# Mispricing of Climate Risk

*A Study of Europe's positive Risk Premium on Green Stocks during 2021*

*accompanied by a snapshot of the ESG Landscape*

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# Abstract

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**Five keywords:** Bloomberg GHG estimates, Risk premium for climate risk, ESG reporting, Sustainable investing, Stock market equilibrium

**Purpose:** Study the relationship between stock returns and GHG emissions regarding a risk premium related to greenness. This by using GHG emissions estimated by Bloomberg rather than companies self-reported estimates.

**Methodology:** The study conducts a time-invariant model by cross-sectional OLS regression to estimate the risk premium for greenness. Weighted Least Square regression (WLS) to estimate the cross-sectional estimator, which captures market imperfections. A factor capturing greenness is constructed and tested together with three factor models: Capital Asset Pricing Model (CAPM), Fama-French 3 Factor Model and Carhart 4 Factor Model.

**Theoretical perspectives:** The leading theoretical theory is the efficient market hypothesis and the risk premium combined with investors' taste and demand for green investments.

**Empirical foundation:** Daily stock returns of 1602 European companies with mega, large, mid, and small market capitalization, excluding the financial institution and real estate sector for the period March 2021 to February 2022 (12 months).

**Conclusions:** A positive risk premium is found for green companies regarding its main model. The authors conclude that due to sudden higher demand for green stocks through abrupt market shocks, the equilibrium is in transition and therefore does not show a negative premium that would price climate risk accordingly.

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# 1 Introduction

## 1.1 General Background

The dilemma of global warming becomes more problematic with every day passing, and as Gros et al. (2016) suggest, there are two options. Either an abrupt transition towards a low carbon economy and saving the planet by complying with the Paris Agreement, while forcing the immediate repricing of brown assets leading to massive global losses and instability of markets (Gros et al., 2016; Alessi et al., 2021). Alternatively, a gradual transition that will not manage to comply with the Paris Agreement will eventually result in massive global natural disasters followed by massive financial losses (Gros et al., 2016). The odds for this planet are not looking good.

Either way, it is clear that every day counts, and the earlier humanity acts on it, the higher the chances to overcome and smoothen out the effect of the impending climate crisis. Therefore, the European Union is one of the leading roles in implementing new regulations and directives toward a low carbon economy. The use of non-financial reporting for environmental, social, and governance (ESG) shifts into the prime focus, specifically reporting of *Greenhouse Gas (GHG)* emissions, which is one of the core regulations of the *Non-Financial Reporting Directive (NFRD)*.

The constant thematization of climate risk and the introduction of new regulations have raised more awareness that is also displayed within the financial markets. Several previous pieces of literature have found evidence that the market does price climate risk. The majority show, such as Alessi et al. (2021) or Pástor et al. (2021), that, on average, a negative risk premium for green assets is recorded, especially over a long period. Nevertheless, no consensus has been reached as other studies, such as Görgen et al. (2020), also find a positive premium when looking at shorter periods.

## 1.2 Problematization

Within the EU, GHG emission reporting has become a standard for public listed companies with more than 500 employees (European Commission, 2022d). Nevertheless, before the new adaptation of the Sustainable Finance Disclosure Regulation (SFRD), the computation of the GHG estimates was not all too regulated. Hence, the company still had a certain degree of freedom in estimating its GHG emissions. Also, as Alessi et al. (2019) pointed out, greener companies tend to report all three scopes of GHG emissions relatively accurately. In contrast, browner companies tend only to report to follow the law and therefore often skip Scope 3 and report somewhat underestimated numbers than overestimated ones. As mentioned by Kishan (2022), several companies in Europe do struggle with the basics of accounting for GHG emissions, or when said differently, the numbers just do not add up. Kishan (2022) emphasized that several examples were found with "errors, omissions and rounding issues (often down rather than up)" and therefore highlight the flaws within Europe's GHG reporting. This phenomenon is called Greenwashing. In general, greenwashing can be associated with emphasizing green activities to overshadow or hide brown activities through several communication channels (de Freitas Netto et al., 2020). Due to an increase in transparency by new regulative measures, the act of greenwashing is starting to diminish. Yet, in the past, it has been difficult for investors to identify the degree of greenwashing within GHG emission reporting as there has been no accurate, comparable benchmark with the quality that Bloomberg provides. Hence, when Bloomberg introduced its highly aspiring GHG emission estimates for more than 50,000 companies in 2021, investors were finally able to benchmark the reported GHG estimates by the company (Bloomberg, 2021b).

Bloomberg's GHG estimates raise the question if looking at a higher degree of "real greenness" by using these estimates to classify green vs. brown companies, will there still be a negative risk premium for green stocks as primarily found in past studies? Hence, are investors' perceptions of green companies close to Bloomberg's perception?

## 1.3 Purpose and Research Question

The purpose of this study is to investigate the relationship between stock returns and whether investors pay a risk premium based on the greenness of the company. The legislation for environmental reporting has been criticized for being unsatisfactory, as companies are not being obliged to audit their environmental or GHG reporting. Therefore, it is relevant to investigate this relationship from a different angle, utilizing estimated GHG published by Bloomberg, which can fill in the gaps for companies who do not report GHG and potentially provide more precise estimates for companies that do. A more diverse and unbiased sample can be reached as non-reporting companies will not be automatically deselected due to missing data. As Bloomberg's GHG estimates were only introduced in 2021, the period under investigation will range from 01.03.2021 to 28.02.2022. This brings us to the following research question:

*Does the European market price climate risk with a negative risk premium for green stocks in the period from March 2021 to February 2022?*

## 1.4 What Authors Do

1602 European companies' daily stock returns were analyzed. The top and bottom 20% of companies with the highest and lowest GHG emissions estimates created a green and brown portfolio. Bloomberg's GHG emission estimates serve as the core selection criteria. To the authors' knowledge, this is the first paper that utilized Bloomberg's GHG estimates to identify the greenest and brownest companies without the self-reporting bias. Further, a greenness factor was formed based on the difference between the returns of the green and brown portfolios. Moreover, cross-sectional regressions were executed on the unbalanced panel data of the initial sample, to estimate and test the risk premium. The Capital Asset Pricing Model (CAPM), the Fama-French 3 Factor Model, and the Carhart 4 Factor Model serve as the baseline models. Additionally, this paper also covers a snapshot of the non-financial reporting landscape, as the regulations play a significant role in emphasizing climate risk for investors or impacting companies' future cash flows, which will ultimately affect any study about risk premiums for green assets.

## 1.5 Main Findings

For the main model, a positive risk premium related to a constructed greenness factor was found for 2021. However, the risk premium is minimal and close to zero. Compared to previous years' observations, the before negative risk premium grew smaller and even turned slightly positive. This suggests that the equilibrium has been in transition during 2021 due to investors' abrupt higher demand for green stocks. Eventually, this will zero out, and a negative premium will potentially be observable again in the future. Therefore, the conclusion can be derived that the European market did not price climate risk during 2021, or better expressed, the increase in investors' demand overshadowed and outweighed any pricing of climate risk.

## 1.6 Contribution

After realizing that various past studies are based on many different methods when creating a green and brown portfolio, it makes it hard to compare the different periods of the different studies. Also, many methods suffer from the reporting gap, including a degree of greenwashing and bias. Therefore, this study attempts to investigate the premium without such deficits and bridge the reporting gap. By being, to the authors' knowledge, the first study that is based on Bloomberg's GHG estimates, it will undoubtedly bring another perspective to the literature on pricing climate risk.

Therefore, this paper opens the door for many further studies investigating a more accurate version of a company's greenness. Apart from examining the risk premium, it would certainly also be interesting if investors realized the reporting gap. Hence, is the gap between Bloomberg's estimates and the company's reported number incorporated in the market? Also, when considering the different reporting standards, the observable effect could be more extensive when looking at less restrictive countries of GHG reporting such as Australia, the USA (before 2022), China or Japan. Additionally, as soon as more periods are available to measure the effect of the Bloomberg GHG emission estimates, the actual impact of using a potentially very accurate measure of greenness can be investigated.

This study can eventually encourage and inspire future researchers to keep investigating the climate risk in today's fast-paced world that is impacted by annual changes in ESG reporting.

## 1.7 Scope and Limitations

Most importantly, this thesis is limited by the fact that Bloomberg started to publish estimated GHG during 2021; hence only a short time period is covered. Preferably, a more extended period would be researched to provide more reliable results that also cover time-variability as investors' interest in environmental disclosure has increased over time. Furthermore, it is also important to note that variables used to classify companies as more or less environmentally friendly, such as estimated GHG and revenue (to normalize GHG), possibly have been affected by the pandemic as mainly 2020 numbers have been utilized. Companies can have been differently affected depending on their geographical and industry operation, hence, their normalized GHG is also impacted differently. However, as both GHG and revenue are estimated to decrease, it is assumed to be somewhat controlled.

Moreover, in general, the pandemic had a tremendous impact on the global economy. As this thesis covers daily stock returns during 2021 and 2022 on the European market, they are affected by the Covid-19 pandemic (e.g., lockdowns in specific countries). Such exceptional circumstances make it harder to quantify the risk premium of climate risk and fully validate these findings as macroeconomic events' impact on this study is unknown to a certain degree.

The authors of this study believe there is a trade-off between these limitations and the possibility of contributing with new results for a subject which have been hot for quite a while, yet still manages to grow in importance. For example, the covid-19 pandemic or the invasion of Ukraine and it previously observed tensions have both increased focus on companies' environmental performance.

## 1.8 Structure

The thesis follows the consecutive arrangement. First, *section 2* presents the theoretical background, followed by *section 3* that covers a summary of the current theoretical and empirical literature. *Section 4* and *5* present the processing of data and subsequently the methodology of the study. Next, *section 6* and *7* consist of the empirical results as well as a the performed robustness checks. Moreover, *section 8* presents the related analysis and discussion based on the theoretical frameworks of earlier literature. Lastly, *section 9* concludes and examine the empirical results and present suggestions for future research.

# 2 Theoretical Background of non-financial reporting

## 2.1 History of Sustainability

Sustainability and the consciousness about humanity's impact on the planet's future generations' survival are relatively new concepts compared to the years of humankind's existence. Nevertheless, the first indications of such a thought can be traced back to the German Kameralists Hanns Carl von Carlowitz (1645 - 1714), who is believed to be influenced by English author John Evely and French statesman Jean Baptiste Colbert (Grober, 2007). Carlowitz, the head of the Royal Mining Office, was concerned about timber shortages at that time. He is thought to be one of the earliest to apply the concept of sustainability to manage and ensure timber resources for future generations within the Kingdom of Saxony in 1713 (Grober, 2007).

