a traditional event study estimated the reaction on USPE to be negative, albeit insignificant. Regression-based results suggest that corporate bonds of both types had some reaction with the change in returns that is economically significant, but statistical significance is only at the 10% level.

Results suggest that all bonds adjusted their prices significantly three days after the event. These changes are up to -3% for *GB, GB S*, and *Muni B*. *Corp B* and *Muni GB* returns dropped by 3.2-4.7% depending on the model.

The volatility of municipal bonds increased by more than 4 pp. Green corporate bonds' volatility raised by 2-2.74 pp, while *Corp B* got only 1.39 pp. USPE-induced volatility is statistically significant at the 1% level for municipal conventional, green corporate and conventional bonds.

7.4.3 The US pullout from the Paris Agreement

Mean adjusted and Market models suggest that there was no reaction on the event day. The only exception is the negative reaction to the US pullout from the Paris Agreement, estimated by the market adjusted model. According to it, all but *Corp B* lost 79-91 bp on the day of USPO. However, this decline is significant only at the 10% level. According to the market model, *Muni GB*'s returns increased by 62 bp after the USPO.

In contrast, regression-based analysis shows that USPO was associated with negative shock to return for all bond types: smaller for conventional bonds (around 13 bp) and greater for green bonds (18-22 bp). In terms of volatility, USPO decreased the volatility of *Muni B* and *Muni GB* by 0.62 and 0.47 pp, respectively, which are significant at the 1% level. Corporate conventional bonds' volatility increased by 0.17 pp, but corporate green bonds became less volatile by 0.9-1.16 pp. These changes in the volatility of corporate bonds are significant only at the 10% level.

Table 7.3: Estimated reaction on the events.

Model	event	-1;1	-3;-1	1;3	event	-1;1	-3;-1	1;3
	the Paris Agreement				**the US Presidential election**			
GB								
Mean adj.	-0.13	-0.31	0.95 *	-0.86	-0.05	-1.45 ***	-0.48	-2.73 ***
Market	-0.10	-0.34	0.79	-0.80	-0.05	-1.52 ***	-0.51	-2.75 ***
Market adj.	-0.64	0.02	3.37 **	-1.94	-0.39	-5.04 ***	-1.99 *	-3.78 ***
EGARCH ret.	-0.13 *				0.23 *			
EGARCH vol.	-1.16 *				2.74 *			
GB S								
Mean adj.	-0.14	-0.28	1.12 *	-0.93	-0.03	-1.51 ***	-0.55	-2.74 ***
Market	-0.10	-0.31	0.90	-0.85	-0.03	-1.58 ***	-0.58	-2.76 ***
Market adj.	-0.65	0.06	3.53 **	-2.01	-0.37	-5.10 ***	-2.05 *	-3.80 ***
EGARCH ret.	-0.13 ***				-0.01 *			
EGARCH vol.	-0.80 *				1.96 ***			
Corp B								
Mean adj.	-0.30	-1.05	1.07	-1.81 **	-0.06	-1.82 **	-0.29	-3.11 ***
Market	-0.26	-1.09	0.87	-1.74 **	-0.12	-2.46 ***	-0.55	-3.29 ***
Market adj.	-0.81	-0.73	3.48 **	-2.90 *	-0.42	-5.43 ***	-1.81	-4.19 ***
EGARCH ret.	-0.31 *				-0.02 *			
EGARCH vol.	-0.55 *				1.39 **			
Muni B								
Mean adj.	-0.12	-0.11	0.29 **	-0.06	-0.06	-0.65 ***	0.00	-2.14 ***
Market	-0.11	-0.12	0.24 *	-0.04	-0.04	-0.50 ***	0.06	-2.10 ***
Market adj.	-0.58	0.34	2.82 **	-1.02	-0.42	-4.29 ***	-1.55	-3.25 **
EGARCH ret.	-0.03 **				0.14 **			
EGARCH vol.	0.01 *				4.31 ***			
Muni GB								
Mean adj.	-0.22	-0.17	0.56 **	0.00	-0.10	-1.22 ***	0.01	-3.63 ***
Market	-0.20	-0.19	0.47 *	0.04	-0.08	-0.94 ***	0.12	-3.55 ***
Market adj.	-0.68	0.29	3.11 **	-0.95	-0.47	-4.86 ***	-1.54	-4.74 ***
EGARCH ret.	-0.09 ***				0.33 **			
EGARCH vol.	0.06 *				4.11 ***			

Note:
This table shows estimated abnormal returns in percentages obtained based on the mean adjusted, market, and market adjusted models (*Mean adj, Market, and Market adj.* respetively). It also presents estimated abnormal returns (*ret.*) and abnormal volatility (*vol.*) obtained by ARMA-EGARCH with S&P500 or T-Bond index as an external regressor to mean model and event dummy variables added to mean and variance modeling.

(Continues on the next page)

Table 7.3: Estimated reaction on the events (*continued*).

Model	event	-1;1	-3;-1	1;3	event	-1;1	-3;-1	1;3
	the US pullout from PA				COVID-19 Lockdown			
GB								
Mean adj.	-0.13	0.62	0.41	0.52	-0.89 ***	-3.81 ***	-3.88 ***	-4.56 ***
Market	-0.10	0.66	0.40	0.51	-0.17	-4.93 ***	-4.70 ***	-5.55 ***
Market adj.	-0.88 *	-0.46	0.55	0.55	-9.74 ***	10.14 ***	6.37 ***	7.77 ***
EGARCH ret.	-0.18 *				0.58 *			
EGARCH vol.	-1.16 *				3.34 *			
GB S								
Mean adj.	-0.16	0.62	0.39	0.53	-1.09 ***	-4.45 ***	-4.31 ***	-5.58 ***
Market	-0.12	0.67	0.37	0.52	-0.16	-5.90 ***	-5.38 ***	-6.86 ***
Market adj.	-0.91 *	-0.45	0.53	0.57	-9.94 ***	9.51 ***	5.94 ***	6.76 ***
EGARCH ret.	-0.20 ***				-0.24 *			
EGARCH vol.	-0.90 *				3.12 ***			
Corp B								
Mean adj.	-0.22	0.38	-0.01	0.56	-1.69 ***	-6.81 ***	-5.53 ***	-9.58 ***
Market	-0.20	0.42	-0.02	0.56	-1.25 ***	-7.50 ***	-6.04 ***	-10.19 ***
Market adj.	-0.98	-0.69	0.13	0.60	-10.55 ***	7.14 ***	4.73 ***	2.76 *
EGARCH ret.	-0.12 *				-2.22 *			
EGARCH vol.	0.17 *				3.24 ***			
Muni B								
Mean adj.	-0.03	0.30	0.34	0.34	0.07	-2.61 ***	-4.35 ***	-1.80 ***
Market	-0.03	0.30	0.34	0.34	0.49 ***	-3.26 ***	-4.83 ***	-2.37 ***
Market adj.	-0.79 *	-0.79	0.46	0.36	-8.78 ***	11.36 ***	5.92 ***	10.56 ***
EGARCH ret.	-0.13 ***				1.51 ***			
EGARCH vol.	-0.62 ***				4.93 ***			
Muni GB								
Mean adj.	-0.05	0.53	0.56	0.62 *	0.04	-3.10 ***	-5.25 ***	-2.24 ***
Market	-0.05	0.53	0.56	0.62 *	0.56 ***	-3.93 ***	-5.86 ***	-2.97 ***
Market adj.	-0.82 *	-0.60	0.65	0.61	-8.81 ***	10.88 ***	5.04 ***	10.13 ***
EGARCH ret.	-0.22 ***				1.86 *			
EGARCH vol.	-0.47 **				4.30 ***			

For each event we look on the abnormal outcomes on the event day (*event*) cumulative abnormal returns three days prior the event (-3;-1) and after the event (1;3). Also we report cumulative abnormal return for one day before and after the event (-1;1). Asterisks indicate the significance of the coefficients: $* p < 0.1$; $** p < 0.05$; $* * * p < 0.01$.

7.4.4 COVID-19 lockdown

Although COVID-19 is not related to the climate regulatory risk, the pandemic is a source of big market uncertainty, affecting bond index performance. Anecdotal evidence of the lockdown effect on the bond indices in Figure 7.1 is also supported by empirical results. According to traditional event study methodology, lockdown brings a negative shock to both types of corporate bonds. Their reaction is present before and after the announcement about the national emergency. The same is true for municipal bonds; however, results vary between models.

All indices but *GB* got a volatility increase on the day of the lockdown announcement in the 3.12–4.93 pp range, significant at the 1% level. Municipal bonds experience a greater volatility shock.

7.4.5 Bond indices' performance

We further analyze the correlation between the various indices in our study, both the correlation over the entire period and for sub-periods defined by studied events. We find that the overall correlation for the same bond type is high; namely, correlation within corporate bonds sample and correlation between *Muni B* and *Muni GB* is above 0.9. There is also co-movement of corporate and municipal bonds, but it is weaker: correlation is within the 0.25–0.39 range. Figure 7.2 shows that corporate and municipal bond correlation was the lowest after PA and highest after USPE.

Municipal bonds co-move with *VIX* and T-Bond index, and the correlation with the latter is much stronger. In addition, the correlation between *VIX* and *Muni B* and *Muni GB* is positive but becomes weaker after USPE and forward. On average, correlation with other indices, such as S&P 500, *Dollar, Commodity,* CO_2, *Clean Energy*, and *Brent* for municipal bonds is negative and below 0.5. These relationships are statistically significant and persist over time (Figure 7.2). Only after USPE did these correlations change direction, but these estimates are not statistically different from zero.

Corporate bonds are highly negatively correlated with the *Dollar* index. They also have weak positive relationships with the T-bond index and *Clean Energy*, statisti-

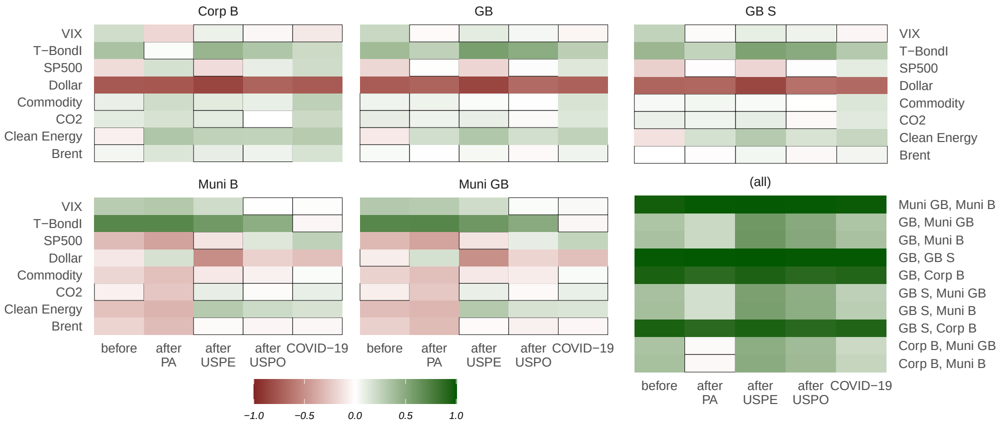

Figure 7.2: Correlation between green bonds and other assets, by periods. Black frame shows cases when estimated Pearson's correlation is not significantly different from zero.

cally significant at the 5% level. Correlation with S&P 500, *Commodity*, CO_2, and *Brent* are positive but rather low for corporate bonds so that they are not statistically different from zero in most sub-periods.

The correlation between studied bonds and *S&P 500*, CO_2, and *Clean Energy* is changed to significant and positive during the lockdown. Corporate conventional and green bonds also gain a statistically significant correlation with T-bond and Commodity indices. In contrast, the relationship between municipal bonds and the T-bond index is insignificant during the COVID-19.

Table 7.4 presents different performance measures for bond indices. These measures are also calculated for sub-periods. We also test changes in average returns and standard deviations between periods and find that differences in returns are not statistically significant. Only *GB* and *GB S* had a significant change in long-term mean return after PA – others are not significantly different from zero even at 10% level.

We see that *Corp B* had a significantly higher risk at 0.09%, while the risk of *GB* became significantly lower (0.5%). After PA, corporate green bonds and *Muni B* became less risky based on the value-at-risk measure (VaR, calculated with 95% probability) and offered a higher reward per unit of risk. *Corp B* became riskier, but a positive

Table 7.4: Performance measures for the bond indices, by periods.

Index	Measure	before	after PA		after USPE		after USPO		COVID - 19	
Corp B	Return	-0.1004	0.0199		0.0705		0.0131		0.0759	
	Std.Dev	0.0812	0.0960	***	0.0915		0.0592	***	0.0889	***
	VaR	-0.0089	-0.0098	↘	-0.0100	↘	-0.0065	↗	-0.0092	↘
	Sharpe	-1.2376	0.2069	↗	0.7700	↗	0.2204	↘	0.8530	↗
GB	Return	-0.0908	0.0572	*	0.0308		0.0277		0.0401	
	Std.Dev	0.0581	0.0481	***	0.0563	*	0.0394	***	0.0546	***
	VaR	-0.0066	-0.0040	↗	-0.0061	↘	-0.0042	↗	-0.0055	↘
	Sharpe	-1.5635	1.1885	↗	0.5480	↘	0.7041	↗	0.7350	↗
GB S	Return	-0.0870	0.0589	*	0.0369		0.0273		0.0376	
	Std.Dev	0.0623	0.0539	**	0.0608		0.0469	***	0.0649	***
	VaR	-0.0070	-0.0046	↗	-0.0065	↘	-0.0050	↗	-0.0066	↘
	Sharpe	-1.3958	1.0936	↗	0.6081	↘	0.5834	↘	0.5792	↘
Muni B	Return	0.0422	0.0411		0.0132		0.0318		0.0434	
	Std.Dev	0.0163	0.0151		0.0286	***	0.0229	***	0.0512	***
	VaR	-0.0016	-0.0009	↗	-0.0033	↘	-0.0003	↗	-0.0003	↘
	Sharpe	2.5813	2.7288	↗	0.4634	↘	1.3874	↗	0.8465	↘
Muni GB	Return	0.0521	0.0452		0.0093		0.0355		0.0370	
	Std.Dev	0.0305	0.0274	*	0.0493	***	0.0305	***	0.0666	***
	VaR	-0.0031	-0.0020	↗	-0.0056	↘	-0.0020	↗	-0.0020	↗
	Sharpe	1.7076	1.6504	↘	0.1887	↘	1.1647	↗	0.5554	↘

Note:
This table reports performance measures such as annualized average return (*Return*), standard deviation (*Std.Dev*) , and Sharpe ratio (*Sharpe*); daily expected shortfall (*ES*), and value-at-risk (*VaR*) given in percentages. Asterisks indicate the test significance for difference in measures: $* p < 0.1$; $** p < 0.05$; $* * * p < 0.01$. Red color shows significant negative and green color shows significant positive change in measure, compared with the previous period.

average return helped get a meaningful (not-negative) Sharpe ratio of 0.2%. The outcome is the opposite for *Muni GB*: despite lower risk by VaR, the Sharpe ratio changed from 1.7 to 1.65%.

After USPE, all bonds but *Corp B* became riskier and, thus, offered lower return per unit of risk. Despite higher risk by VaR measure, *Corp B* improved their Sharpe ratio from 0.2 to 0.77%. After USPO, all bonds became less risky; however, only *Corp*

B started to offer less return per unit of risk: its Sharpe ratio was reduced to 0.22%. During the lockdown, all bonds became riskier in terms of volatility. However, corporate green and conventional bonds also improved their Sharpe ratio, the former ones from 0.22 to 0.85%

7.5 DISCUSSION

Our findings show that municipal and selected green bond indices react to political events associated with climate change policy. Their response to the arrival of the news is generally negative: most estimates of abnormal returns on the event day are negative and significant on the 1% level. The decline of the bond index prices suggests that investors associate studied events with increased uncertainty about market developments. This uncertainty leads to an increase in bond price volatility, meaning that the events studied in this paper initiate significant price adjustment, thus impacting the trading in the market. This finding supports Pham and Luu Duc Huynh's (2020) results on the significant effect of investor attention on bond market performance.

However, bond index reaction to an event depends on its features: whether an issuer is a corporation or municipality and whether bonds are conventional or green. In addition, bond indices need time to fully incorporate information into prices, as significant cumulative abnormal returns after events suggest.

A closer look at each event reveals that the Paris Agreement boosted the development of green bonds. The results show that the market anticipated this event because most bond indices had a significant positive cumulative return before the announcement about the reached agreement. However, we also admit that the Paris Green Bond Statement could shape this reaction from the global institutional investors in support of policies related to climate finance. This statement was media-released three days before the PA agreement, and thus, our cumulative returns also capture bond indices' reaction to this statement.[2]

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[2] We checked the bond indices' reaction to the Paris Green Bond Statement and found a positive abnormal return for corporate and negative abnormal return for municipal bonds,

The Paris Agreement contributed to corporate green bonds' increase in reward per unit of risk until the US presidential election. It has a reciprocal effect because green bonds contributed significantly to achieving climate goals (Tolliver et al., 2020b). The Paris Agreement's positive effect does not extend to conventional corporate bonds: on this event and during days after it, corporate bonds' returns declined and offset positive anticipation.

Unlike the Paris Agreement, the US presidential election had a significant effect on the volatility on the event day, which is in line with the unexpected nature of the election results. All bond indices experienced a negative cumulative abnormal return after the election. Interestingly, municipal bonds faced greater event-induced volatility. Municipal green bonds lost most in returns, suggesting that this sector is more vulnerable to climate regulatory risks. Although green bonds return decreased less or even gained compared with conventional ones, the former was subject to higher volatility shock on the event days. After USPE, all but conventional corporate bonds performed poorer, as the Sharpe ratio shows.

The US pullout from the Paris Agreement caused a negative return shock to green and municipal bonds. Only some models showed a positive return shock in the days after USPO for the municipal green bonds. Because our sample contains only US municipal bonds, such a specific reaction to USPE and USPO is justified. Both events brought uncertainty about the development of the US climate policy that is expected to affect municipal green bonds, not corporate bonds.

Similar to Monasterolo and de Angelis's (2020) findings for stocks, we document a lower correlation between green and conventional bonds after the Paris Agreement. Starting from the Paris Agreement, corporate green bonds became positively correlated with clean energy prices. In contrast, their correlation with commodity and stock market almost disappears (is statistically insignificant). In addition, our results corroborate the work of Pham (2016), suggesting a time-varying correlation between green and conventional bonds and extending this finding also up to 2020 and for the municipal bond universe. According to our findings, the COVID-19 pandemic is associated with a tighter relationship between bonds and other assets. Most of

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significant at 1% level in both cases.

these relationships became statistically significant during 2020-2021, especially in the case of green bonds. This impact is also discovered in Bouri et al. (2021) based on the observed higher connectedness between asset classes in the period.

Although according to our results, conventional corporate bonds offer a better rewards-per-unit-risk recently, they might be subject to market inefficiency (Naeem et al., 2021b). During the pandemic, corporate conventional and corporate green bonds' changes follow the same direction (higher VaR risk and Sharpe ratio), but not the selected green bonds. This difference in performance might depend on the credit ranking because the selected green bonds have a minimum BBB- one; thus, they have a lower risk. Corporate green bonds are found to be less risky in terms of volatility and value-at-risk. Given positive changes in the Sharpe ratio after the Paris Agreement, it is reasonable to expect a similar reaction to a new climate policy introduction. Their insignificant correlation with the crude oil index is also favorable in the long run during the transition to a low-carbon economy.

Our findings suggest that the green bond market accounts for the regulatory risk of unexpected events and related to climate change. The results show that climate policy events have short- and long-term effects on green bond pricing and performance on the secondary market. Changes in climate policy also affect relationships between green bonds and other assets. It indicates that despite the many benefits of issuing green bonds to firms and investors, political risks to these assets are challenging to account for. Previous research showed that these relationships could be utilized in portfolio diversification (Horsch and Richter, 2017; Reboredo, 2018; Nguyen et al., 2020) and as a hedging instrument (Jin et al., 2020). Indeed, corporate green bonds come with lower idiosyncratic risk and lower correlation to more conventional financial assets, and as such, carry great diversification benefits to a portfolio of assets. Our study highlights the necessity of portfolio re-adjustment after changes of regulatory risk to obtain all benefits from such diversification.

REFERENCES

Antoniuk, Y. and Leirvik, T. (2021). Climate change events and stock market returns. *Journal of Sustainable Finance and Investment*.

Arif, M., Hasan, M., Alawi, S. M., and Naeem, M. A. (2021). COVID-19 and time-frequency connectedness between green and conventional financial markets. *Global Finance Journal*, 49:100650.

Bachelet, M. J., Becchetti, L., and Manfredonia, S. (2019). The green bonds premium puzzle: The role of issuer characteristics and third-party verification. *Sustainability*, 11(4):1098.

Banga, J. (2019). The green bond market: A potential source of climate finance for developing countries. *Journal of Sustainable Finance and Investment*, 9(1):17–32.

Bartram, S. M., Hou, K., and Kim, S. (2021). Real effects of climate policy: Financial constraints and spillovers. *Journal of Financial Economics*.

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., and Visentin, G. (2017). A climate stress-test of the financial system. *Nature Climate Change*, 7(4):283–288.

Berument, H. and Kiymaz, H. (2001). The day of the week effect on stock market volatility. *Journal of Economics and Finance*, 25(2):181–193.

Bessembinder, H. and Zhang, F. (2013). Firm characteristics and long-run stock returns after corporate events. *Journal of Financial Economics*, 109(1):83–102.

Birindelli, G. and Chiappini, H. (2021). Climate change policies: Good news or bad news for firms in the European Union? *Corporate Social Responsibility and Environmental Management*, 28(2):831–848.

Bolton, P. and Kacperczyk, M. T. (2021). Do investors care about carbon risk? *Journal of Financial Econometrics*, 142(2):517–549.

Bouri, E., Cepni, O., Gabauer, D., and Gupta, R. (2021). Return connectedness across asset classes around the COVID-19 outbreak. *International Review of Financial Analysis*, 73:101646.

Broadstock, D. C. and Cheng, L. T. (2019). Time-varying relation between black and green bond price benchmarks: Macroeconomic determinants for the first decade. *Finance Research Letters*, 29:17–22.

Buigut, S. and Kapar, B. (2019). Effect of Qatar diplomatic and economic isolation on GCC stock markets: An event study approach. *Finance Research Letters*, 37:101352.

Burke, M., Hsiang, S. M., and Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527(7577):235–239.

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., and Tanaka, M. (2018/06/01, 2018). Climate change challenges for central banks and financial regulators. *Nature Climate Change*, 8(6):462–468.

Capasso, G., Gianfrate, G., and Spinelli, M. (2020). Climate change and credit risk. *Journal of Cleaner Production*, 266:121634.

Chambwera, M., Heal, G., Dubeux, C., Hallegatte, S., Leclerc, L., Markandya, A., McCarl, B. A., Mechler, R., and Neumann, J. E. (2014). Chapter 17. Economics of adaptation. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*, pages 945–977. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Clapp, C. (2014). Climate finance: Capitalising on green investment trends. In de Coninck, H., Lorch, R., and Sagar, A., editors, *The Way Forward in International Climate Policy: Key Issues and New Ideas 2014*, pages 44–48. Climate and Development Knowledge Network and Climate Strategies, London.

Deeney, P., Cummins, M., Dowling, M., and Smeaton, A. F. (2016). Influences from the European Parliament on EU emissions prices. *Energy Policy*, 88:561–572.