Nonetheless, society had to endure roughly 260 more years until the term *Sustainable Development* was first introduced, which is believed to be in 1972 at the first *United Nations Conference on Environment and Development*, also known as the *Stockholm Conference* (Janicka & Sajnóg, 2022). Later in 1987, the World Commission on Environment and Development then defined the term *Sustainable Development* as enabling the needs of societies without limiting the possibilities for future generations (Report of the World Commission, 1987). One of the more significant turning points for globally recognizing the term *Sustainable Development* was the United Nations' presentation at the *Earth Summit* in 1992 (Grober, 2007). The United Nation’s goal was to introduce a concept to save the planet regarding its natural resources (Grober, 2007).

*Sustainable Development* has become more and more a matter of discussion and a necessity when considering the increasing climate risk, the world is exposed to with every day passing. Nevertheless, it took until late 2015 to achieve significant milestones. In September 2015, the *2030 Agenda for Sustainable Development* was presented by the United Nations in September 2015, declaring *17 Sustainable Development Goals (SDGs)* to be achieved by 2030 (Janicka & Sajnóg, 2022). Later, this agenda presented by the United Nations was an inspiration for the first legally binding treaty signed in December 2015 at the *Climate Conference in Paris*, also known as the infamous *Paris Agreement*; a document that directly concerns environmental issues and climate change for the first time (UNFCC 2022). The Paris Agreement, signed by

196 parties, turned effective on 4th November 2019, with its target to "limit global warming well below 2 degrees Celsius" (UNFCC 2022). As a first effort, in 2020, countries can submit their plan of climate actions in order to lower greenhouse gas emissions for the future (UNFCC 2022). However, this submission is based voluntarily, which might question the effectiveness of the Paris Agreement overall; also, now, when looking back at the targets, they seem to become harder and harder to achieve. Still, it can be considered a leading milestone as this document increased the relevance of climate change activities immensely. Countries have potentially not been ready to act on it actively. However, awareness has undoubtedly increased tremendously in society, which further pressures different governmental institutions and might eventually fulfill its purpose. Another criticism of the Paris Agreement is that it did not consider the financial system within the "sustainable economic reconstruction"; instead, it was listed as a complement (Janicka & Sajnóg, 2022, p.3). Hence, this is a massive shortcoming from an economic view and a misjudgment of the importance of sustainable finance in creating a future integrated with sustainable development (Janicka & Sajnóg, 2022).

Nevertheless, the Paris Agreement and the United Nations' Sustainable Development Goals (UN SDGs) are considered the landmarks for today's regulatory practices of environmental, social, and governance (ESG) reporting (KPMG, 2022). Even though the Paris Agreement's goals were much more sophisticated, this alone is an outstanding achievement when considering the disparate reporting standards within different financial markets and jurisdictions globally. Finally, sustainable development has reached global awareness and high relevance in the 21st century.

## 2.2 The Role of CSR in the Emergence of ESG

Corporate Social Responsibility (hereafter CSR) is considered the pre-successor of today's ESG concept. CSR shows a longer-lasting history, originating in the 1950s in the United States and Europe, and has a variety of literature available (Carroll, 1999). Initially, the concept of CSR is to shift companies' focus from a shareholders-only-view toward an including-all-stakeholders-view in order to prevent financial underperformance due to underestimation of stakeholders' powers (Cini & Ricci, 2018). It is a form of a company's self-protection to create a positive impact for the greater society - or at least a non-harmful one. Friedman (1970) also defines it as an effort to maximize shareholders' wealth, whereas McWilliams and Siegel believe it to be a tool to create social good afar financial achievements (Friedman, 1970; McWilliams & Siegel, 2000)

The EU Commission calls itself a pioneer due to its active role in promoting CSR since its *2001 Green Paper* publication (European Commission, 2011). Later in 2008, a new policy called the *European Alliance for CSR* was published, which led to a respective increase in European enterprises, from 600 (2006) to 1900 (2011), that signed up to follow the United Nation's *10 CSR Principles* (European Commission, 2011). The *International Organization for Standardization (ISO)* published 2010 a guide of voluntary standards to support firms in participating in CSR activities (ISO, 2022). In 2011, the EU Commission published *A renewed EU strategy 2011-14 for Corporate Social Responsibility*, where the newly defined CSR as "the responsibility of enterprises for their impact on society". It states that firms can "become socially responsible" by: (1) "integrating social, environmental, ethical, consumer, and human rights concerns into their business strategy and operations" and (2) "following the law" (European Commission, 2011, p. 6; European Commission, 2022a). At this point, the EU Commission's role was to monitor large European countries with a plan to present a report to implement United Nations' *Guiding Principles* (IISD, 2011). Nevertheless, the environmental factor was not a core CSR principle but an indirect objective.

A variety of studies connect a firm's socially and environmentally responsible management with a climb in operating income (Griffin & Mahon, 1997). Hence, firms have realized the potential advantages of participating in CSR activities while understanding that companies operate in an ecosystem with several actors and not in isolation (Kramer & Pfitzer, 2016). By satisfying these different actors and the society's well-being, the increase of firms participating in CSR activities greatly accelerated. Hence this ultimately raised the question of how a company can showcase its positive efforts toward society. Thus, the need for a measurement tool that can be used internally to evaluate the success of companies' CSR projects and externally on the investors' side has become incremental. Earlier, the only tools available for companies were by connecting their CSR projects to the industry standard KPI benchmarks (Cini & Ricci, 2018). Today, ESG serves as the primary tool to quantify the environmental, social, and governance programs of companies' CSR activities (Cini & Ricci, 2018). Therefore, ESG does provide satisfaction to the need for quantification of CSR, which is detrimental to the successful implementation of any non-financial reporting standards. Also, it puts the environmental aspect into a prime location.

However, the concept of ESG did not just suddenly appear to serve CSR; yet, without CSR, ESG would not exist in the way we know it today. The introduction of ESG can be credited to the former UN Secretary-General Kofi Annan, who was leading a joint initiative by UN Global Compact, to find a solution to incorporate ESG into capital markets (Kell, 2018). This led to the publication of *Who Cares Wins* by Ivo Knoepfel in 2005, which is a landmark piece (United Nations, 2004; Kell, 2018). Around the same time, in 2005, the so-called *Freshfield Report* was published by the *United Nations Environment Programme Finance Initiative (UNEP FI)*. The report highlighted the relevancy of ESG issues regarding investment decision-making and ownership practices. It also refers to the legal framework at that time within several jurisdictions around the world and how the regulatory landscape will need to evolve (Deringer, 2005). Both of the reports led to the *Principles for Responsible Investment (PRI)* at the NYSE in 2006 and the *Sustainable Stock Exchange Initiative (SEEI)* in 2007 (Kell, 2018). The latter serves as a "global platform including" all stakeholders, companies, and policymakers to explore "how exchanges" can "enhance performance on ESG issues" in order to finance the *UN Sustainable Development Goals* (Sustainable Stock Exchanges, 2022).

Today, there are several standard setters and guidelines providers regarding ESG reporting. It has transformed from the idea of "sustainable development" and being concerned about the future resources of timber towards a company's CSR activities ensuring stakeholders' satisfaction to increase financial performance, and eventually created the tool for ESG reporting. A concept that allows quantifying CSR activities and serves as the core backbone for today's non-financial reporting standards and any foreseeable future regulative actions. Moreover, with ESG, the environmental aspect concerning climate change risk, especially greenhouse gas emissions, has become a prime relevancy issue. As an example, to this day, more than 80% of the largest corporations globally follow standards by the Global Reporting Initiative (GRI) for reporting ESG data (Kell, 2018).

## 2.3 Today’s Regulatory & Framework Landscape

Since the demand for non-financial reporting has increased in recent years, a new playground for different institutions with frameworks and standards has been shaped to support and guide companies in their activities of non-financial reporting. This section will briefly summarize the most critical bodies of standard setters.

The *Global Reporting Initiative (GRI)* Standards and its latest version, GRI-G4 from 2013, are considered the ultimate benchmark. With this, the GRI provides a framework that strongly relies on the question of materiality and therefore does not explicitly see itself as binding legislation (Hirschi, 2022). Moreover, the *United Nation Global Compact (UNGC)* provides ten principles to guide companies to operate with integrity, as well as the *United Nations Sustainable Development Goals (SDGs)* forms the norm for applying societal dimensions within their sustainability actions (Hirschi, 2022). Additionally, the *Task Force on Climate-related Financial Disclosures (TCFD)*, created by the Financial Stability Board, help listed companies improve their disclosure of climate-related risk and opportunities (TCFD, 2022). According to a report published by the *European Financial Reporting Advisory Group* in 2021, the institutions mentioned above are the four leading frameworks/standards in terms of the number of applying companies (European Reporting Lab, 2021).

Another standard provider is the so-called *IR Framework* published by the *International Integrated Reporting Council (IIRC)*. It follows the objective to increase the adoption of integrated reporting globally by improving the quality of information available, increasing its efficiency, and enhancing the accountability and stewardship of companies' actions to create a holistic picture of the overall performance of companies (Integrated Reporting Framework, 2022). Further, the *International Organization for Standardization (ISO)* offers the *ISO 26000:2010*, a set of international standards that claim to help firms manage their social responsibilities, including environmental impact (ASQ, 2022). Moreover, the *Carbon Disclosure Project (CDP)* has its primary objective of helping persuade companies globally to "measure, manage, disclose and ultimately reduce their greenhouse gas emission" (CDP, 2022). Also, the governmental-backed *Organisation for Economic Co-Operation and Development (OECD)* sets standards on responsible business conduct, including human rights, labor rights, and the environment. It creates an international mechanism for communication between society and companies (OECD Watch, 2022). Similarly, the United Nations also provides the six *Principles for Responsible Investments* that focus on assuring "environmentally and socially compatible management," which concentrates on ESG reporting (Hirschi, 2022).

Additionally, the *Climate Disclosure Standards Board (CDSB)* was consolidated in early 2022, and the *Sustainability Accounting Standards Board (SASB)* will be consolidated in June 2022, with the newly formed *International Sustainability Standards Board (ISSB)* by the *International Financial Reporting Standards (IFRS)*. This newly created board within the IFRS landscape tries to deliver the base for sustainability-related disclosure standards on a global level to satisfy the demand for "high quality, transparent, reliable and comparable reporting" of companies on ESG matters (IFRS, 2021). Lastly, there are the EU directives by the EU Commission, which are primarily principles-based standards for companies with more than 500 employees which will be emphasized more in detail within the following sector (Hirschi, 2022).

### 2.3.1 European Union's Taxonomy

The EU's goal of its *Sustainable Finance Program* is to include environmental, social, and governance (ESG) factors when undergoing investment decisions to achieve a greater extent of long-term sustainable investments (European Commission, 2022b). With the *Paris Climate Agreement* and the adoption of the *United Nations 2030 Agenda* in 2015, the first steps in the right direction of a lower carbon-emission future in Europe have been achieved (European Commission, 2022b). However, it all comes down to the implementation process and whether the goals are achievable in today's world and within the proposed period. Therefore, one of the earlier initiatives by the EU was the launch of the *European Commission Action Plan* for the *Capital Market Union (CMU)* in 2015 (CFA Institute, 2021).