Diaz-Rainey, I., Gehricke, S. A., Roberts, H., and Zhang, R. (2021). Trump vs. Paris: The impact of climate policy on U.S. listed oil and gas firm returns and volatility. *International Review of Financial Analysis*, 76:101746.

Duarte-Silva, T. and Tripolski Kimel, M. (2014). Testing excess returns on event days: log returns vs. dollar returns. *Finance Research Letters*, 11(2):173–182.

Duqi, A., McGowan, D., Onali, E., and Torluccio, G. (2021). Natural disasters and economic growth: The role of banking market structure. *Journal of Corporate Finance*, 71:102101.

Ehlers, T. and Packer, F. (2017). Green bond finance and certification. *BIS Quarterly Review*, 3:89–104.

Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. *The Journal of Finance*, 25(2):383–417.

Fatica, S., Panzica, R., and Rancan, M. (2021). The pricing of green bonds: Are financial institutions special? *Journal of Financial Stability*, 54:100873.

Flaherty, M., Gevorkyan, A., Radpour, S., and Semmler, W. (2017). Financing climate policies through climate bonds — A three stage model and empirics. *Research in International Business and Finance*, 42:468–479.

Ghalanos, A. (2020). *rugarch: Univariate GARCH models.*

Ginglinger, E. and Moreau, Q. (2019). Climate risk and capital structure. Finance Working Paper 737/2021, European Corporate Governance Institute, Brussels.

Gulev, S., Thorne, P., Ahn, J., Dentener, F., Domingues, C. M., Gerland, S., Gong, D., Kaufman, D., Nhamchi, H., Quaas, J., Rivera, J. A., Sathyendranath, S., Smith, S., Trewin, B., von Shuckmann, K., Vose, R., Azar, Z., and Osborn, T. (2021). Changing state of the climate system. In Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S., Péan, C., Chen, Y., Goldfarb, L., Gomis, M. I., Matthews, J., Berger, S., Huang, M., Yelekçi, O., Yu, R., Zhou, B., Lonnoy, E., Maycock, T. K., Waterfield, T., Lietzell, K., and Caud, N., editors, *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge.

Heyden, K. J. and Heyden, T. (2020). Market Reactions to the Arrival and Containment of

COVID-19: An Event Study. *Finance Research Letters*, 38(4):101745.

Horsch, A. and Richter, S. (2017). Climate change driving financial innovation: the case of green bonds. *The Journal of Structured Finance*, 23(1):79–90.

Hung, N. T. (2021). Nexus between green bonds, financial, and environmental indicators. *Economics and Business Letters*, 10(3):191–199.

Immel, M., Hachenberg, B., Kiesel, F., and Schiereck, D. (2021). Green bonds: shades of green and brown. *Journal of Asset Management*, 22(2):96–109.

In, S. Y., Park, K. Y., and Monk, A. (2019). Is ”Being Green” rewarded in the market? An empirical investigation of decarbonization risk and stock returns. Working paper, Stanford Global Projects Center, Stanford.

Jin, J., Han, L., Wu, L., and Zeng, H. (2020). The hedging effect of green bonds on carbon market risk. *International Review of Financial Analysis*, 71:101509.

Kanamura, T. (2020). Are green bonds environmentally friendly and good performing assets? *Energy Economics*, 88:104767.

Karpf, A. and Mandel, A. (2018). The changing value of the ’green’ label on the US municipal bond market. *Nature Climate Change*, 8(2):161–165.

Kling, G., Volz, U., Murinde, V., and Ayas, S. (2021). The impact of climate vulnerability on firms’ cost of capital and access to finance. *World Development*, 137:105131.

Koch, N., Grosjean, G., Fuss, S., and Edenhofer, O. (2016). Politics matters: Regulatory events as catalysts for price formation under cap-and-trade. *Journal of Environmental Economics and Management*, 78:121–139.

Kochetygova, J. and Jauhari, A. (2014). Climate change, green bonds, and index investing: The new frontier. Technical Report August, S&P Dow Jones Indices, London.

Kotz, M., Wenz, L., and Levermann, A. (2021). Footprint of greenhouse forcing in daily temperature variability. *Proceedings of the National Academy of Sciences*, 118(32).

Kumar, A., Xin, W., and Zhang, C. (2019). Climate sensitivity and predictable returns. *SSRN Electronic Journal*, pages 1–38.

Larcker, D. F. and Watts, E. M. (2020). Where’s the greenium? *Journal of Accounting and Economics*, 69(2-3):101312–101312.

MacAskill, S., Roca, E. D., Liu, B., Stewart, R. A., and Sahin, O. (2020). Is there a green premium in the green bond market? Systematic literature review revealing premium determinants. *Journal of Cleaner Production*, 280(2):124491.

Monasterolo, I. and de Angelis, L. (2020). Blind to carbon risk? An analysis of stock market reaction to the Paris Agreement. *Ecological Economics*, 170:106571.

Mukanjari, S. and Sterner, T. (2018). Do markets trump politics? Evidence from fossil market reactions to the Paris Agreement and the US election. Technical Report 18-24, Resources for the Future, Washington, DC.

Naeem, M. A., Adekoya, O. B., and Oliyide, J. A. (2021a). Asymmetric spillovers between green bonds and commodities. *Journal of Cleaner Production*, 314:128100.

Naeem, M. A., Farid, S., Ferrer, R., and Shahzad, S. J. H. (2021b). Comparative efficiency of green and conventional bonds pre- and during COVID-19: An asymmetric multifractal detrended fluctuation analysis. *Energy Policy*, 153:112285.

Naeem, M. A., Mbarki, I., Alharthi, M., Omri, A., and Shahzad, S. J. H. (2021c). Did COVID-19 Impact the Connectedness Between Green Bonds and Other Financial Markets? Evidence From Time-Frequency Domain With Portfolio Implications. *Frontiers in Environmental Science*, 9:180.

Nanayakkara, M. and Colombage, S. (2019). Do investors in green bond market pay a premium? Global evidence. *Applied Economics*, 51(40):4425–4437.

Nguyen, T. T. H., Naeem, M. A., Balli, F., Balli, H. O., and Vo, X. V. (2020). Time-frequency comovement among green bonds, stocks, commodities, clean energy, and conventional bonds. *Finance Research Letters*, 40:101739.

Partridge, C. and Medda, F. R. (2020). The evolution of pricing performance of green municipal bonds. *Journal of Sustainable Finance and Investment*, 10(1):44–64.

Pham, L. (2016). Is it risky to go green? A volatility analysis of the green bond market. *Journal of Sustainable Finance and Investment*, 6(4):263–291.

Pham, L. and Luu Duc Huynh, T. (2020). How does investor attention influence the green bond market? *Finance Research Letters*, 35:101533.

Pynnönen, S. (2005). On regression based event study. In Laitinen, E. and Laitinen, T., editors, *Contributions to Accounting, Finance, and Management Science. Essays in Honor of Professor Timo Salmi.*, pages 327–354. Univ. Wasaensis, Vaasa.

Ramadorai, T. and Zeni, F. (2019). Climate regulation and emissions abatement: Theory and evidence from firms' disclosures. *SSRN Electronic Journal*, page 60.

Reboredo, J. C. (2018). Green bond and financial markets: Co-movement, diversification and price spillover effects. *Energy Economics*, 74:38–50.

Reboredo, J. C. and Ugolini, A. (2020). Price connectedness between green bond and financial markets. *Economic Modelling*, 88:25–38.

Reboredo, J. C., Ugolini, A., and Aiube, F. A. L. (2020). Network connectedness of green bonds and asset classes. *Energy Economics*, 86:104629.

Sakhel, A. (2017). Corporate climate risk management: Are European companies prepared? *Journal of Cleaner Production*, 165:103–118.

Sarkodie, S. A., Owusu, P. A., and Leirvik, T. (2020). Global effect of urban sprawl, industrialization, trade and economic development on carbon dioxide emissions. *Environmental Research Letters*, 15(3):034049.

Seltzer, L., Starks, L., and Zhu, Q. (2021). Climate regulatory risks and corporate bonds. Research Paper 20-05, Nanyang Business School, Singapore.

Sharpe, W. F. (1994). The Sharpe ratio. *The Journal of Portfolio Management*, 21(1):49–58.

Shishlov, I., Morel, R., and Cochran, I. (2016). Beyond transparency: unlocking the full potential of green bonds. Technical Report June, I4CE – Institute for Climate Economics, Paris.

Storelvmo, T., Leirvik, T., Lohmann, U., Phillips, P. C., and Wild, M. (2016). Disentangling greenhouse warming and aerosol cooling to reveal Earth's climate sensitivity. *Nature Geoscience*, 9(4):286–289.

Tolliver, C., Keeley, A. R., and Managi, S. (2020a). Drivers of green bond market growth: The importance of Nationally Determined Contributions to the Paris Agreement and implications for sustainability. *Journal of Cleaner Production*, 244:118643.

Tolliver, C., Keeley, A. R., and Managi, S. (2020b). Policy targets behind green bonds for renewable energy: Do climate commitments matter? *Technological Forecasting and Social Change*, 157:120051.

Tran, V. L. and Leirvik, T. (2019). A simple but powerful measure of market efficiency. *Finance Research Letters*, 29:141–151.

Tsoukala, A. and Tsiotas, G. (2021). Assessing green bond risk: An empirical investigation. *Green Finance*, 3(2):222–252.

Wagner, A. F., Zeckhauser, R. J., and Ziegler, A. (2018). Company stock price reactions to the 2016 election shock: Trump, taxes, and trade. *Journal of Financial Economics*, 130(2):428–451.

Warner, J. and Brown, S. (1985). Using daily stock returns: The case of event studies. *Journal of Financial Economics*, 14(1):3–31.

Wulandari, F., Schäfer, D., Stephan, A., and Sun, C. (2018). The impact of liquidity risk on the yield spread of green bonds. *Finance Research Letters*, 27:53–59.

Yuan, M., Leirvik, T., and Wild, M. (2021). Global trends in downward surface solar radiation from spatial interpolated ground observations during 1961–2019. *Journal of Climate*, 34(23):9501–9521.

Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking and Finance*, 98:39–60.

Zhang, D., Zhang, Z., and Managi, S. (2019). A bibliometric analysis on green finance: Current status, development, and future directions. *Finance Research Letters*, 29:425–430.

7.A APPENDIX

The estimation of the ARMA-GARCH models is made with the `rugarch` package (Ghalanos, 2020). In order to identify suitable ARMA specifications, all combinations of ARMA-orders up to the fourth lag were tested for the bond indices with the following distributions:

- *norm*: the normal distribution
- *snorm*: the skew-normal distribution
- *std*: the Student *t*-distribution
- *sstd*: the skew-Student *t*-distribution
- *ged*: the generalized error distribution
- *sged*: the skew-generalized error distribution
- *nig*: the normal inverse Gaussian distribution
- *jsu*: Johnson's S_U distribution
- *ghyp*: the generalized hyperbolic distribution

S&P 500 was introduced as an external regressor to all models. The choice of the initial ARMA specification is based on the Akaike Information Criteria (AIC). Table 7.A1 shows the top-three specifications with the lowest AIC. The starred ARMA specification was used in the ARMA(p, q)–EGARCH(2, 4) model. After eliminating insignificant ARMA-orders and remaining serial autocorrelation in residuals and squared residuals, the final specifications have changed (Table 7.A2).

Moreover, the serial autocorrelation in residuals of the municipal bond indices with the S&P 500 index as a regressor remained significant at high lags order. Thus, the S&P 500 was replaced with the T-Bond index for the municipal bond indices, and dummy variables for Mondays (which impacts bond indices, see Berument and Kiymaz, 2001) and January were introduced. The models are tested for serial autocorrelation in residuals and squared residuals, so that final models do not have significant serial autocorrelation present. These models also have no uncaptured asymmetry present in the residuals. Estimated coefficients of the models are given in Table 7.A3, where their significance is derived based on the robust standard errors.

Table 7.A1: The top-three selected ARMA specifications by the lowest Akaike Information Criteria (AIC). Asterisks denote specifications used in the first run of ARMA-EGARCH models.

Bond index	Distribution	AR (p)	MA (q)	Mean	AIC	Used
Corp B	std	4	2	0	1.2491	*
	std	4	2	1	1.2496	
	sstd	4	2	0	1.2497	
GB	std	2	4	0	0.3832	*
	std	2	4	1	0.3834	
	sstd	2	4	0	0.3835	
GB S	ghyp	4	3	1	0.6534	*
	std	2	4	0	0.6539	
	std	2	4	1	0.6543	
Muni B	sstd	2	4	1	-1.9055	*
	sstd	1	0	1	-1.9043	
	sstd	1	1	1	-1.9040	
Muni GB	jsu	4	3	1	-0.9201	*
	jsu	1	0	1	-0.9200	
	jsu	1	1	1	-0.9194	

Table 7.A2: Final specification for the ARMA models with associated Akaike Information Criteria (AIC)

Bond index	Distribution	AR (p)	MA (q)	s	m	AIC
Corp B	std	4	2	2	2	1.1779
GB	std	2	4	2	3	0.3183
GB S	ghyp	4	2	2	2	0.6014
Muni B	snorm	4	4	2	2	-1.3531
Muni GB	snorm	2	2	2	2	-2.3481

Table 7.A3: Estimation results for the ARMA-EGARCH models. Asterisks indicate the significance of the coefficients: $*\ p < 0.1;\ **\ p < 0.05;\ ***\ p < 0.01$

	GB		GB S		Corp B		Muni B		Muni GB	
Mean model										
μ			0.007	*			0.010	***	0.016	***
ϕ_1	-0.187	***	-0.162	***	-1.622	***	-0.336	***	0.073	**
ϕ_2	-0.991	***	-0.941	***	-0.595	***	-0.386	***	0.354	***
ϕ_3			0.034	***	0.018	***	0.368	***		
ϕ_4			0.045	***	-0.009	***	0.158	***		
θ_1	0.237	***	0.183	***	1.647	***	0.710	***	0.275	***
θ_2	1.047	***	0.982	***	0.646	***	0.705	***	-0.206	***
θ_3	0.066	*					-0.021	**		
θ_4	0.055						-0.094	***		
c	-0.016	*	-0.024	***	0.008	*	0.225	***	0.336	***
Mon							0.010	***	0.006	*
Jan							0.043	***	0.047	***
Variance model										
ω	-0.100	*	-0.107	**	-0.073	*	-0.279	***	-0.183	***
α_1	0.008	*	0.019	*	-0.009	*	-0.084	*	-0.063	*
α_2	0.017	*	0.019	*	0.014	*	0.077	*	0.076	*
β_1	0.182	*	0.321	***	0.440	*	1.000	***	1.000	***
β_2	0.333	*	0.632	***	0.516	*	-0.056	**	-0.047	
β_3	0.446	*								
γ_1	0.050	*	-0.013	*	0.023	*	0.407	***	0.402	***
γ_2	0.185	*	0.193	***	0.192	**	-0.130	*	-0.110	*
Distribution										
skew			-0.604	*			0.968	***	0.984	***
shape	7.287	*	0.250	*	6.552	***				
λ_{gh}			-3.790	***						

8 SUSTAINABLE INVESTMENTS IN THE NORWEGIAN STOCK MARKET

Abstract

This article investigates the link between environmental, social and corporate governance (ESG) ratings and financial performance in the Norwegian stock market. Using Norwegian stock data, we rank companies based on their sensitivity and exposure (beta) toward ESG factors from 2009 to 2018 using the Dow Jones Sustainability Nordic Index. The econometric framework applies a portfolio strategy, as well as a cross-sectional regression. The constructed ESG portfolios do not show any significant return difference based on a high-low strategy, which is robust for market sensitivity, investment style, and industry bias. Regarding the explanatory power and pricing of the ESG factor, we find no supporting evidence. Our results do not suggest any connection between ESG and stock returns in the Norwegian stock market.

8.1 INTRODUCTION

This paper investigates the link between corporate social performance and financial performance based on environmental, social and corporate governance (ESG) ratings in the Norwegian stock market from 2009 to 2018. The case for sustainable investments has been quite contradictory, which may be caused by differences in the methodology and in the choice of financial and environmental performance indicators. Some researchers have provided evidence for a positive relationship between sustainability scores and financial performance (Servaes and Tamayo, 2013); some suggest that there is a negative correlation (Baron et al., 2011); and some argue that there is no correlation at all (McWilliams and Siegel, 2000). However, research conducted on the Norwegian market has been limited primarily by the lack of availability of ESG scores. Our study, therefore, seeks to highlight and provide evidence on the link between social responsibility and financial performance based on a standard regression procedure. To this end, we apply an alternative method to rate companies as opposed to the traditional rating methodology used in many ESG-related studies. We apply a positive screening of the Norwegian stock market by examining the sensitivity of companies towards a sustainability index, representing ESG-related factors. Based on this measure, we rate the companies. Previous literature has highlighted the importance of screening choice when incorporating social, corporate governance, ecological or ethical criteria in investment strategies and its effect on return. The primary screening processes are explained in a paper by Kempf and Osthoff (2007). In addition to the positive screening, we also do a robustness check, where we apply a best-in-class version of the model.

To evaluate the performance, we compare the high and low portfolios and use a high-low strategy to provide evidence whether 'good stocks' significantly outperform 'bad stocks' when they are differentiated based on their sensitivity towards the ESG factor. For the high-low strategy the top portfolio is held in a long position while the bottom portfolio is held in a short position. This method of performance evaluation is widely used in the literature. Statman and Glushkov (2009) constructed high and low portfolios on an equally weighted approach based on KLD rating data from 1992 to 2007, with findings suggesting that both the capital asset pricing model (CAPM) and the Carhart (1997) four-factor model indicate a significant positive abnormal return with a high-low strategy. Further, Lee et al. (2013) analyzed U.S. companies and their performances based on ESG ratings. Based on the Carhart (1997) four-factor model from 1998 to 2007, they found evidence in favor of a significant outperformance of high-low rated companies as well as of high-rated sectors. Kempf and Osthoff (2007) also compared the performance of high- and low-rated companies in the U.S. for the period of 1992–2004. As opposed to Lee et al. (2013), they constructed their portfolios based on a value-weighted approach and found a significant performance for the high-low portfolio, with an abnormal return of up to 8.7% per year. Accordingly, we apply the Carhart (1997) four-factor model to evaluate the performance of the portfolios, which are constructed based on an equally weighted and value-weighted approach.

Several arguments have been made on the relationship between social responsibility and financial performance. One of the many views is that investors face a trade-off between higher returns and cost of social responsibility. Those holding this view believe that limiting the investment universe has a negative impact on risk-adjusted returns (Barnett and Salomon, 2006; Renneboog et al., 2008). A contrasting view is that socially responsible investments actually reduce financial risk and therefore yield higher risk-adjusted returns (Ashwin Kumar et al., 2016; Boutin-Dufresne and Savaria, 2004; Lee and Faff, 2009). This can be explained by leading companies within sustainability taking actions towards future restrictions, regulations, environmental effects, and social effects that may influence their operations. The effect of carbon tax (climate policies) on company performance was examined by Austin and Sauer (2002), who found that performance was affected by at least 10% for some companies. The idea is that recognizing risks and opportunities related to economic, social and environmental growth strengthens company performance in the long run and will, therefore, be profitable for investors. At the same time, a number of metastudies have been constructed in attempts to provide a better picture of the link between sustainability and corporate performance. Margolis et al. (2012) conducted a meta-study of more than 250 studies, finding a positive but very small empirical link between corporate social performance (CSP) and corporate financial performance (CFP). Further, a report based on more than 2000 empirical studies from 1970 to 2015 found that ESG and CFP had a non-negative relationship of 90% at the time and that most studies reported positive results (Friede et al., 2015). Others, Jin (2018) and Lioui (2018) have investigated whether ESG is systematically compensated by the broad market. According to their findings, ESG-related systematic risk is significantly priced in the U.S. We apply the same methodology by the two-step procedure of Fama and MacBeth (1973) to investigate if ESG-risk is priced in the Norwegian stock market.

In summary, the empirical literature does not provide conclusive evidence on the link between social responsibility and stock performance. Our research will, therefore, attempt to answer the question of whether sustainable investments are beneficial to shareholder value in the Norwegian market. Our paper proceeds as follows. Section 8.2 describes the dataset, as well as the financial variables used in this study. Section 8.3 outlines the statistical methodology and portfolio-construction procedure. Section 8.4 presents our empirical findings. Finally, section 8.5 offers a conclusion and recommends areas for further research on the topic.

8.2 DATA

The dataset used in this study covers Norwegian stock data over the period 2009–2018, derived from TITLON, a financial database that contains detailed daily financial data for all stocks traded on the Oslo Stock Exchange. Our sample includes daily stock prices and sector classifications for all stock that are or have been listed during the period, providing a sample free of survivorship bias. The importance of a survivor biasfree sample is explained in a paper by Elton et al. (1996). The data is adjusted for all applicable splits and dividend distributions. To reduce the impact of market microstructures, we set a limit of 5 Norwegian krones (NOK) per stock. The reason for setting a limit this low is because many stocks on the Norwegian market trade at a low price. In accordance with Hong et al. (2019), we set returns to ‘missing’ for suspicious stock returns with large deviations from the typical outcome. For our dataset, we treat stocks that rise by 100% or more within a day and those that drop by 25% or more within a day as ‘missing’. We apply the same procedure when dealing with monthly returns, where stocks that rise by 300% or drop by more than 50% are treated as ‘missing’.

Table 8.1 presents the composition of our sample by year (Panel A) and by industry (Panel B). The dataset contains a total of 360 companies and a yearly average of 213 throughout the period 2009–2018, with a high share of the energy sector. The composition of industries displays the number of companies that have been classified within each sector in the period 2009–2018.

Because of the availability of ESG data, our measure for the sensitivity of companies towards sustainability factors is the Dow Jones Sustainability Nordic Index (Dow

Table 8.1: Sample composition by year and by industry.

Panel A: composition by year		Panel B: composition by industry	
2009	230	Bank	24
2010	229	Consumer Discretionary	16
2011	236	Consumer Staples	23
2012	215	Energy	108
2013	220	Financials	47
2014	217	Healthcare	23
2015	195	Industry	56
2016	190	Information Technology	46
2017	203	Materials	17
2018	196		
2009–2018	360	Total	360

[a] Table 8.1 shows the composition of our sample by year (Panel A) and by industry (Panel B). Panel A presents the number of companies each year listed on the Oslo Stock Exchange (OSE), with a total of 360 listed companies throughout the period 2009–2018. Panel B presents the composition of industries on OSE in the period 2009–2018. For example, there have been a total of 24 listed companies in the banking industry from 2009 to 2018. Because of few listed companies in some sectors, we havecombined those with similar economic drivers. Accordingly, telecom and information technology, and financials and ETF (Exchange Traded Funds) have been combined

Jones Sustainability Index Nordic (DJSND)). This index represents the top 30% of the largest Nordic companies in the S&P Global BMI (Broad Market Index) based on ESG-criteria. In order to calculate monthly stock returns, we obtained daily prices from S&P Dow Jones Indices. Further description of the index is presented in section 8.2.1 Sustainability measure.

As this analysis is done on the Norwegian market, the Oslo Stock Exchange Benchmark Index (Oslo Stock Exchange Benchmark Index (OSEBX)) is used as the market proxy. OSEBX contains a representative selection of all listed shares on the Oslo Stock Exchange and is rebalanced semi-annually. The daily adjusted prices are also provided by TITLON. The risk-free interest rate is represented by the Norwegian 10-year government bond, and all data are denominated in the Norwegian currency (NOK).