Nevertheless, significant legislative progress on ESG only became more substantial at the start of 2018 through the EU Commission's High-Level Group - a group of many individuals and experts aspiring to create a European legislative landscape emphasizing financial activities on sustainable investments (CFA Institute, 2021). This group published an Action Plan that included the *Sustainable Finance Disclosure Regulation (SFDR)* and the *EU Paris-Aligned Benchmarks* as a regulative mechanism (CFA Institute, 2021). Moreover, in 2019, the EU Commission published the *European Green Deal* with its highly aspiring goal to be a climate-neutral continent by 2050. After 2019, further plans have been presented to achieve the goals, such as the *European Green Deal Investment Plan* or the *2030 Climate Target Plan* (European Commission, 2022b). The *European Green Deal* also includes the E*U Emissions Trading System (EU ETS)*, a market mechanism of a cap-and-trade approach for company's annual tonnes of $CO_2$ emissions which needs to hold a European Emission Allowance (EUA) (Appunn, 2021).

One of the EU's most vital tools to reach the goals of the *European Green Deal* is the *EU Taxonomy Regulation*, a classification system that "establishes a list of environmentally sustainable economic activities" that turned effective on 12th July 2020 (European Commission, 2022c). The *EU Taxonomy Regulation* includes the following six environmental objectives that qualify an activity to be environmentally sustainable: (1) climate change mitigation, (2) climate change adaptation, (3) the sustainable use and protection of water and marine resources, (4) the transition to a circular economy, (5) pollution prevention and control, (6) the protection and restoration of biodiversity and ecosystems (European Commission, 2022c). In order to establish that so-called list of "environmentally sustainable economic activities", specific screening criteria had to be established, resulting in the EU commission publishing the first *Taxonomy Delegated Act* on 9th December 2021, which was officially approved four days later (European Commission, 2022c). This delegated act covers two out of the six taxonomy objectives. It represents the economic activities of around 40% of listed companies that create around 80% of greenhouse gas (GHG) emissions in Europe (European Commission, 2022c).

With the *Taxonomy Delegated Act* becoming effective in January 2022, it specifies how specific large financial and non-financial companies have to report non-financial information such as the proportion of a company's total environmentally sustainable economic activities (Staunig et al., 2022). With this, the regulatory body that these companies have to report under is currently the *Non-Financial Reporting Directive (NFRD)*, the *Sustainable Finance Disclosure Regulation (SFDR)*, but also the upcoming *Corporate Sustainability Reporting Directive (CSRD)* (Staunig et al., 2022). Additionally, on the 2nd February 2022, the EU Commission proposed the *Complementary Climate Delegated Act* concerning the energy sector and to what extent their activities contribute to decarbonization (Staunig et al., 2022).

### 2.3.2 European Union's Regulative Landscape of Non-Financial Reporting

Within the *EU Taxonomy*, there are several standard setters. In this section, the following directives will be explained more in detail: NFRD, CSRD, SFRD, and CSDD.

**Non-Financial Reporting Directive (NFRD):**

The NFRD, as mentioned earlier, serves as one of the central regulatory bodies of non-financial reporting within the EU. It has been embodied in EU's member states' national law since the end of 2017, resulting in the execution of the first reporting for the fiscal year 2017 (EU Non-Financial Reporting Directive - how to prepare, 2018). Therefore, NFRD's legal requirements apply to "large public-interest companies with more than 500 employees," which includes around 11,700 companies and groups in the EU, including "listed companies, banks, insurance companies, and other companies designated by national authorities as public-interest entities" (European Commission, 2022d).

Under the NFRD (also called the Directive 2014/95/EU), the applicable companies have to publish information with the use of various *Key Performance Indicators (KPIs)* related to (1) environmental matters, (2) social matters, and treatment of employees, (3) respect for human rights, (4) anti-corruption and bribery, and (5) diversity on company boards (European Commission, 2022d). Additionally, disclosure is required about a company's business model, policies, outcomes, risks, risk management, and key performance (Directive 2014/95/EU, 2014; Welling-Steffens et al., 2021). The EU Commission also published two accompanying guidelines that support companies in fulfilling the requirements. The first accompanying guidelines were published in June 2017 and contain non-mandatory environmental and social information disclosure guidelines. Each company retains the right to "decide to use international, European or national guidelines" (European Commission, 2022d). In June 2019, a supplement version to the 2017 version of accompanying guidelines was published, concentrating on reporting climate-related information (European Commission, 2022d).

**Corporate Sustainability Reporting Directive (CSRD):**

Furthermore, the EU Commission proposed in April 2021 the new Corporate Sustainability Reporting Directive (CSRD) to replace the NFRD. Earlier this year, in 2022, the EU Council agreed on the proposal to become effective on the 1st of January 2024, meaning that the fiscal year 2023 will be the first year reporting must apply (European Council, 2022). Hence, it is the first time a "common reporting framework for non-financial data" within the EU has been defined and is mandatory (Bernoville, 2022). The CSRD extends the NFRD and concentrates strongly on ESG reporting and its quality of non-financial information in general, including the data gathering process of the reporting requirements (Bernoville, 2022). This new regulation will apply to all large companies that are listed on EU markets (except companies with less than ten employees or € 20m turnover) or fulfill two out of the following three criteria: (1) more than 250 employees, (2) more than € 40m turnover, (3) more than € 20m total assets (Bernoville, 2022). Thereby, this will increase the applicable companies from 11,700 (under NFRD) to approximately 49,000 companies (under CSRD), which will represent around 75% of the total EU's companies' turnover (Bernoville, 2022). The new regulation follows a double materiality concept, including sustainability risk and companies' impact on the environment and society.

The CSRD is expected to be much more detailed by questioning the business model and strategy in terms of sustainability and if the company follows the goal of a sustainable economy that includes limiting global warming to 1.5 °C as aligned with the Paris Agreement (Welling-Steffens et al., 2021). It will also question the mechanics of such a strategy and if the implementation is successful. The CSRD will require qualitative and quantitative information disclosure, and will include new information about value and supply chain and an analysis of operations, products, services, and business relationships. In addition, companies will be required to publish intangibles information on "intellectual, human, social and relationship capital" (Welling-Steffens et al., 2021). Lastly, the CSRD will require a third party assurance by including the scope and process of non-financial reporting in the auditor's report. Compared to the NFRD guidelines, there was no mechanism required for third-party assurance (Bernoville, 2022).

Under CSRD, companies will now be mandated to report in a separate report instead of having the option of reporting within the annual report (as in NFRD) (Bernoville, 2022). The first official draft for the new reporting standards will be submitted to the EU Commission in June 2022 with the plan that EU member states will have to adopt the new requirements in their national law by the end of 2022. The fiscal year 2023 will be the first year that companies must report under the CSRD guideline (Bernoville, 2022). However, a smooth introduction is planned as only large companies must report for the fiscal year 2023, which is planned to be expanded for all SME companies in 2026 when reporting for the fiscal year 2025 (Habermann, 2022).

Some voices criticize the pace of the implementation, the early emphasis on only large companies, and the fact that it is still dependent on the different member states' jurisdictions' implementations. Nevertheless, the new CSRD will be a significant milestone within the EU Sustainable Finance Program and a step closer to the goals of the Paris Agreement and the EU Green Deal of becoming climate neutral.

**Sustainable Finance Disclosure Regulation (SFDR):**

Furthermore, within the EU Taxonomy, the Sustainable Finance Disclosure Regulation (SFDR)'s goal is to create more transparency on the sustainability of financial institutions such as banks, insurance companies, asset managers, and investment firms within the EU, in order to minimize the act of so-called "greenwashing" (PwC, 2022a). The regulation applies to the entity level, as well as to the product level. The entity-level disclosure demands publishing the entity's information on the corporate websites to explain the following: (1) Sustainability Risk Policy, (2) Principal Adverse Impacts on Sustainability (PAIS), and (3) Consistency of the Remuneration Policy with Sustainability Risk (PwC, 2022a). The product level requires publishing product-specific information about sustainability on the website and in pre-contractual disclosure, such as a brochure (PwC, 2022a). Since March 2021, the before-mentioned entities have to fulfill the required disclosures. Also, in the same month, the ESAs announced to have the intention to merge the Regulatory Technical Standards (RTS) and the SFRD to create only one directive in the future (EBA, 2022). Since the SFRD applies explicitly to financial institutions, no further discussions will be presented within this report, as financial institutions have been excluded from this study.

**Corporate Sustainability Due Diligence (CSDD):**

This February 2022, the EU Commission proposed the Corporate Sustainability Due Diligence (CSDD) directive that asks to report on companies' due diligence duties that include "adverse impact on human rights and the environment in global value chains" (PwC, 2022b). Hence, this directive should create an EU-wide framework that helps companies evaluate and act on their sustainability risks, including human rights and environmental risks within the value chains (PwC, 2022b). The directive will affect large companies in the EU and more minor companies in particular high-risk industries. After identifying the risk, the EU Commission requires companies to align their strategies to create a sustainable economy and limit global warming to 1.5°C as per the Paris Agreement (PwC, 2022b). The CSDD is considered complementary to the future CSRD directive and is expected to have a scope of around 13,000 EU companies (PwC, 2022b). Nevertheless, this directive is not yet in force; therefore, it will not be further discussed within this paper.

### 2.3.3 Non-EU European Countries' Regulative Landscape of Non-Financial Reporting

Other European Countries that are non-EU member states also have different ESG disclosure landscapes. The following countries are briefly summarized: the United Kingdom, Norway, Turkey, Russia, Switzerland, Ukraine, and Serbia.

The United Kingdom has *Regulation No 1245 of 19/12/2016*, which follows the NFRD reporting requirements (Commission Regulation (EU) 2020/1245, 2020). However, in the post-Brexit era, the UK will not apply the newly established CSRD by the EU Commission but rather develop its own Taxonomy regulation. In October 2021, the UK government's economic and finance ministry (HM Treasury) published the report *Greening Finance: A Roadmap to Sustainable Investing*, which contains plans for the UK's own *Green Taxonomy* (Oakey et al., 2021). So far, with today's knowledge, the *Sustainability Disclosure Requirements' (SDRs)* will replace the NFRD. However, significant alignments between the EU's upcoming CSRD regulations and SDRs can be expected, especially on environmental objectives, and the ISSB standard will serve as a core component (Oakey et al., 2021).

Moreover, Norway has been following its *Norwegian Accounting Act*, which includes a social report of non-final reporting. The non-financial reporting requirements have been mostly aligned with the NFRD. However, ongoing adjustments are made for better alignment to the NFRD. In June 2021, the Norwegian government decided to implement the SFRD and EU Taxonomy into the Norwegian law, with the *Transparency Act* entering into force on the 1st of July 2022 (Berntsen & Tønseth, 2021; The Green Traffic Light, 2022).