To analyze the excess return, we look at the three major factors that have been identified in the literature. The best-known explanatory variables in modern multifactor models are arguably size and book-to-market ratios. The size factor implies that stocks with a low market capitalization (low value factor) outperform stocks with a high market capitalization (high value factor) (Banz, 1981). More recent studies have also focused on momentum, which is the idea that the past winners will continue to win, and the past losers continue to lose in the near future (Jegadeesh and Titman, 1993). Therefore, we apply the widely recognized four-factor model by Carhart (1997). In this context, we need risk premia related to size, value, and momentum. These risk factors are commonly used from Kenneth French's data library. However, these factors are constructed based on the U.S. market. According to Fama and French (2012), regional asset-pricing models perform better than global models. Further, Griffin (2002) notes that country-specific factor models explain the returns better than international versions. For this reason, we apply a dataset constructed by Ødegaard (2017) on the Norwegian market, which is calculated in accordance with those developed by Eugene Fama and Kenneth French.

In the final section of our analysis, we apply the Fama-MacBeth procedure to analyze whether or not there is a risk premium for the ESG factor for stocks in the Norwegian market. For this process, we use portfolios constructed by Ødegaard (2017). These portfolios are sorted according to different characteristics, including size (*MCAP*), value (*B/M*) and industry. The reasoning behind using portfolios will be discussed in section 8.3.2 Risk premium.

8.2.1 Sustainable measure

Our key objective is to examine the relationship between stock return and ESG sensitivity in the Norwegian stock market. To measure this sensitivity, we use an index, which is an approach largely inspired by Hong et al. (2019), who measured the effect of drought on food companies' stock returns based on a climate index. The reason for this choice of method is predominantly due to the lack of available ESG ratings for Norwegian companies. For the index (DJSND), the rating is done by RobecoSAM, a company focused on sustainable investing. Based on these ratings, the construction is done by a rules-based constituent selection. To be qualified, ratings must be among the top 40% of all companies appraised. Further, a best-in-class approach is applied for the top 20% of companies in each industry, with a buffer rule of 0.3 points. Finally, the companies within the index that perform within the top 30% of their sector are kept to reduce turnover. The weighing of the index is based on float-adjusted market capitalization, with a constituent cap at 10%. Available information for the index runs back to March 2009, while it launched in November 2010. The performance prior to its launch is back-tested.

8.3 METHODOLOGY

8.3.1 ESG perfromance

Using one of the most common approaches to investigate the relationship between the social and financial performance of companies, we construct ESG portfolios. This method allows the application of basic asset-pricing models and a straightforward trading strategy to investors. Our portfolios are constructed by performing a rolling regression for each company against the DJSND index, with 2 March 2009, as our starting point. Our objective is to generate a measure of their sensitivity towards ESG factors with the following equation:

$$r_{i,t} = \delta_0 + \delta_i DJSND_t + \varepsilon_{i,t} \tag{8.1}$$

where $r_{i,t}$ is the company return at time t and δ_i is the beta coefficient representing the sensitivity towards ESG factors. We apply a 12-month window, rolling forward month by month. This results in 117 subperiods. Based on these estimates, we sort companies into quintiles based on the beta coefficient at $t-1$, with the top, or quintile-1 group, comprised of companies with the highest sensitivity, and the bottom, or quintile-5 group, consisting of companies with the lowest sensitivity. Our focus is on the performance of the companies in the top and bottom, as opposed to the mean performance of the middle group (quintiles 2—4).

From this process, we do a sector-evaluation of which companies the top and bottom portfolios contain to get further insight concerning the next step, which is evaluating the performance. To evaluate the performance of our top and bottom portfolios, we apply the Carhart (1997) four-factor model. The abnormal risk-adjusted return of the portfolios is therefore estimated by:

$$r_{i,t} = \alpha_i + \beta_i MKT_{i,t} + s_i SMB_{i,t} + h_i HML_{i,t} + m_i MOM_{i,t} + \varepsilon_{i,t} \quad (8.2)$$

where $r_{i,t}$ is the portfolio excess return at time t; α_i is the abnormal risk-adjusted return; $MKT_{i,t}$, $SMB_{i,t}$, $HML_{i,t}$ and $MOM_{i,t}$ are the returns on the market, size, value and momentum factors at time t; and ε_t is the error term. Following Bauer et al. (2005), excess returns (over a risk-free rate) are calculated by subtracting the risk-free rates from the monthly stock returns. We then test whether there is a statistically significant difference in returns across time between the two portfolios. We also investigate a high-low strategy, which contains the top portfolio in a long position while the bottom portfolio is held in a short position. Furthermore, we apply a longer holding period by reducing the rebalancing to a yearly frequency. In each year from 2009 to 2018, we construct our portfolios and compare the performance in accordance with the prior approach. We also control for time consistency by splitting the data into two subperiods, April 2009 — March 2014 and April 2014 -— December 2018. The portfolios are constructed by both value- and equally weighted versions. Given the main objective of this paper, all robustness checks focus on the alphas as a measure of the abnormal performance. With respect to the value-weighted portfolios, the weighting is done by a different approach as opposed to the standard weighing procedure. We apply the logarithmic market capitalization to avoid a few economically large companies to drive our results.

As shown in Table 8.1, the energy sector has a large impact on the market, with companies such as Equinor having a large market capitalization in contrast to the mean market capitalization of the market. The weighting is therefore done via the following equation:

$$W_i = \frac{Log(MCAP_i)}{\sum_{j=1}^{n} Log(MCAP_j)} \quad (8.3)$$

where $Log(MCAP_i)$ is the logarithmic market capitalization of company i and $\sum_{j=1}^{n} Log(MCAP_j)$ is the sum of the sample's logarithmic market capitalization. The logarithmic transformation reduces the value-weighted effect in our portfolio construction but is arguably a better approach, given our dataset.

In order to gain further robustness, we also estimate the full sample model by modifying for sectorspecific issues. This is done by testing a best-in-class version. The best-in-class score of a company is calculated by running the same regression of returns against DJSND and then filtering the data based on sector classifications. We then select the top 20% of companies in each sector based on their beta-coefficients (sensitivity towards ESG-related factors). The same procedure is done for the bottom portfolio. During the portfolio selection, firms are, by implication, ranked among their own peers. As a result, companies can be eligible for a high-level portfolio even if they are classified among companies that are difficult in terms of ESG requirements.

For the best-in-class test, companies are only grouped into nine sectors to ensure a sufficient number of firms in each sector. These sectors are basic materials, consumer staples, consumer discretionary, energy, financials, healthcare, industrials, and information technology. Because of Norway's natural resources, the Norwegian market is heavily concentrated in some specific sectors, e.g. the energy sector. This skews the distribution of sectors, as shown in Table 8.1. Due to this being a characteristic of the Norwegian market, no further steps are taken to correct this.

8.3.2 Risk premium

In this section, we apply a panel-based strategy using Fama and MacBeth (1973) regressions to analyze the direct impact of ESG variables on stock return. The Fama-MacBeth procedure is a two-step regression that tests how factors describe portfolio or asset returns. According to Shanken (1992), these types of two-pass approaches suffer from the well-known 'errors-in-variables problem', and might cause a downward bias in the standard errors, resulting in an overestimation of the t-statistic. This is also supported by Chen et al. (1986), who argue that a consequence of this problem is biased factor loadings. In accordance with Friend and Blume (1970), Blume

(1970) and Fama and MacBeth (1973), we address this problem by grouping stocks into portfolios and use these as test assets. While the previous approach only includes companies with a very high and very low ESG score, this procedure does not make any ESG-related assumptions when forming portfolios. Our test asset portfolios are sorted according to different characteristics; size (MCAP), value (B/M) and industry. Appendix A outlines the descriptive statistics of the different test assets.

To construct our ESG factor, we use the data from the portfolio analysis, where we use monthly rebalancing, resulting in a time series of monthly average returns. In accordance with Fama and French (2019), the portfolios are value weighted. The clean minus dirty factor (CMD) is the average return of the top portfolio minus the average return of the bottom portfolio.

In the first step, we regress each portfolio's return against our different factors (MKT, SMB, HML, momentum factor (MOM) and CMD) to determine the factor exposure. For the second step, we run T cross-sectional regressions of returns against the estimated βs $(\widehat{\beta})$ to estimate the reward earned per unit of exposure:

$$\begin{gathered}
r_{i,1} = \lambda_{1,0} + \lambda_{1,1}\widehat{\beta}_{i,F_1} + \lambda_{1,2}\widehat{\beta}_{i,F_2} + \cdots + \lambda_{1,m}\widehat{\beta}_{i,F_m} + \varepsilon_{i,1} \\
r_{i,2} = \lambda_{2,0} + \lambda_{2,1}\widehat{\beta}_{i,F_1} + \lambda_{2,2}\widehat{\beta}_{i,F_2} + \cdots + \lambda_{2,m}\widehat{\beta}_{i,F_m} + \varepsilon_{i,2} \\
\vdots \\
r_{i,T} = \lambda_{T,0} + \lambda_{2,1}\widehat{\beta}_{i,F_1} + \lambda_{2,2}\widehat{\beta}_{i,F_2} + \cdots + \lambda_{2,m}\widehat{\beta}_{i,F_m} + \varepsilon_{i,T}
\end{gathered} \tag{8.4}$$

where $r_{i,T}$ is the excess return of portfolio i over the risk-free rate. $\widehat{\beta}$ is the estimated betas, λ are regression coefficients used for estimating the risk premiums and 1 is the error term. The risk premiums, standard deviations, and t-statistics are calculated via the following equations:

$$\widehat{\lambda}_j = \frac{1}{T}\sum_{t=1}^{T}\widehat{\lambda}_{j,t},\ \widehat{\sigma}_j = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(\widehat{\lambda}_{j,t} - \widehat{\lambda}_j)^2} \text{ and } t_{\lambda_j} = \sqrt{T}\frac{\widehat{\lambda}_j}{\widehat{\sigma}_j} \tag{8.5}$$

The purpose of using portfolios is to reduce bias in the risk premium point estimate by grouping stocks and thus reducing beta measurement error. According to Ang et al. (2020), creating portfolios leads to larger standard errors of cross-sectional risk premia estimates because it destroys information. To avoid these problems, one can work with individual stocks as test assets. Therefore, we run the same Fama-MacBeth procedure for individual stocks, where our test assets are all stocks that are or have been listed during the period 2009–2018. In this process, we set a cap of a minimum of 20 observations per stock, resulting in a sample of 254 companies.

8.4 EMPIRICAL ANALYSIS

In this section, we analyze whether investors can expect a risk-adjusted return when investing in a portfolio comprised of sustainable companies. The analysis of our constructed portfolios is based on the multi-factor performance model by Carhart (1997). The use of three control variables mitigates potential bias that could result from tilts in stock portfolios (size, value versus growth, or momentum effects). This report is based on various holding periods, portfolio weightings and subperiods. For further robustness, we include a best-in-class version to account for potential industry effects. We begin our analysis by dividing our data sample into subperiods to observe the sector distribution and trends across time. The subperiods are 2009–2010, 2011–2012, 2013– 2014, 2015–2016, 2017–2018. We see a clear trend that companies within the banking industry are placed consistently in the bottom portfolio, while a larger amount of energy companies are placed in the top portfolio. Further investigation reveals that this difference is also statistically significant. When controlling other sectors, healthcare and industrials are also significantly different between the two portfolios, where a large number of companies classified within these sectors are placed in the bottom portfolio apposed to the top portfolio. Other sectors seem to have no particular pattern (Appendix B). We also investigate the sector-based returns from our subperiods. In 2015, the oil price dropped significantly, down to a low of $30 per barrel, causing the Norwegian energy sector to suffer. The effect carried over to the next subperiod. There is also a significant increase in returns for the technology sector and consumer staples in subperiod four

(2015–2016). When we compare our portfolios across time, portfolio 2 (quintile-2) shows a turning point in 2015, with a high growth period from 2015 to 2018. Further investigation reveals that this effect comes from abnormal growth in technology stocks in portfolio 2, caused by unpredictable news with no connection to ESG. Our top and bottom portfolios are not affected by this.