Borsa Istanbul in Turkey has been one of the earliest stock exchanges to participate in the *UN Sustainability Stock Exchanges (SSE)* initiatives. In 2020, the *Capital Markets Board* provided ESG guidelines and obligated public entities to report sustainability activities starting in the first fiscal year of 2020. However, the ESG framework is still voluntary based (Doing business in Turkey: Environmental, social and corporate governance (ESG), 2022). Also, the Turkish government has been generally proactive with legislative actions. They have been changing the Turkish law by issuing the *Green Deal Action Plan* that aligns significantly with the *EU's Green Deal Regulations* (Doing business in Turkey: Environmental, social and corporate governance (ESG), 2022). Additionally, in October 2021, the adapted *Paris Climate Agreement* law was enforced.

Further, Russia has not been all too proactive about ESG disclosures and environmental laws in the past. Nevertheless, Russia has agreed to the *Glasgow Climate Pact* and plans to become climate neutral in 2060 (Russia ESG Update, 2021). Also, in July 2021, the *Bank of Russia (CBR*) published a guide for voluntary ESG disclosures for public equities, and in November 2021, the *State Development Bank (VER.RF)* issued the *Russian Green Taxonomy* (Azizuddin, 2021; Green Finance Platform, 2021).

Switzerland will have new legislation in place in 2022 that requires large Swiss companies to disclose various non-financial information and due diligence obligations. The so-called *Article 964bis et seq.* of the *Swiss Code of Obligations (CO)* strongly aligns with the *EU Directive 2014/95/EU* or the NFRD (Oser & Marti, 2021). If Switzerland will also align with the newly-created EU's CSRD is, to this date, unknown; however, the tendencies show that there is the possibility.

*Ukraine's National Bank (NBU)* published the *Sustainable Finance Development Policy 2025* in November 2021, which included a plan for implementing ESG regulatory frameworks. The NBU planned to enforce ESG disclosure regulations for banks within 2022 and non-bank financial institutions within 2024 (Badovska, 2022). Only in 2020 did Ukraine's *National Securities and Stock Market Commissions (NSSMC)* mention sustainable development issues for the first time (Badovska, 2022).

In contrast, Serbia suffers publicly from passive environmental protection activities and human rights violations. Hence, ESG reporting is not a legislative backbone in Serbia and is practiced only on a solely voluntary basis (Radović, 2022). Nevertheless, Serbia intends to reduce its GHG emissions by 9.8% by 2030 (compared to 1990) and has also passed the *Climate Changed Act* in 2021, which would lay out the basis for any future ESG disclosure regulation (Colić &

Ristić, 2022). Moreover, in September 2021, Serbia adopted the *Green Bond Framework* under the *International Capital Market Association (ICMA)* standards (Ralev, 2021).

### 2.3.4 Other Countries Regulative Landscape of Non-Financial Reporting

In order to get an overview of the global standpoint of non-financial reporting, this section will briefly discuss the United States, Canada, Australia, Japan, and China. ESG disclosure will be inevitable as the trend towards required ESG reporting accelerates quickly globally. However, it also emphasizes that the EU Commission's actions have been one of the first to start that trend on such a vital matter.

Since the change of the former Trump administration to the current Biden administration, non-financial reporting has dramatically changed within the United States. Trump followed a limiting sustainable investing strategy, whereas President Biden is changing into the complete opposite (Global Sustainable Investment Alliance, 2021). The SEC requested in March 2021 climate risk and ESG disclosures, followed by an *Executive Order on Climate-Related Financial Risk* by the Biden Administration in May 2021 (Global Sustainable Investment Alliance, 2021). Moreover, the SEC has publicly announced that it will accelerate the progress toward ESG disclosure requirements (Harrington & Garzon, 2022). So far, ESG disclosure is handled through a recommended framework that requires public companies to report on material information to investors, including the aspect of climate change. Nevertheless, no further specific requirements have been defined, and ESG reporting suffers from consistency, transparency, and reporting by itself (Harrington & Garzon, 2022). In 2022, the SEC plans to create specific disclosure requirements on ESG and environmental information (Harrington & Garzon, 2022).

In Canada, the *Expert Panel in Sustainable Finance* published a report with 15 recommendations that are needed to shift towards a low-carbon economy in 2019 (Global Sustainable Investment Alliance, 2021). In May 2021, the *Sustainable Finance Action Council (SFAC)* was formed, which became the regulatory body for future recommendations and regulations (Global Sustainable Investment Alliance, 2021). To this point, ESG disclosure was required when it was considered to be "material information" (Erlichman & Langlois, 2021). Finally, on April 7th 2022, the Canadian government released the plan for an official ESG disclosure requirement to become effective in 2024 (Chell et al., 2022).

Australia has so far not implemented any regulations on ESG reporting. It follows a natural mechanism believing that ESG reporting will become the future by itself due to strong investors' demand. In October 2021, 80 companies of the ASX200 did voluntarily report ESG-related information (Wynn-Pope et al., 2021). Even though a strong force asks for ESG disclosure requirements, the Australian government believes ESG disclosures to remain voluntary in the near future (Wynn-Pope et al., 2021).

Japan's goal to become climate neutral by 2050 led to the *Basic Guidelines on Climate Transition Finance* publication in 2021 (Global Sustainable Investment Alliance, 2021). Moreover, the Tokyo Stock Exchange changed its *Corporate Governance Code (CC Code)* by including sustainability topics, specifically climate change related. Also, in 2020 the revised *Stewardship Code (SS Code)* will include ESG factors for companies other than those listed (Global Sustainable Investment Alliance, 2021). Therefore, some part of ESG reporting has become mandatory through a concept described as soft-law rulemaking (Honda, 2021).

The Chinese government has been creating several directives and regulations regarding climate-related matters. However, ESG reporting has not been mandatory (Global Sustainable Investment Alliance, 2021). In 2020, China announced it to become climate neutral by 2060 (Global Sustainable Investment Alliance, 2021). Nevertheless, it seems that the Chinese government is planning to eventually create requirements for ESG reporting, as seen by their latest publication *Measures for the Administration of Legal Disclosure of Enterprise Environmental Information* in late 2021 (Huld, 2022). So far, these measures are rather guidelines but still a road in the right direction.

## 2.4 Estimated Greenhouse Gas Emissions provided by Bloomberg LP

Bloomberg LP is the global leader in providing financial and business analytics and current news and insights. As an ESG data provider, Bloomberg is considered the most comprehensive and unique platform accessible for the widest variety of subjects. It covers a 360-degree view, ranging from information about research to regulations or data itself (Bloomberg, 2022a). As an example, Bloomberg currently provides their own ESG scores for more than 11,800 companies globally, which is equivalent to around 88% of global market capitalizations, to fulfill its goal of creating transparency and minimizing greenwashing (Bloomberg, 2022a).

The essential tool for this paper is the *GHG Emissions Estimates* provided by Bloomberg. The estimates are also recommended for companies to use within their ESG reporting activities (Bloomberg, 2021a). Therefore, this underlines its accuracy to the actual GHG emissions and the fact that they are often more accurate than the reported numbers by the companies, which strongly emphasizes the existing reporting gap. In 2021, Bloomberg first published the GHG Emissions Estimates for Scope 1 and Scope 2 for the 2020 fiscal year. Today, the estimates can be filtered backward for earlier fiscal years and are available for more than 50,000 companies globally (Bloomberg, 2021b). The exact date for the publication of the estimates is not definable as it is assumed to be uploaded gradually. However, after distinguishing between Version 1 and Version 2 of the estimates, the daily publications of the estimates during 2021 were filtered. It was possible to see that the first set of estimates (Version 1) was published on the 5th of March 2021 for the fiscal year 2020. On the 1st of October 2021, Version 2 for the same fiscal year was uploaded, which included a more comprehensive range of companies. For this paper, the latest available GHG estimates were used for the fiscal year 2020.

Moreover, Scope 1 emissions are defined as the direct GHG emissions that an organization creates, such as fuel combustion in boilers or vehicles (US EPA, 2021). Scope 2 is the GHG emissions generated indirectly by an organization related to the "purchase of electricity, steam, heat or cooling" (US EPA, 2021). Bloomberg has also recently published Scope 3 GHG emissions estimates; however, only for 4,000 companies due to its complexity. Bloomberg plans to expand the Scope 3 estimates in the near future (Bloomberg, 2022b). Scope 3 GHG emissions are defined as all indirect GHG emissions that are not with the organization by itself but through the value chain and are not included in Scope 2 (Deloitte, 2022). For example, the range could be from business travels to waste decomposition or purchased goods from suppliers (GHG Insight, 2021).

Bloomberg provides estimated GHG emissions of Scope 1 and 2 based on a machine learning model. The model has been developed using ESG data, fundamentals data (which includes data from the three key financial statements), industry segmentation data, and various Bloomberg datasets (Bloomberg, 2022b). Overall, more than 800 data points are included within the estimation of Scope 1 and Scope 2 (Bloomberg, 2022c). Gradient-Boosted Decision Trees were used as the first part of training to achieve amortized inference. Next, the calibration of the distributions was improved by applying normalizing flows. Specialized models are applied to the model for companies that report GHG emissions. Also, a patterned dropout is utilized for companies that have never reported emissions, which allows the model to predict values (Bloomberg, 2022d). Additionally, the precautionary principle is applied, meaning that in case of uncertainty, the estimates are more likely to be overestimated than underestimated in order to prevent companies from underreporting (Bloomberg, 2021c). When benchmarked against baseline models (BICS Levels 1 through 4 & Gamma Generalized Linear Model), the model exhibited a "strong performance across a variety of metrics including squared error, percentage error, and calibration error" (Bloomberg, 2022d, p.13). Further, each estimate comes with a confidence score out of a scale of 10 (i.e., 10 being highly confident), which correlates to the before uncertainty factor. Hence, a lower confidence score would indicate a higher degree of uncertainty (Bloomberg, 2022c). Nevertheless, as mentioned earlier, a low confidence score would also mean that the estimates are rather overestimated than underestimated. Overall, most of the companies within the data set in this paper had a confidence score above 7 (see *Appendix 1*).

The estimates are a massive improvement in terms of transparency. This achievement was also praised by the *A-Team Innovation Awards 2022*, where Bloomberg's ESG Regulatory Data solutions won the *Most Innovative ESG Data Provider* award in March 2022 (A-Team Insight, 2022). Hence, a revolutionary act within the ESG data world that brings light to the reporting gap and the flaws of current regulations or directives with the intention of bringing the ball running and enforcing a change in today's investment world.

# 3 Literature Review

## 3.1 Theoretical Literature Review

The following section will cover the theoretical literature review concerning the Efficient Market Hypothesis, the Risk Premium, and the Risk Premium in the Equilibrium Model.