8.4.1 Regression analysis

Table 8.2 presents the descriptive statistics for the two ESG portfolios, constructed based on both a value-weighted and an equally weighted method. These statistics suggest that the portfolio comprised of low-rated companies performed better than the portfolio comprised of high-rated companies after adjusting for volatility. The high volatility in the top portfolio may be caused by the high concentration in the energy sector, which is known to be volatile. Nevertheless, both portfolios substantially underperform compared to the market proxy, which has an annual return of 12.41%. Regardless, the skewness and kurtosis estimates indicate a moderate deviation from the normal distribution. It is worth mentioning that portfolio 2 generated a mean annual return of 17.70%, indicating a higher return for companies that are sustainable to some extent. However, we suspect that industry sectors drive some of these results.

To analyze the differences in our two constructed portfolios, we apply the Carhart four-factor model (equation 2) to account for market risks. Table 8.3 presents the results for our portfolios based on the high, low and high-low construction, providing results for the high-rated portfolios, the low-rated portfolios, and the long-short strategy. First of all, we can observe that the R2 value is relatively acceptable, indicating incremental explanatory power of the multivariate framework, which supports our choice of model. However, according to the alpha estimates and corresponding t-statistics of the top and bottom portfolios, only the value-weighted portfolios in Panel C generate significant values. Even though it is significant at a 10% level, the results are not compelling.

Apart from this, the factor loadings on the additional determinants, SMB, HML, and MOM, are generally significant. However, we can see a difference between the

Table 8.2: Descriptive statistics for ESG-ranked portfolios, March 2009–December 2018.

	Mean (%)	Std. Dev. (%)	Sharpe ratio	Max Mth. return(%)	Min Mth. return(%)	Skew	Kurtosis	Difference of means t-stat	Difference of means p-value
Equally weighted									
High	10.85	20.91	0.42	17.11	-15.75	0.09	0.32		
Low	7.35	12.18	0.69	10.93	-10.64	0.08	0.92		
High-Low	3.29	17.54	0.19	17.18	-14.18	0.35	0.66	0.58	0.56
Value weighted									
High	11.89	20.81	0.45	17.30	-15.81	0.07	0.37		
Low	8.72	12.16	0.51	11.06	-10.21	0.12	0.28		
High-Low	2.94	17.55	0.17	16.39	-15.12	0.26	0.69	0.52	0.61
	12.41	15.01	0.83	15.49	-10.41	0.09	1.08		

[a] This table presents the descriptive statistics for the two ESG portfolios constructed based on both a value-weighted and an equally weighted method, consisting of all stocks on the Norwegian market in the period 2009–2018. The Sharpe ratio is the ratio of the excess return to the standard deviation of returns. The mean return, the standard deviation, and the Sharpe ratio are annualized. Column eight and nine provide statistics of skewness- and kurtosis data. The two last columns report the t-statistics and p-values from the difference in means.

betas of the high and low portfolios, where companies with a lower ESG rating are exposed to lower systematic risk, resulting in a lower beta. This contradicts Ashwin Kumar et al. (2016), who found that companies more related to ESG factors had lower volatility and risk. For both the high-rated and the low-rated rated portfolios, the SMB coefficient is significantly positive, indicating a bias towards small-cap stocks in the Norwegian market. The factor loadings on HML are negative for the high-ranked portfolios and positive for the low-ranked portfolios, indicating that the high-ranked portfolios was somewhat growth-stock oriented during the period and that low-ranked portfolios were tilted towards value stocks. We should also note the negative coefficients for the momentum factor, suggesting that both stocks with bad past-year performance and stocks with good past-year performance tend to have a low ESG score. These findings are similar to Derwall et al. (2005), who investigated the performance of ESG portfolios in the U.S. market in the period 1995–2003. When

Table 8.3: Multifactor regression results.

	Intercept	β_{MKT}	β_{SMB}	β_{HML}	β_{MOM}	R^2
Panel A: One month holding horizon						
Equally weighted						
high	-0.003	1.255***	0.571***	-0.166*	-0.352***	0.73
low	-0.002	0.612***	0.539***	0.019	-0.077	0.40
high-low	-0.002	0.643***	0.032	-0.184	-0.275***	0.42
Value weighted						
high	-0.003	1.267***	0.557***	-0.163**	-0.339***	0.74
low	-0.001	0.613***	0.539***	0.024	-0.076	0.40
high-low	-0.002	0.655***	0.019	-0.187	-0.263***	0.43
Panel B: 1 year holding horizon						
Equally weighted						
high	-0.003	1.205***	0.467***	-0.191**	-0.364***	0.78
low	-0.001	0.631***	0.590***	0.016	-0.207***	0.48
high-low	-0.003	0.574***	-0.123	-0.206*	-0.157*	0.42
Value weighted						
high	-0.003	1.224***	0.450***	-0.193**	-0.356***	0.79
low	0.000	0.615***	0.563***	0.021	-0.212**	0.50
high-low	-0.003	0.610***	-0.113	-0.213*	-0.144*	0.45
Panel C: Two period holding horizon						
Equally weighted						
high	0.002	1.089***	0.384***	-0.220***	-0.313***	0.74
low	0.003	0.510***	0.366***	0.085	-0.139**	0.49
high-low	-0.001	0.580***	0.018	-0.304***	-0.174**	0.42
Value weighted						
high	0.002	1.222***	0.366***	-0.220***	-0.299***	0.74
low	0.003*	0.507***	0.359***	0.082	-0.140**	0.51
high-low	-0.001	0.615***	0.007	-0.301***	-0.158*	0.45

[a] This table presents estimations of the time-series regression: $r_{i,t} = \alpha_i + \beta_i MKT_{i,t} + s_i SMB_{i,t} + h_i HML_{i,t} + m_i MOM_{i,t} + \varepsilon_{i,t}$. Panel A represents a one-month holding period starting from March 2009 – December 2018. Panel B shows a rebalancing of the portfolios each year throughout the period March 2009 – March 2018. Panel C represents two subperiods from April 2009 to March 2014, and from April 2014 to December 2018. t -statistics were derived from Newey-West heteroscedasticity- and autocorrelation-consistent standard errors. *, **, and *** indicate significance at the 10%, 5%, and 1% level.

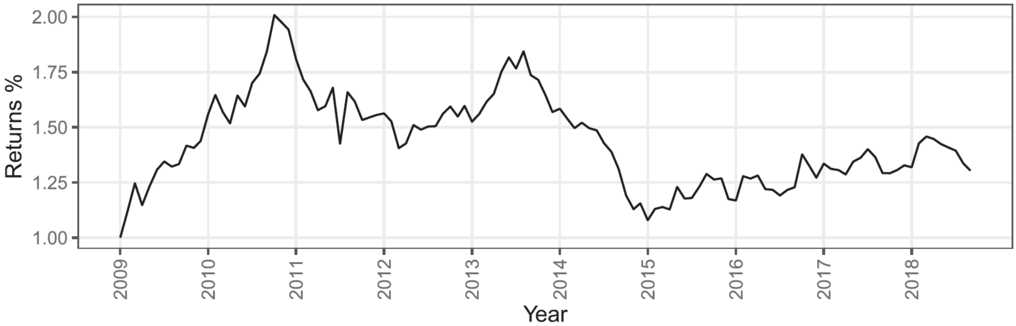

Figure 8.1: Cumulative return of CMD factor, April 2009 to December 2018.

we look at the results regarding the high-low, for all periods, it is evident that the performance difference between the two portfolios is limited, with no statistical significance.

We have now provided evidence that a portfolio comprised of companies ranking high and low on ESG is not able to generate any significant return difference after adjusting for market risk and investment style. In this section, we will, therefore, do an analysis to test whether the industry tilts have any substantial effect on companies' stock returns. We construct our portfolios based on a best-in-class approach, which is a common method in socially responsible investing analysis. As in the previous section, our portfolios are constructed both on an equally weighted and value-weighted approach. Summary statistics of the portfolios are given in Table 8.4, indicating that the worst-in-class portfolio outperformed the best-in-class portfolio, after adjusting for volatility, as shown by the Sharpe ratio. Table 8.5 reports performance results in the Carhart framework based on a best-in-class strategy. These findings are similar to those previously reported in Table 8.3, and we therefore conclude that our results are not caused by industry bias. Overall, we find that there is no significant relationship between companies that performs well along environmental dimensions and those who do not. The average return on the high-low strategy is economically small and not statistically significant on a risk-, style-, and industry-neutral basis.

Table 8.4: Descriptive statistics, best-in-class, March 2009–December 2018.

	Mean (%)	Std. Dev. (%)	Sharpe ratio	Max Mth. return(%)	Min Mth. return(%)	Skew	Kurtosis
Equally weighted							
Best-in-class	11.62	19.69	0.45	18.83	-15.08	0.16	0.69
Worst-in-class	11.06	11.32	0.74	9.53	-10.45	-0.01	0.89
Value weigted							
Best-in-class	11.69	19.62	0.46	18.83	-15.08	0.16	0.71
Worst-in-class	11.11	11.29	0.76	9.53	-10.22	0.01	0.83
Market proxy							
	12.41	15.01	0.83	15.49	-10.41	0.09	1.08

[a] This table presents the descriptive statistics for our best-in-class and worst-in-class portfolios constructed based on both a value-weighted and equally weighted methods, consisting of all stocks on the Norwegian market in the period 2009–2018. The Sharpe ratio is the ratio of the excess return to the standard deviation of returns. The mean return, the standard deviation, and the Sharpe ratio are annualized. The last two columns provide statistics of skewness and kurtosis data.

Table 8.5: Multifactor regression results, one month holding period.

	Intercept	β_{MKT}	β_{SMB}	β_{HML}	β_{MOM}	R^2
Equally weighted						
high	-0.003	1.223***	0.545***	-0.134*	-0.324***	0.76
low	0.001	0.630***	0.449***	0.039	-0.075	0.49
high-low	-0.004	0.593***	0.096	-0.173*	-0.248***	0.44
Value weighted						
high	-0.002	1.234***	0.526***	-0.134*	-0.309***	0.78
low	0.002	0.636***	0.450***	0.046	-0.071	0.49
high-low	-0.004	0.598***	0.076	-0.1799*	-0.238***	0.45

[a] This table presents estimations of the time-series regression: $r_{i,t} = \alpha_i + \beta_i MKT_{i,t} + s_i SMB_{i,t} + h_i HML_{i,t} + m_i MOM_{i,t} + \varepsilon_{i,t}$ with one-month holding for our best-in-class strategy from March 2009 – December 2018. *, **, and *** indicate significance at the 10%, 5%, and 1% level.

8.4.2 Fama-MacBeth results

Our previous regression results were not able to document a relation between firm characteristics, sustainability, and expected return, which indicates that ESG-risk is not priced. To investigate this further, we do a two-stage procedure to simply evaluate if the ESG ratings help predict returns and if there is a risk premium for exposure to the CMD factor. Figure 8.1 shows the cumulative return for the constructed CMD factor in the period from March 2009 to December 2018. The graph shows significant time variability, particularly during the period from 2009 to 2015. The ascending trend in the periods from 2009 to 2011 and 2012 to mid-2013 reflect outperformance of the high-rated portfolio compared to the low-rated portfolio, followed by a turning point at the start of 2011– 2012 and mid-2013–2015. From there on out, it follows an upward trend.