### 3.1.1 The Efficient Market Hypothesis (EMH)

The Efficient Market Hypothesis (EMH) is one of the most cited theories within financial research and was created by Paul A. Samuelson and Eugene F. Fama in the 1960s (Lo, 2008). Essentially, the EMH means that in an ideal world without market frictions or trading costs and rational investors, the equilibrium price must always fully reflect all available information instantaneously (Lo, 2008). Hence, past and present knowledge and anticipated predictions of the future are reflected in the asset price (Fama, 1961). EMH also assumes that with no uncertainties, a stock's present value of all future dividends, discounted with the appropriate discount rate, equals the market stock price (Lo, 2008). Therefore, in the case of an unanticipated event, the new information is immediately incorporated into the asset price when considering semi-strong market-efficiency. If markets are efficient in the strong form, investment opportunities will be very difficult to identify, as under- or overvaluation of an asset does not exist due to the asset price being equal to the asset's fundamental value (Fama, 1961). Also, an arbitrage opportunity does not exist in a-strong efficient market (Lo, 2008).

Even though EMH is the core of many theories and future research, economists have not yet come to a consensus, and some even consider it controversial. For example, Grossman and Stiglitz (1980) argue that EMH is an economically unrealizable idealization in a frictionless world, yet this impractical hypothesis can become of use in computing relative efficiency (Grossman & Stiglitz, 1980; Lo, 2008). On this idea, much further research evolved; an example would be the infamous evolutionary game theory developed by Friedman (1991). In 1999, Farme and Lo connected the EHM with behavioral finance, meaning that "markets, instruments, institutions, and investors interact and evolve dynamically". This view is called the Adaptive Markets Hypothesis (AMH) (Farmer & Lo, 1999).

### 3.1.2 Risk Premium

The equity risk premium - the core of modern financial theory - is a concept that has shaped many finance theories. This section will mention the Revolution of the Risk Premium, the Definition of the Risk Premium, and Risk Premium in a Context of Market Imperfections.

**Evolution of the Risk Premium**

John Stuart Mill published 1848 one of the essential books in early economic history called *Principle of Political Economy and* described the concept of a risk premium as the "value of the risk" of an investment (Goetzmann & Ibbotson, 2005). Nevertheless, this idea was not progressed as quickly as someone might expect. During the early 20th century, various macroeconomists started to create stock price indexes. Nevertheless, they looked at daily market activities instead of researching the long-term investment performance as returns (Goetzmann & Ibbotson, 2005). Only in 1924, Edgar Lawrence Smith is considered the first person to look at equity investments to attain higher returns by defining an early measure of equity premium (Goetzmann & Ibbotson, 2005). Smith's book was an inspiration for many following research publications, such as by Alfred Cowles III in 1938 called *Common Stoch Indices* (Goetzmann & Ibbotson, 2005). Finally, Williams J. B. (1938) explicitly defined, modeled, and estimated the equity risk premium in his book *The Theory of Investment Value*.

Major milestones shaped the period from the 1950s to the 1960s within the research of the risk premium. Harry Markowitz released his infamous *Markowitz Mode*l creating the *Modern Portfolio Theory* in 1952 and defines the equity risk premium as the "difference between the return of the riskless asset and the expected return of the tangency portfolio" (Goetzmann & Ibbotson, 2006, p. 30). In 1964, economists Lawrence Fisher and James H. Lorie started systematically analyzing US stock prices and dividends in their study *Rates of Return on Investments in Common Stocks* (Fisher & Lorie, 1964). In the 1960s, the *Capital Asset Pricing Model (CAPM)* was independently created by William F. Sharpe (1964), Jack L. Treynor (1962), John Lintner (1965), and Han Mossin (1966) in order to find the Markowitz's optimal portfolio of risky assets (Perold, 2004). The Markowitz Model and the CAPM create the foundation to calculate the risk premium (Goetzmann & Ibbotson, 2005). Nevertheless, it took around 20 more years until Mehra and Prescot (1985) looked at excess returns between the historical US returns and the risk-free rate that defined the risk premium in the publication known as the *Equity Premium Puzzle* (Goetzmann & Ibbotson, 2005).

**Definition of the Risk Premium**

The Market Risk Premium is the difference between the expected market portfolio return and the risk-free rate. The simple definition of the market risk premium can be annotated as the following (Berk & DeMarzo, 2019):

$$Market\ Risk\ Premium\ = E(R_m) - r_f \tag{1}$$

Where:

$E(R_m) = expected\ market\ return$
$r_f = risk\ free\ rate$

Moreover, the Equity Risk Premium measures the "financial compensation asked by investors for bearing systematic risk," where "financial and macroeconomic variables" influence systematic risk in comparison to holding a risk-free asset (Gagliardini et al., 2016, p. 985). The investment can range from a single stock to a portfolio of stocks for which the risk premium is calculated. Hereby, firstly, CAPM is needed (Sharpe, 1964):

$$E(R_i) = r_f + \beta_i \times (E(R_m) - r_f) \tag{2}$$

Where:

$E(R_i) =\ expected\ return\ of\ investment$

$r_f = risk\ free\ rate$

$\beta_i = beta\ of\ the\ investment\ (systematic\ risk)$

$(E(R_m) - r_f) = market\ risk\ premium$

In order to solve for the risk premium of the investment, CAPM needs to be rearranged to the following equation:

$$Equity\ Risk\ Premium\ = E(R_i) - r_f = \beta_i \times (E(R_m) - r_f) \tag{3}$$

A negative risk premium indicates that investors accept an additional pricing factor to hedge for systematic risk (Alessi et al., 2019). Also, this would mean that a risk-free government bond generates a higher return (Voss, 2011). On the contrary, a positive risk premium designates that investors expect higher compensation for the additional risk (Alessi et al., 2019).

Within this paper, the *Capital Asset Pricing Model (CAPM)* (Sharpe, 1964; Treynor, 1962; Lintner, 1965; Mossin, 1966), the *Fama-French 3 Factor Model* (Fama & French, 1993), and the *Carhart 4 Factor Model* (Carhart, 1997) will be used as the empirical models to estimate the Risk Premium. In *section 5.2* the models will be discussed in more detail.

### 3.1.3 Risk Premium & the Equilibrium Model in a Sustainability Context

The concept of supply and demand determining the price is one of the most fundamental concepts in economics. In a general equilibrium theory, the interplay of supply and demand will direct an overall general equilibrium (where supply and demand are equal). On the contrary, the partial equilibrium only analysis a single market while every other factor is kept constant (Lai & Ben, 2002).

Whenever there is a change in supply or demand, a new equilibrium is created. Hence, the old price will either suffer from a shortage or have a surplus, forcing the price to be adjusted until the new equilibrium is reached (Lai & Ben, 2002). Within the concept of green versus brown stocks, agents can have different tastes with multiple dimensions for green assets. For example, agents can care about the utility of holding green stocks over brown stocks, firms' social impact, climate risk, or financial wealth (Pástor et al., 2021). Therefore, the agent's willingness to pay for green stocks is higher, which also means it lowers the firm's cost of capital (Pástor et al., 2021). This taste can impact asset price, as a higher taste would make investors accept lower compensation for green stocks. Hence this negative premium (also called *Greenium*) means that investors are willing to accept lower future returns to satisfy their taste for green stocks, such as hedging for environmental risk (Pástor et al., 2021). Here, brown stocks are riskier, and investors demand higher compensation, whereas green stocks are considered less risky and yield lower expected returns. Therefore, brown stocks outperform green stocks over a more extended period, and a negative risk premium is on average recorded for green stocks in contrast to brown stocks (Pástor et al., 2021). This is because investors with a higher taste for green assets usually have a portfolio consisting of more green than brown stocks and thus, ultimately earn lower expected returns. The investors willingly accept this lower compensation as they compensate for the lower returns with the utility they derive from holding the green stocks (Pástor et al., 2021).

On the contrary, if ESG concerns or climate shocks increase rapidly, agents' tastes and also demand for green stocks increase rapidly. This demand is strengthened by non-ESG taste investors that suddenly create an ESG taste (Pástor et al., 2021). Therefore, the overall demand for green stocks increases rapidly, allowing for green stocks to outperform brown stocks by hurting brown stocks' payoffs. ESG tasted investors will now find a surplus, meaning that the return they had to give up for holding such green assets diminishes; hence the negative risk premium decreases. Whereas now, non-tasted ESG investors investing in green stocks will earn a positive risk premium (Pástor et al., 2021). Hence, overall a reduction of the negative risk premium or even a positive risk premium can be recorded for green stocks compared to brown stocks. However, this depends on the size of the shock; thus, assuming the brown stocks' value drops more than the green stocks' value increases during that transitional period towards a new equilibrium. It also depends on the new demand created by investors with less holdings in green assets that develop ESG taste and decrease their brown taste (Pástor et al., 2021). Nevertheless, eventually, the equilibrium asset prices will adjust to the new level of ESG-tasting investors, and again a negative premium will be recorded (Pástor et al., 2021). The results of a positive premium have usually been found within a short period under investigation. In more extended periods under investigation, the investor's different tastes usually average out to zero and, therefore, do not lead to a positive risk premium (Pástor et al., 2021). In conclusion, the change to a different equilibrium dimension through a rapid increase in demand can potentially explain a positive risk premium on green assets over brown assets.

## 3.2 Empirical Literature Review

Early research on s*ustainability* investigated the connection between sustainability activities and corporate performance. For example, Bragdon and Marlin (1972) found that firms that participate in environmental activities will generate additional costs and, therefore, lower their overall profit. However, within the 1990s, Porter (1991), Gore (1993), and Porter and van der Linde (1995) all found independent evidence that companies that participate in improving environmental-related activities will record better financial performances, such as operating income. Also, they emphasize that sustainability activities do not always lead to an increase in costs (Alessi, 2019). Furthermore, a summary review of various studies by Ambed and Lanoie (2008) reveals that enhancements in environmental activities are mostly connected with better financial performance allowing for revenue increases and cost decreases. One more recent study by Hoepner et al. (2018) found evidence that ESG issues benefit shareholders' by lowering a firm's downside risk by looking at institutional investors with more than $200 billion in assets under advisement.

As GHG reporting has increased, so have empirical papers about climate risk. A study in 2014 on S&P 500 stocks (2006 to 2008) by Matsumura, Prakash, and Vera-Munoz (2014) showed that higher voluntary CO2 disclosures and lower firm value are closely related. Nevertheless, only companies that have voluntarily disclosed CO2 emissions were considered, so the study is slightly biased (Matsumura et al., 2014). In 2017, Bansal et al. proposed a long-rung risk model that includes temperature, economic growth, and risk factors on the US and global capital markets. By assessing the *Social Cost of Carbon (SCC)*, they found that SCC will grow enormously with increasing temperature, estimating the economic climate risk and its long-term impact. As a final recommendation, Bansal et al. (2017) strongly motivate climate policies for early actions. In 2016, Andersson et al. developed a carbon risk hedging strategy with low carbon emission company indexes. Climate-related risks have become more critical in recent years. Krueger et al. (2020), who surveyed institutional investors, clearly show that institutional investors believe carbon emissions are a substantial risk.

Even though vast advancements of new evidence in the empirical research of sustainability have been made, as well as an increase in available ESG data has been recorded. Yet, no final consensus has been derived within the asset pricing literature about green assets' performance and climate risk being priced (Alessi et al., 2021).

On the one hand, most studies show that green assets, on average, underperform the market and, therefore, suggest that investors are willing to accept lower expected returns to minimize climate risk by hedging a long-run environmental risk (Alessi et al., 2021). In 2007, Fama and French found evidence that the following two assumptions of the standard asset pricing models are unrealistic: (1) investors agree on probability distributions of future payoffs, and (2) assets are chosen only on the expected payoff. They suggest that investors' taste for green assets can affect the asset price by using equilibrium arguments (Fama & French, 2007). Hong and Kacperczyk (2009) analyzed "sin" stocks (i.e., public stocks producing alcohol, tobacco, and gaming) in the US and large markets in Europe and Canada that can be classified as brown. Their study shows that sin stocks outperform non-sin stocks and explains this through social norms that force investors to ask for compensation for holding sin stocks (Hong & Kacperczyk, 2009). Further, El Ghoul et al. (2011) and Chava (2014) found evidence for a lower cost of capital in green companies due to investors' ESG tastes. Both looked at US companies during the 1990s and early 2000s. In 2018, Baker et al. looked at 19 US green bonds from 2014 to

2016. They found that the green bonds market suffers from lower expected returns and is characterized by a higher ownership concentration. Baker et al. (2018) also argue that investors' environmental concerns are the drive for such a premium. Zerbib (2019) derived a similar conclusion on the US and European bond markets. In 2019, Allessi, Ossola & Panzica found a negative premium for green and transparent European stocks by creating a greenness and transparency factor. This factor was based on the GHG emission and ESG quality disclosure. They looked at a sample from 2006 to 2018, representing 95% of the *STOXX Europe Total Market Index (TMI)* (Alessi et al., 2019). Similarly, Hsu et al. (2021) found a pollution premium on US stock returns (2005 - 2017); hence high polluting firms are riskier and therefore ask for higher returns. Moreover, Hong et al. (2019) looked specifically at food producers' stocks by analyzing the effect of climate risk in terms of droughts. Hence, food producer companies in countries that will face droughts as a climate risk will also face poor stock returns. Their sample included 31 countries with 910 stocks from 1985 to 2014. Barber et al. (2021) saw that social impact venture capital (VC) funds earn 4.7 percentage points lower IRRs than traditional funds. They say that the obtained nonpecuniary utility for investors by holding dual-objective funds explains such underperformance. Furthermore, both Engle et al. (2020) and Choi et al. (2020) contribute by showing evidence that brown assets' climate betas are higher than green assets'. Hence, they show that their expected returns are higher as a result of riskier brown assets. Furthermore, Bolton and Kacperczyk (2021) investigate US stock returns and total carbon dioxide emissions. They found that high CO2 emission companies generate higher returns and therefore conclude that investors ask for compensation for carbon emission risk in the form of higher returns for high carbon-producing companies.

On the other hand, studies showing green assets outperforming brown ones are less common. Neverthelless, Kempf & Osthoff (2007) found that firms perform better if they have higher ESG ratings. They looked at the period 1992 - 2004 on the US stock market. Nofsinger and Varma (2014) found that socially responsible mutual funds outperformed during market crises when looking at the overall period 2000-2011. Moreover, Hatzmark and Sussman (2019) argue that sustainability is a positive predictor of the performance of US mutual funds. However, no evidence was found that high-sustainability funds outperform low-sustainability funds. Görgen et al. (2020) tried to quantify the carbon risk that results in higher compensation when investing in brown firms. However, they were unable to confirm the presence of such a carbon risk premium when looking at global stocks from 2010 to 2017. Hence, they found that brown firms were, on average, outperforming green firms over the total period by around 14%, but also noted that the period 2010 to 2012 strongly showed the opposite. They concluded by explaining that the transition toward a low carbon economy is in progress, and therefore the new equilibrium has not yet been reached. Several studies have found mixed evidence when looking at sustainable investment funds' performances while comparing them to peers. Such studies are Statman (2000), Renneboog et al. (2007) or Seitz (2010) (Alessi et al., 2021).

Despite the differences in the research, several studies have been published concentrating on climate risk hedging portfolios. This research area would also include the before-mentioned literature by Hong et al. (2019), Choi et al. (2020), Engle et al. (2020), and Görgen et al. (2020). Additionally, Alok et al. (2020) look at the overreaction of large climate disasters on funds. Monasterolo and De Angelis (2020) created low-carbon and high-carbon indices for the EU, US, and global markets and investigated the Paris Agreement's effect. They found that the correlation between the two indices decreases after the Paris Agreement. They conclude that low-carbon assets are still attractive investments after the Paris Agreement, even though no carbon penalization has happened.

Lastly, several studies have tried to quantify the risk premium by creating specific stress test scenarios. In 2015, central banks and international institutions raised awareness by stating that climate change could affect systematic risk (Alessi et al., 2021). Gros et al. (2016) suggest there can be financial stability consequences in both cases, (1) in a gradual transition and (2) in an abrupt transition to a low-carbon economy. Significantly, an abrupt transition would mean an immediate repricing of brown assets. In contrast, a gradual would indicate that the Paris Agreement would be unable to fulfill and result in other environmental and financial problems (Gros et al., 2016). Furthermore, only in 2017 did Battiston et al. (2017) start to stress-test the exposure of climate risk on financial institutions. They conclude that the timing of climate policies matters and urge for an early and stable policy framework allowing for smooth value adjustments. Monasterolo et al. (2018) stress-tested climate consequences on the loan portfolio of Chinese policy banks. They concluded that due to the current leverage on Chinese policy banks, the losses could create severe financial distress in a scenario where the 2°C climate policies were not to be fulfilled. Finally, Alessi et al. (2019) report shows a climate stress-test scenario where green and transparent stocks outperform browns by a lot. Therefore, indicating that there could be losses at the global level if investors would fail in pricing climate-transition risks. Hence, they urge the need for climate stress tests for systemically important financial institutions.

To the authors' knowledge, this is the first paper that uses the Bloomberg GHG Emission Estimates to determine green and brown portfolios. Hence, it can be argued that such an accurate measure of a stock's greenness might impact the results and differ from past studies that had to estimate a stock's green with various other tools.

## 3.3 Hypothesis Development

According to the literature mentioned above, a negative risk premium would be reasonable to expect in the European market. However, as demonstrated in detail, the year 2021 was deeply concerned with introducing many new futures regulative measures concentrating on non-financial reporting, especially on GHG emissions. Moreover, this will bring new consequences and actual cash flow disadvantages for companies who will not comply with the law or cannot reduce their GHG emissions as aspired. Additionally, some national disasters or recent publications of new UN reports about climate risk intensified the whole topic of climate change.

Hence, with such an increase in relevancy, it can be assumed that the risk of climate change has been more present than ever in 2021. Therefore, it would be reasonable to expect a certain degree of shift in demand for green stocks. Hence, this raises the question of how much the negative risk premium is impacted, indicating that it could lead to temporary mispricing of climate risk. Consequently, this leads to the following null hypothesis $H_0$ and alternative hypothesis $H_1$ stated:

$H_0$=There is no significant risk premium on the European market for green stocks
$H_1$=There is a significant risk premium on the European market for green stocks

# 4 Data and Sample Description

First, a sample of the *STOXX All Europe Total Market Index (TMI),* consisting of European mega to small market cap companies from Western and Eastern Europe regions, was retrieved from Bloomberg. The *STOXX All Europe (TMI)*, represent around 95% of the free float market capitalization of European companies (Stoxx.com, n.d.) The sample was then subject to data removal. In accordance with Alessi et al. (2021a), companies with fewer than 500 employees are deleted from the sample as these companies fall below the threshold of EU environmental reporting regulation (European Commission, 2022d). Additionally, companies whose main activities concern the *NACE Sectors K and L: Financial and Insurance Activities, and Real Estate Activities*, were deleted in line with Fama and French (2008). Additionally, the sampling also included a few Russian stocks. However, these stocks were at risk of being strongly impacted by the current geopolitical developments with Russia's invasion of Ukraine and the EU's counteractions of introducing new sanctions. Additionally, Russia's non-financial reporting standards a far away from the overall non-financial reporting developments in Europe as can be seen in *section 2.3.3*. For these reasons, Russian companies were not included in the sample. For further information see *Appendix 2* to *Appendix 4*.

## 4.1 Summary Statistics

*Table 1* presents the summary statistics based on the final sample of stocks, consisting of 1,602 companies covering 261 days, which results in 402,112 observations. First, the excess return is winsorized at a 99%-level as severe outliers were detected and could potentially affect the results. With a maximum excess return of 6.99%, a minimum of -5.90%, and a standard deviation of 2.08%, the winsorized variable now suggest no extreme outliers anymore. Furthermore, the average stock has a daily excess return of 0.57% and the median firm 0.56%. As the mean and median are almost identical, it would suggest the observations are centered around the mean. This can be confirmed by the histogram to the variable (see *Appendix 5*). The histogram indicates that the variable appears relatively normally distributed, however, the sample suffers a bit of excess kurtosis with slightly larger tails to the ends.

Considering the model factors, who are defined in more detail in *section 5*, during the studied time series the market factor ($f_{MkRf}$) is on average 0.022%, the size factor ($f_{SMB}$) is on average -0.030%, high-minus-low factor ($f_{HML}$) 0.048%, the momentum factor ($f_{MOM}$) 0.023% and the greenness factor ($f_G$) -0.02%. Regarding the greenness factor, it means that on average the daily return on the green portfolio is lower than the brown portfolio by 0.02%. Additionally, the histogram of the greenness factor is presented in the *Appendix 5*. It appears somewhat normally distributed; however, gaps are noted within the distribution. As the mean is lower than median (-0.02%<0.04%), it would suggest left-side skewness. The greenness factor is concluded not be winsorized as it would appear less normally distributed.