Table 8.6 summarizes the results from the first stage of the procedure where returns are regressed against our different factors. The factor exposure to MKT is close to one for both size portfolios and for the value-weighted B/M portfolio. This implies that these portfolios are sufficiently diversified, while the average exposure for all test-assets are 0.781, which deviates to some extent from the broad market. The exposure to SMB is, on average, positive, which means that the portfolios have been exposed to small-cap stocks during the period. The average exposure to HML is positive, implying that the sample portfolios have been tilted towards value stock. The table also shows that the exposure toward MOM and CMD is neutral, on average.

Table 8.7 reports the average coefficients (λ) and t-statistics in parenthesis. The average intercept (λ_C) is significant for the equally weighted portfolios sorted by size (*MCAP*) and value (*B/M*) and for all value-weighted portfolios. The industry-sorted portfolios have the lowest intercept in both equally weighted and value-weighted portfolios. In panel A (equally weighted), the only portfolio with significant coefficients is the industry-sorted one, with 3.74%, -2.15% and 1.44% for the MKT-, SMB- and HML factors, respectively, at a significance level of 10% or less. Interestingly, panel A reports that the market factor is negative for the size (*MCAP*) and the value (*B/M*) portfolio, while it is positive and significant at a 1% level for the industry portfolio. In panel B (value-weighted), the portfolio sorted by size (*MCAP*) has a signif-

Table 8.6: Average factor exposure, portfolios.

Portfolios	α	β_{MKT}	β_{SMB}	β_{HML}	β_{MOM}	β_{CMD}
Size EW	0.003	1.048	-0.115	-0.015	-0.023	0.001
Size VW	0.006	0.926	-0.094	0.007	0.018	0.020
B/M EW	0.011	0.562	0.428	0.272	-0.149	0.027
B/M VW	0.008	1.122	0.196	0.699	-0.060	0.279
Industry EW	0.009	0.499	0.142	0.237	0.028	-0.082
Industry VW	0.006	0.529	0.152	0.241	0.004	-0.091
Average	0.006	0.781	0.118	0.240	-0.030	0.026

[a] This table presents factor exposure estimations of the time-series regression where returns are run against our different factors. MKT is the market exposure; SMB, HML, MOM and CMD are the size, value, momentum and ESG exposure. Portfolios that are value weighted are denoted VW, and those that are equally weighted are denoted EW.

icant market factor with a negative risk premium of -4.90% per month, while the value (*B/M*) portfolio has a positive SMB factor with a risk premium of 2.81% per month. All other coefficients are not significant at a 10% level or less. R^2 is lowest for the equally weighted portfolio sorted by value (B/M), with an R^2 of 0.59. The highest R^2 is for the equally weighted portfolio sorted by industry, with a value of 0.69.

We note that neither the momentum factor (MOM) nor the CMD is significantly different from zero for any of the test portfolios, implying that these risk factors are not priced in the Norwegian market. As our main objective is determining if exposure to the risk factor, CMD, is priced in the market, we find no supporting evidence.

We also use individual stocks instead of portfolios to check the robustness of our results. Examining individual stock returns allows us to address the potential concern that a portfolio approach may lead to larger standard errors of cross-sectional risk premia estimates (Ang et al., 2006). Table 8.8 reports average coefficients and t-statistics. The model is estimated for the full period, as well as for two subperiods. The intercept (λ_C) is significant at a 1% level, while none of the coefficients are sig-

Table 8.7: Average risk premiums, portfolios.

	λ_C	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{CMD}	R^2
Panel A: Equally weighted							
Size (MCAP)	2.22	-1.04	-0.32	0.48	-1.12	0.69	0.63
	(3.01)***	(-1.22)	(-0.43)	(0.49)	(-0.60)	(0.49)	
Value (B/M)	1.67	-0.92	1.67	-0.11	2.38	1.73	0.59
	(2.44)**	(-0.75)	(1.43)	(-0.14)	(1.51)	(0.91)	
Industry	-0.53	3.74	-2.15	1.44	2.00	-0.49	0.69
	(-0.79)	(3.09)***	(-1.88)*	(1.67)*	(1.53)	(-0.37)	
Panel A: Equally weighted							
MCAP	6.46	-4.90	0.31	-2.11	-1.28	-3.89	0.67
	(3.59)***	(-2.64)***	(0.65)	(-1.47)	(-0.89)	(-1.62)	
B/M	3.03	-1.46	2.81	0.68	1.51	-2.41	0.60
	(2.93)***	(-1.21)	(2.02)**	(1.15)	(1.43)	(-1.64)	
Industry	1.78	0.10	-1.71	0.91	-0.16	-0.11	0.66
	(3.32)***	(0.14)	(-1.28)	(1.01)	(-0.15)	(-0.10)	

[a] Table reports the results of the Fama-MacBeth regression. For each month t, we conduct the following cross-sectional regression for each stock: $r_{i,T} = \lambda_{T,0} + \lambda_{2,1}\hat{\beta}_{i,F_1} + \lambda_{2,2}\hat{\beta}_{i,F_2} + \cdots + \lambda_{2,m}\hat{\beta}_{i,F_m} + \varepsilon_{i,T}$, where $i = 1, 2, \cdots, N$ and $t = 1, 2, \cdots, T_i$. Is are the average factor premiums in percent, MKT is the market risk premium; SMB, HML and MOM are the size, value and momentum premium. The last column reports the R^2. *, **, and *** indicate significance at the 10%, 5%, and 1% level.

nificant at a 10% level or less, with the exception of the momentum factor in Panel B. Contrary to the portfolio approach, the R^2 is lower for the whole period and both subperiods. To ensure that our Fama-MacBeth standard errors are not understated due to the error-in-variables problem, we apply the Newey-West standard errors. The t-statistics for our CMD factor are already small, and with the Newey-West standard errors, they become even smaller. Applying robust standard errors does not change our interpretation of the factor. However, because we are sensitive to the concern that our tests may have low power to find a significant relation between ESG and stock returns, the reported t-statistics are based on the Fama-Macbeth standard errors. In conclusion, the applied model does not indicate any risk premium for the CMD factor in accordance with the prior approach.

In summary, the findings of the cross-sectional analysis suggest that the CMD factor has no significant influence on returns. These results are robust for different

Table 8.8: Average risk premiums, individual stocks.

	λ_C	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{CMD}	R^2
Panel A: 2009–2018							
Estimate	1.00	0.20	-0.54	0.37	0.72	0.16	0.15
	(5.23)***	(0.47)	(-1.37)	(0.91)	(1.58)	(0.27)	
Panel B: 2009–2014							
Estimate	1.15	-0.80	-0.04	-0.16	1.44	0.09	0.22
	(4.31)***	(-1.57)	(-0.08)	(-0.31)	(2.24)**	(0.13)	
Panel C: 2014–2018							
Estimate	1.12	0.27	-0.29	0.34	-0.03	0.54	0.18
	(4.34)***	(0.38)	(-0.49)	(0.69)	(-0.05)	(0.67)	

[a] See notes to Table 8.2. Panel B and C represents the subperiods April 2009 to March 2014, and April 2014 to December 2018. ** and *** indicates a 95% and 99%, respectively, level of significance.

subperiods and with different test assets. However, regarding the Fama-MacBeth analysis, it should be noted that the portfolio approach only includes ten portfolios for each test asset, which makes the power of these results weak. Previous studies have used larger test assets, with 20–30 portfolios (Fama and MacBeth, 1973; Gregory et al., 2013).

8.5 CONCLUSION

The contribution of this article is to offer an insight into the world of socially responsible investing and to investigate whether investors can expect an abnormal risk-adjusted return when investing in portfolios comprised of sustainable companies. Because of the availability of ESG ratings for the Norwegian market, we rank companies based on their sensitivity and exposure (beta) toward ESG factors by using the DJSND. Our portfolios were constructed in the period from March 2009 to December 2018. To provide evidence from different perspectives, we apply a portfolio strategy by Carhart (1997), as well as a cross-sectional approach by Fama and MacBeth (1973).

The portfolios based on ESG rating do not show any significant return difference based on a high-low strategy. This finding is robust for various holding periods, as well as for different portfolio weightings. When testing for industry bias through a best-in-class approach, our results remain consistent. These results firmly contradict previous studies, which provide evidence of abnormal return through the use of an ESG portfolio strategy (Kempf and Osthoff, 2007; Lee et al., 2013; Statman and Glushkov, 2009), and support those who find no relationship (Cohen et al., 1997; Guerard, 1997; McWilliams and Siegel, 2000). Based on the Fama and MacBeth (1973) regression, it is evident that the CMD factor does not provide any explanatory power of returns and is not priced in the Norwegian market.

In summary, the results of the empirical analysis based on market sensitivity, investment style, and industry bias give no base for the presence of any connection between ESG and stock returns in the Norwegian market. The portfolio comprised of high-rated companies in terms of our ESG measure does not perform statistically better or worse than the portfolio comprised of low-rated companies. From an investor perspective, our results indicate that one does not have to sacrifice return for investment opportunities that are in line with their personal values.

These results heavily rely on the index applied to generate our sustainability measure. We, therefore, leave our findings open for interpretation and encourage further research to apply different rating methods to the Norwegian market. Further research may also apply different factors than the ones constructed by Ødegaard (2017). The Norwegian market is a small, less liquid market, making the variability large. This affects the constructed factors and our results. Regionally based factors may, therefore, be applied in future studies.

REFERENCES

Ang, A., Hodrick, R. J., Xing, Y., and Zhang, X. (2006). The cross-section of volatility and expected returns. *Journal of Finance*, 61(1):259–299.

Ang, A., Liu, J., and Schwarz, K. (2020). Using stocks or portfolios in tests of factor models. *Journal of Financial and Quantitative Analysis*, 55(3):709–750.

Ashwin Kumar, N. C., Smith, C., Badis, L., Wang, N., Ambrosy, P., and Tavares, R. (2016). ESG factors and risk-adjusted performance: A new quantitative model. *Journal of Sustainable Finance and Investment*, 6(4):292–300.

Austin, D. and Sauer, A. (2002). *Changing oil : Emerging environmental risks and shareholder value in the oil and gas industry*. World Resource Institute, Washington, DC.

Banz, R. W. (1981). The relationship between return and market value of common stocks. *Journal of Financial Economics*, 9(1):3–18.

Barnett, M. L. and Salomon, R. M. (2006). Beyond dichotomy: The curvilinear relationship between social responsibility and financial performance. *Strategic Management Journal*, 27(11):1101–1122.

Baron, D. P., Agus Harjoto, M., and Jo, H. (2011). The economics and politics of corporate social performance. *Business and Politics*, 13(2).

Bauer, R., Koedijk, K., and Otten, R. (2005). International evidence on ethical mutual fund performance and investment style. *Journal of Banking and Finance*, 29(7):1751–1767.

Blume, M. E. (1970). Portfolio Theory: A Step Toward Its Practical Application. *The Journal of Business*, 43(2):152–152.

Boutin-Dufresne, F. and Savaria, P. (2004). Corporate social responsibility and financial risk. *The Journal of Investing*, 13(1):57–66.

Carhart, M. (1997). On persistence in mutual fund performance. *The Journal of Finance*, 52(1):57–82.

Chen, N.-F., Roll, R., and Ross, S. (1986). Economic forces and the stock market. *The Journal of Business*, 59(3):383–403.

Cohen, M. A., Fenn, S. A., and Konar, S. (1997). Environmental and financial performance: Are they related? Working paper, Investor Responsibility Research Center, New York.

Derwall, J., Guenster, N., Bauer, R., and Koedijk, K. (2005). The eco-efficiency premium puzzle. *Financial Analysts Journal*, 61(2):51–63.

Elton, E., Gruber, M., and Blake, C. (1996). Survivorship bias and mutual fund performance. *Review of Financial Studies*, 9(4):1097–1120.

Fama, E. F. and French, K. R. (2012). Size, value, and momentum in international stock returns. *Journal of Financial Economics*, 105(3):457–472.