*Table 1: Summary Statistics*

| Index | | Mean | Median | Max | Min | SD | Obs |
|---|---|---|---|---|---|---|---|
| Index | $\tilde{R}_I$ | 0.0057 | 0.0056 | 0.0699 | -0.0590 | 0.0208 | 402,112 |

| Factor | Mean | Median | Max | Min | SD |
|---|---|---|---|---|---|
| $f_{MkRf}$ | 0.0222 | 0.1100 | 3.6600 | -3.6500 | 0.9630 |
| $f_{SMB}$ | -0.0308 | -0.0300 | 1.3900 | -0.8900 | 0.3524 |
| $f_{HML}$ | 0.0485 | -0.0300 | 2.3600 | -2.7800 | 0.7643 |
| $f_{MOM}$ | 0.0225 | 0.0300 | 1.5100 | -2.0500 | 0.5913 |
| $f_G$ | -0.0002 | 0.0004 | 0.0098 | -0.0154 | 0.0052 |

*Note: This Table provides a statistical summary of the final sample characteristics that includes 1,602 European companies of mega, large, mid, and small market capitalization of the STOXX All Europe Total Market Index (TMI), after the real estate sector and the banking sector have been dropped from the sample. This sample's variable, excess returns, was winsorized at 99%. The summary statistic for the Index $\tilde{R}_I$, is in absolute numbers and require multiplying by 100 to write in %. The factors are already stated in %.*

## 4.2 Correlation and Multicollinearity

*Table 2* presents the correlation table for the different explanatory variables as well as the returns on the index. The greenness factor, $f_G$, is mainly correlated with the market factor, $f_{MkRf}$, with a positive correlation of 0.411, meaning that 41.1% of the sample variation of the difference between the green and brown portfolio, can be explained by the return on the European market portfolio. Additionally, the greenness factor is relatively negatively correlated with $f_{HML}$, at -0.409. Moving along to the issue of multicollinearity, which Wooldridge (2012) defines as when the correlation between at least two independent variables is close to 1, it can be said that when considering the sample, multicollinearity not considered an issue as no independent variables have a correlation close to 1. The largest correlation between the independent variables would be between the momentum factor and the market factor at 0.581. Multicollinearity is further investigated in the cross-section between the different stocks.

*Table 2: Correlation Table*

| Factor \| Index | Index $\tilde{R}_I$ | $f_{MkRf}$ | $f_{SMB}$ | $f_{HML}$ | $f_{MOM}$ | $f_G$ |
|---|---|---|---|---|---|---|
| Index $\tilde{R}_I$ | 1 | | | | | |
| $f_{MkRf}$ | 0.083 | 1 | | | | |
| $f_{SMB}$ | 0.026 | -0.100 | 1 | | | |
| $f_{HML}$ | -0.013 | -0.161 | -0.432 | 1 | | |
| $f_{MOM}$ | 0.048 | 0.581 | 0.125 | -0.227 | 1 | |
| $f_G$ | 0.011 | 0.411 | -0.076 | -0.409 | 0.267 | 1 |

*Note: On the left, the table shows the correlations between the individual factors from the Linear Factor Models and the excess returns of the final sampled index. On the right, the correlations between each of the factors of the Linear Factor Models are displayed.*

Moreover, Gagliardini et al. (2016) suggest two trimming conditions, which will remove separate assets from the sample of stocks. The first one can be defined by the following formula:

$$Conditional\ Number = \sqrt{\mu_1(\hat{Q}_{x,i})/\mu_d(\hat{Q}_{x,i}) \leq x_{i,T}} \quad (4)$$

With this, $\mu_1$ represents the largest eigenvalue of the matrix $\hat{Q}_{x,i}$ and $\mu_d$ the smallest eigenvalue of the matrix $\hat{Q}_{x,i}$. While referring to Belsley et al. (2004), Greene (2008), and Gagliardini et al. (2016), a too large a value of the conditional number can indicate that the model is badly conditioned and the existence of multicollinearity. Gagliardini et al. (2016) follow the suggestion of Greene (2008) with a maximal value for $x_{i,T}$ at 15. The factor structure for each stock is tested utilizing the user-written command *collin.* In *Appendix 6* the result for one of the sample stocks is presented. This procedure has resulted in one stock being deleted from the sample. The second condition means that stocks with a too short time period are deleted. In line with Bai and Ng (2002), this threshold is set equal to 60. Therefore, in this sample two more stocks have been removed. Consequently, the final sample consists of 1602 individual stocks.

Furthermore, an issue present in time-series data is potential autocorrelation, where the error terms are correlated with each other across time. Thus, causing the assumption of independent observations to no longer hold (Wooldridge, 2012). However, as Fama (1988) means that a time-series holding period based on daily (and weekly) stock returns experience weak autocorrelation, this is assumed to not cause issues.

# 5 Methodology

First, the methodology of this study is rooted in the methodology of Alessi et al. (2021), which further based their methodology on Gagliardini et al. (2016) and Gagliardini et al. (2019). Their procedure also partly follows Fama & Macbeth (1973). The following section is structured in four different subsections. Firstly, the methodology for creating the portfolio is specified. Secondly, the linear factor models are specified. In the third subsection, the risk premiums are calculated. Lastly, some methodology criticisms are discussed.

## 5.1 Greenness Factor

In line with Alessi et al. (2021), a factor for greenness is created based on the difference between a more environmentally friendly (green) portfolio and a less environmentally friendly (brown) portfolio. Alessi et al. (2021) point out that studies regarding portfolio building mainly base the distribution on different percentiles. They further emphasize that it is a trade-off between capturing the most different companies regarding the specific matter of interest yet ensuring an adequate sample size. As there is no explicit choice of percentile in the asset pricing literature, portfolios are built using the top and bottom quintile (Alessi et al, 2021). Additionally, as Alessi et al. (2021), robustness checks are carried out using the top and bottom deciles as well as terciles.

In order to capture the most and least environmentally friendly companies, the sample of companies defined in *section 4* is ranked based on their GHG intensity. GHG intensity is calculated as the following:

$$GHG\ Intensity = (Total\ Estimated\ GHG * 1000)/Revenue \qquad (5)$$

Where total estimated GHG includes emission related to both Scope 1 and Scope 2 estimates by Bloomberg, measured in thousands of tons. In order to normalize GHG estimates, the more frequent appearing method of dividing by revenue was selected. However, other literature also has used total assets. Regarding the unusual macroeconomic impacts of the coronavirus pandemic, the authors believe the use of revenue to normalize the GHG estimates is more appropriate in hindsight of the alignment of lower GHG emissions due to lower operating capacity and hence, lower resulting revenue.

As mentioned earlier, when the green and brown portfolios are constructed, the return of the green portfolio ($r_t^G$), is then subtracted by return on the brown portfolio ($r_t^B$). The return on the green and the brown portfolio are defined as follows:

$$r_t^G = \sum_{i \in G} w_{i,t} r_{i,t} \text{ , } and\ r_t^B = \sum_{i \in B} w_i r_{i,t} \tag{6}$$

Where $w_i$ is defined as the value of the weight of stock *i* at day *t* related to the excess return of stock *i* at day *t.* The calculation of the excess return is defined in *section 5.2*. The return is weighted by the market capitalization value of stock *i* at day *t* divided by the total market capitalization at day *t.* In other words:

$$w_i = MC_{i,t}/\Sigma_t MC_{i,t} \tag{7}$$

## 5.2 Linear Factor Models

First, the relationship between the excess return and the factors can be described as follows:

$$R_{i,t} = \alpha_i + \sum_{k=1}^{K} b_{i,k} f_{t,k} + \varepsilon_{i,t} \tag{8}$$

$R_{i,t}$, being the excess return for stock *i* at day *t*, $\alpha_i$ the constant for stock *i,* $b_{i,k}$ being the coefficient related to stock *i* and factor *k,* $f_{t,k}$ being factor *k* at day *t* and lastly $\varepsilon_{i,t}$ being defined as the error term for stock *i* at day *t.* Moreover, the excess return is calculated as the natural logarithm of the daily return for stock *i* subtracted by the risk-free rate:

$$R_{i,t} = LN\left(\frac{r_{i,t}}{r_{i,t-1}}\right) - r_{f,t} \tag{9}$$

The risk-free rate is proxied by applying the daily EURIBOR 1 month rate, which is retrieved from the Bank of Finland (Euribor rates, daily values, 2022).

Furthermore, three linear factor models are defined where the greenness factor defined previously is included. Similar as in Alessi et al. (2021), the CAPM, Fama French Three-Factor Model, and Carhart Four-Factor Model are applied as baseline models. The data is retrieved from Kenneth R. French's website (French, n.d). Considering the baseline models, four different factors are thus used.

As defined by French (n.d), the market factor $\boldsymbol{f}_{\text{MkRf}}$ is as the value-weighted excess return on a portfolio consisting of European stocks, where the risk-free rate is proxied by government bonds. Moreover, Small-Minus-Big (SMB), $\boldsymbol{f}_{\text{SMB}}$, is specified as the average return of portfolios consisting of small companies subtracted by the average return on portfolios including large companies. Regarding High-Minus-Low (HML), $\boldsymbol{f}_{\text{HML}}$, it is defined as the average return on value portfolios subtracted by the average return on growth portfolios (French, n.d). With value portfolios, consisting of stocks with a smaller market-to-book value, whereas growth portfolios with the opposite (Alessi et al., 2021). Lastly, the momentum factor, $\boldsymbol{f}_{\text{MOM}}$, is estimated as the average return on portfolios that previously have earned high returns subtracted by the average return on portfolios that previously earned low returns (French, n.d). The different models are summarized in Table 3. For further information about the summary statistics of the portfolios and the linear factors as well a summary table of the correlations refer to *Appendix 7* to *Appendix 9*.

*Table 3: Summary of Linear Factor Models*

| Baseline Model | Number of Factors | Factors | Reference |
|---|---|---|---|
| Capital Asset Pricing Model | 2 | $\boldsymbol{f}_{\text{MkRf}}$, $\boldsymbol{f}_{\text{G}}$ | Sharpe (1964); Lintner (1965) |
| Fama-French Model | 4 | $\boldsymbol{f}_{\text{MkRf}}$, $\boldsymbol{f}_{\text{SMB}}$, $\boldsymbol{f}_{\text{HML}}$, $\boldsymbol{f}_{\text{G}}$ | Fama and French (1993) |
| Carhart Model | 5 | $\boldsymbol{f}_{\text{MkRf}}$, $\boldsymbol{f}_{\text{SMB}}$, $\boldsymbol{f}_{\text{HML}}$, $\boldsymbol{f}_{\text{MOM}}$, $\boldsymbol{f}_{\text{G}}$ | Carhart (1997) |

*Note: This Table provides an overview of the different Linear Factor Models used. Hereby, the $\boldsymbol{f}_{\text{MkRf}}$ represents the market factor, the $\boldsymbol{f}_{\text{SMB}}$ the size factor, the $\boldsymbol{f}_{\text{HML}}$ the value factor, the $\boldsymbol{f}_{\text{MOM}}$ the momentum factor, and the $\boldsymbol{f}_{\text{G}}$ the greenness factor.*

### 5.2.1 Portfolio Return

*Table 4* illustrates the different linear factor models regressed based on the green and brown portfolio returns respectively. Across the different models, the coefficients appear stable throughout the respective portfolios, suggesting the model is correctly specified. However, the brown portfolio has a notably smaller R-squared in comparison to the green portfolio.