Fama, E. F. and French, K. R. (2019). Kenneth R. French: Data library. http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/f-f_factors.html.

Fama, E. F. and MacBeth, J. (1973). Risk, return, and equilibrium: Empirical tests. *Journal of Political Economy*, 81(3):607–636.

Friede, G., Busch, T., and Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance and Investment*, 5(4):210–233.

Friend, I. and Blume, M. (1970). Measurement of portfolio performance under uncertainty. *The American Economic Review*, 60(4):607–636.

Gregory, A., Tharyan, R., and Christidis, A. (2013). Constructing and testing alternative versions of the Fama-French and Carhart models in the UK. *Journal of Business Finance and Accounting*, 40(1-2):172–214.

Griffin, J. M. (2002). Are the Fama and French factors global or country specific? *Review of Financial Studies*, 15(3):783–803.

Guerard, J. B. (1997). Is there a cost to being socially responsible in investing? *Journal of Forecasting*, 16(7):475–490.

Hong, H., Li, F. W., and Xu, J. (2019). Climate risks and market efficiency. *Journal of Econometrics*, 208(1):265–281.

Jegadeesh, N. and Titman, S. (1993). Returns to buying winners and selling losers: Implications for stock market efficiency. *The Journal of Finance*, 48(1):65–91.

Jin, I. (2018). Is ESG a systematic risk factor for US equity mutual funds? *Journal of Sustainable Finance and Investment*, 8(1):72–93.

Kempf, A. and Osthoff, P. (2007). The effect of socially responsible investing on portfolio performance. *European Financial Management*, 13(5):908–922.

Lee, D. D. and Faff, R. W. (2009). Corporate sustainability performance and idiosyncratic risk: A global perspective. *Financial Review*, 44(2):213–237.

Lee, D. D., Faff, R. W., and Rekker, S. A. (2013). Do high and low-ranked sustainability stocks perform differently? *International Journal of Accounting & Information Management*, 21(2):116–132.

Lioui, A. (2018). Is ESG risk priced? *SSRN Electronic Journal*.

Margolis, J. D., Elfenbein, H. A., and Walsh, J. P. (2012). Does it pay to be good... and does it matter? A meta-analysis of the relationship between corporate social and financial performance. *SSRN Electronic Journal*.

McWilliams, A. and Siegel, D. (2000). Corporate social responsibility and financial performance: Correlation or misspecification? *Strategic Management Journal*, 21(5):603–609.

Ødegaard, B. A. (2017). Empirics of the Oslo stock exchange. Asset pricing results 1980-2016. *UiS Working Papers in Economics and Finance*.

Renneboog, L., Ter Horst, J., and Zhang, C. (2008). The price of ethics and stakeholder governance: The performance of socially responsible mutual funds. *Journal of Corporate Finance*, 14(3):302–322.

Servaes, H. and Tamayo, A. (2013). The impact of corporate social responsibility on firm value: The role of customer awareness. *Management Science*, 59(5):1045–1061.

Shanken, J. (1992). On the estimation of beta-pricing models. *Review of Financial Studies*, 5(1):1–33.

Statman, M. and Glushkov, D. (2009). The wages of social responsibility. *Financial Analysts Journal*, 65(4):33–46.

8.A DESCRIPTIVE STATISTICS OF PORTFOLIOS

Table 8.A1: Descriptive statistics of portfolios sorted on size, value, and industry
This table outlines the descriptive statistics of the different test assets applied to the two-stage Fama-MacBeth procedure. Returns run from April 2009 to December 2018. The analysis includes both equally weighted and value weighted portfolios. Test-assets sorted by size incorporates s1 which is aportfolio of small size firms, while s10 is a portfolio of large size firms. The same applies to the B/M portfolios.

	Equally weighted				Value weighted			
	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Size								
s1 (small)	0.020	0.041	-0.063	0.135	0.032	0.069	-0.065	0.435
s2	0.015	0.046	-0.101	0.218	0.026	0.053	-0.081	0.257
s3	0.014	0.038	-0.083	0.193	0.028	0.069	-0.143	0.403
s4	0.012	0.038	-0.083	0.136	0.019	0.040	-0.078	0.147
s5	0.014	0.042	-0.095	0.156	0.021	0.048	-0.075	0.268
s6	0.016	0.048	-0.110	0.188	0.030	0.051	-0.073	0.209
s7	0.015	0.048	-0.127	0.150	0.022	0.049	-0.130	0.202
s8	0.014	0.046	-0.118	0.193	0.020	0.046	-0.119	0.153
s9	0.009	0.051	-0.126	0.133	0.018	0.048	-0.109	0.150
s10 (large)	0.013	0.051	-0.115	0.193	0.015	0.043	-0.088	0.155
Average	0.014	0.045	-0.100	0.170	0.025	0.052	-0.096	0.238
B/M								
b1 (low)	0.010	0.052	-0.122	0.131	0.012	0.074	-0.172	0.202
b2	0.019	0.049	-0.093	0.156	0.015	0.063	-0.187	0.170
b3	0.011	0.043	-0.103	0.115	0.013	0.047	-0.151	0.144
b4	0.013	0.050	-0.164	0.164	0.018	0.049	-0.084	0.200
b5	0.012	0.041	-0.074	0.187	0.019	0.057	-0.109	0.207
b6	0.013	0.046	-0.136	0.166	0.020	0.065	-0.181	0.194
b7	0.021	0.053	-0.084	0.253	0.028	0.064	-0.158	0.180
b8	0.018	0.037	-0.073	0.157	0.012	0.060	-0.137	0.324
b9	0.016	0.038	-0.073	0.120	0.023	0.060	-0.100	0.253
b10 (high)	0.015	0.035	-0.063	0.210	0.017	0.081	-0.222	0.380
Average	0.014	0.045	-0.079	0.170	0.018	0.062	-0.150	0.225
Industry								
Energy	0.01	0.06	-0.13	0.19	0.01	0.05	-0.11	0.14
Materials	0.03	0.17	-0.18	1.49	0.03	0.17	-0.18	1.49
Industry	0.01	0.04	-0.10	0.12	0.02	0.06	-0.15	0.16
ConsDisc	0.02	0.06	-0.13	0.43	0.03	0.10	-0.22	0.66
ConsStapl	0.03	0.06	-0.13	0.21	0.02	0.05	-0.11	0.16
Health	0.02	0.05	-0.15	0.15	0.02	0.06	-0.15	0.29
Finan	0.01	0.03	-0.06	0.15	0.02	0.07	-0.15	0.28
IT	0.02	0.05	-0.09	0.22	0.02	0.06	-0.13	0.24
i50 Telecom	0.01	0.05	-0.13	0.15	0.02	0.06	-0.10	0.29
Util	0.01	0.05	-0.13	0.23	0.01	0.05	-0.13	0.23
Average	0.02	0.06	-0.12	0.33	0.02	0.07	-0.14	0.39

8.B Sector distribution

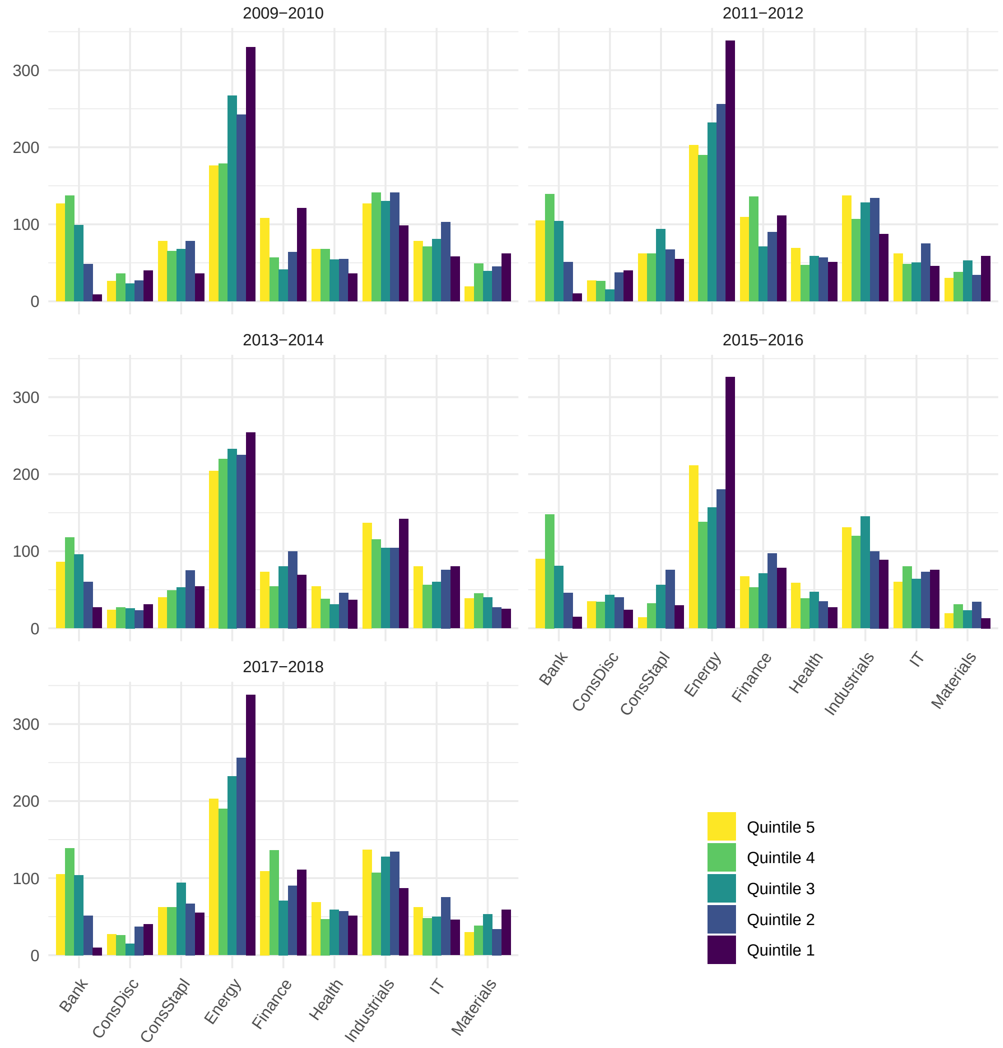

Figure 8.B1: Sector distribution, quintiles. This figure shows the industry distribution across our different ESG portfolios from 2009 to 2018, divided into five subperiods. Quintile-1 represents the top portfolio, and Quintile-5 represents the bottom portfolio. The y-axis denotes the number of monthly observations for each sector and the x-axis denotes the different sectors.

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The financial sector that provides funding for climate change mitigation and adaptation is not protected from climate change. However, there is a lack of knowledge about financial markets' response to climate change regarding asset pricing. The main concern is effects of climate change on companies and their performance in the long term. This thesis studies how climate risks impact financial markets by analyzing assets' market performance. Interested in climate risk in general, the thesis also investigates regulatory climate risk as being the most recognized by companies.

This thesis comprises four scientific articles that present the results of quantitative empirical research conducted on secondary market data. Two of these articles apply event study methodology to assess the market reaction to events related to climate policy, linking them to the regulatory climate risk. The findings show that climate-policy-related events, such as the adoption of the Paris Agreement, significantly affect stock returns and even cause a long-term shift in price fluctuations. In the case of green bonds, such events also influence their return per unit risk and correlation with other assets. The other two articles depart from the assumptions of sustainable investments and investigate the performance of sustainable and climate-aligned in- vestments in the Norwegian context. The results suggest a significant underperformance of high-climate-risk stocks and a neglectable return difference between low and high sustainable stocks. A long-short climate-aligned investment strategy was found to be profitable and thus preferable.

Overall, this thesis discovers a significant impact of climate risk on asset prices and argues that investors might benefit from distinguishing assets by their climate risk exposure. Recognition of climate risks becomes even more important for long-term-oriented value-driven investors.

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