*Table 4: Summary Table of Linear Factor Models for the Green & Brown Portfolios*

| Portfolio | Green $\tilde{R}_G$ | Brown $\tilde{R}_B$ |
|---|---|---|
| **CAPM Model (1 factor)** | | |
| $\alpha$ | 0.0060*** | 0.0064*** |
| $\beta_{MkRf}$ | 0.0033*** | 0.0012*** |
| $R^2_{adj}$ | 0.463 | 0.052 |
| **Fama-French Model (3 factors)** | | |
| $\alpha$ | 0.0061*** | 0.0063*** |
| $\beta_{MkRf}$ | 0.0029*** | 0.0015*** |
| $\beta_{SMB}$ | -0.0025*** | 0.0013 |
| $\beta_{HML}$ | -0.0021*** | 0.0019*** |
| $R^2_{adj}$ | 0.540 | 0.106[1] |
| **Carhart Model (4 factors)** | | |
| $\alpha$ | 0.0060*** | 0.0063*** |
| $\beta_{MkRf}$ | 0.0028*** | 0.0016*** |
| $\beta_{SMB}$ | -0.0026*** | 0.0015* |
| $\beta_{HML}$ | -0.0020*** | 0.0018*** |
| $\beta_{MOM}$ | 0.0004 | -0.0006 |
| $R^2_{adj}$ | 0.541 | 0.110[1] |

*[1] These regressions do show R2 (instead of R2adj) as robust standard errors were used. All other regressions do not use robust standard errors as the heteroskedasticity test is >0.005.*

*Note: This Table provides shows the summary of the outcome of all three Linear Factor Models, the estimates on portfolio excess returns for the green and brown portfolio. The coefficients are already stated in %. Statistically significant outcomes are annotated by the following: *** (p<0.001), **(p<0.05), and *(p<0.1).*

As in Alessi et al. (2021), the coefficients for the market factor $\beta_{MkRf}$ are all positively significant, the coefficient $\beta_{SMB}$ is negatively significant for the green portfolio and positive for the brown (however, only significant in the four-factor-model) and the momentum factor $\beta_{MOM}$ is found to be insignificant for both the green and brown portfolios. Regarding the value factor, the coefficient $\beta_{HML}$, is significantly positively correlated for the brown portfolios, while it is significantly negative for the green portfolio.

Looking at the coefficient for the market factor, the green portfolio correlates more than the brown with the market index $\beta_{MkRf}$. About the size factor $\beta_{SMB}$, the results indicate that the greener portfolio is more correlated with larger firms as the coefficient is negative, as opposed to the brown portfolio, correlating with firms of the smaller size (note only 10% significant in the Carhart model). Moreover, as the coefficient $\boldsymbol{\beta}_{\mathrm{HML}}$ is negative, the greener portfolio correlates more with stocks with a higher market-to-book ratio, while the brown portfolio does the opposite. While insignificant, the momentum factor $\boldsymbol{\beta}_{\mathrm{MOM}}$, indicates that the green portfolio correlates more with the winning portfolio, while the browner portfolio is negatively correlated.

## 5.3 Risk Premium

By utilizing the final sample of stocks defined in *section 4,* cross-sectional regressions are performed on unbalanced panel data in order to estimate and test the risk premium.

### 5.3.1 Cross-Sectional Regression

First, as in Fama & Macbeth (1973), the constant $\alpha_i$ and coefficients $\beta_{i,k}$ related to each particular stock are estimated cross-sectionally using the OLS estimator. Thus, the stocks are separately regressed based on the different linear factor models defined in Table 3 with the winsorized excess return as a dependent variable. In Stata, this procedure is carried out with the user-written command, *asreg*. The following equation can explain the procedure:

$$\begin{aligned} R_{1,t} &= \alpha_1 + \beta_{1,F_1}F_{1,t}\ldots+\beta_{1,F_K}F_{K,t} + \varepsilon_{1,t} \\ R_{2,t} &= \alpha_2 + \beta_{2,F_1}F_{1,t}\ldots+\beta_{2,F_K}F_{K,t} + \varepsilon_{2,t} \\ &\vdots \end{aligned} \tag{10}$$

### 5.3.2 Cross-Sectional Estimator

First, the calculation of the risk premium is based on the following equation.

$$\lambda_k = E\left[f_{t,k}\right] + v_k \tag{11}$$

Where $\lambda_k$ stands for the risk premium related to the $k^{\text{th}}$ factor, $E\left[f_{t,k}\right]$ being the expected excess return for the $k^{\text{th}}$ factor at time $t$. And lastly, $v_k$, being the cross-sectional estimator related to the $k^{\text{th}}$ factor. Moreover, if the different factors, $f_k$, are assumed to be tradeable, the cross-sectional estimator is zero. By allowing the factors to be non-tradeable and the cross-sectional estimator to be non-zero, it allows for the existence of market frictions such as transaction costs and short-selling, which are reflected by $v_k$ (Alessi et al., 2021). In relation to the greenness factor, Alessi et al. (2021, p.8) further hypothesize that the value of the cross-sectional estimator could capture different anticipations of "the future state of the economy", which they argue could be more important in terms of green and brown assets.

In line with Gagliardini et al. (2016), the computation of the cross-sectional estimator $v_k$ can be illustrated by equation 12, where the constant related to stock $i$ is regressed on the coefficients or betas stock *i* related to the *k*th factor. To clarify, these constants and coefficients were estimated in the previous section.

$$\alpha_i = \sum_{k=1}^{K} b_{i,k} v_k \tag{12}$$

The inclusion of the cross-sectional estimator does not impact the size and significance of the coefficients; it only affects the size of the constant.

In line with Gagliardini et al. (2016), a multivariate Weighted Least Squares (WLS) regression is conducted in order to estimate $v_k$. As opposed to OLS, which equally weighs each observation, WLS instead assigns more weight to observations with lower variance in their error terms. Put differently, the WLS estimators are the values that minimize the coefficients, $b_j$, of the following formula that weights the variance (Wooldridge, 2012):

$$\sum_{i=1}^{n} (y_i - b_0 - b_1 x_{i,1} - b_2 x_{i,2} - \ldots - b_k x_{i,k})^2 / h_i \tag{13}$$

Where $h_i$ is based on a function including the independent variables variance (Wooldridge, 2012). WLS can be used in order to adjust for heteroscedastic error terms, meaning that the variance of the error terms that are non-constant, and can be more efficient than OLS if the equation weighting the variance is correctly specified (Wooldridge, 2012).

Moreover, there are different methodologies of weighting the variance such as by absolute value, squared residuals, fitted values, and log of squared residuals (Stata Analysis Tools Weighted Leas Squares Regression, 2021). Gagliardini et al. (2016) proposes squared residuals as the weighting method, which this study also implements. In order to test what explanatory variables to include in the weighting equation, they are first separately tested for heteroskedasticity using the White test. If the p-value <0.005, homoskedasticity is rejected and thus included in the weighting equation. However, Wooldridge (2012) means that when differences between the OLS and WLS are larger, it can suggest misspecification and subsequently the WLS estimator can be biased. The WLS estimators will although likely to be consistent (Wooldridge, 2012). Thus, a robustness check where the $\widehat{v_k}$ is estimated with OLS is presented in *section 8*.

### 5.3.3 Annualized Premium

As mentioned, the risk premium attributable to each factor *k* is calculated as the cross-sectional parameter $\widehat{v_k}$ added to the expected excess return on the factor $E[f_{k,t}]$. In line with Alessi et al. (2021) the model is regressed on its annualized excess return:

For the time-invariant model, the annualized return on stock *i* is then regressed on the different company betas together with the cross-sectional estimator, where $\widehat{b_{i,k}}$ consists of both the cross-sectional estimator added to the betas for stock *i* at for the *k*th factor.

$$Annualized\ Return_i = \alpha_i + \lambda_k \widehat{b_{i,k}} \ldots\ldots + \varepsilon_i \tag{14}$$

Additionally, this model is tested for heteroskedasticity using a White-test. For the main linear factor models, homoskedasticity could be rejected for all of them. Hence, robust standard errors are incorporated. See *Appendix 10* for the results concerning the Carhart model.

## 5.4 Methodology Criticisms

A possible criticism of this study is that it utilizes daily returns instead of monthly returns, as that is the general way of doing it in the studied literature. Aside from less comparability in other studies, another weakness could be that a risk premium on a daily basis could be considered less valuable than, for example, weekly or monthly. However, as this study covers a relatively short time period, it is possible to conduct a study like this as the data would not be too big. Moreover, a strength of utilizing daily returns could be that it means less loss of information. For example, Pham & Phuoc (2020) compare estimations of the CAPM on a short-horizon, based on daily and monthly data, and shows that the estimates based on daily data meant a more precise model, including a higher model fit, smaller alpha, and model error as well as a more minor standard deviation in terms of beta.

Moreover, as our sample includes small, mid, and large market cap companies, and this is only controlled for after the portfolios are formed, it results in a skewed distribution between the green and brown portfolios, which can ultimately affect the study. As robustness, which is presented in *section 7,* a different weighting method was chosen, where the companies were sorted by green or brown first, based on their different market cap positions, in order to ensure homogeneity. Hence, it was more homogenous in this aspect. Furthermore, Alessi et al. (2021) initially only studied large capitalization companies with the motivation of smaller companies having less qualitative environmental reporting, but also conduct a robustness test including both mid and small market cap companies. As the results were still in line with their main results, for this study, it was decided to also include them in the main study, based on the argument that environmental disclosure has improved in relation to the years they covered.

Furthermore, a possible criticism of the methodology of this study is that while we say that we follow the methodology of Alessi et al. (2021), this study does not conduct a diagnostic test constructed by Gagliardini et al. (2019), which Alessi et al. performed. In short, the diagnostic test means that the largest eigenvalue of the residual covariance-matrix is being subtracted by a specific penalty. If the difference is positive, it would suggest that the error terms at least share one omitted factor (Gagliardini et al., 2019). While there were attempts to execute this test, from a time-perspective it was not possible to perform this test.

Moreover, the portfolio selection is solely based on Bloomberg's GHG emissions estimates, which can be considered another criticism. Hence, the impact of transparency, which was included in several previous studies, is not incorporated in the portfolio creation of this paper. This can be considered as a trade-off, as the idea of capturing a more accurate measure of the "real greenness" of the companies was chosen.

Lastly, another criticism of this study, but not directly relating to the methodology, is that much information had to be drawn from news articles covering the current legislative landscapes of different countries. Due to the high relevancy of non-financial reporting in today's fast-paced world, government websites mainly did not indicate current discussions or new regulative proposals. However, in the case of the empirical and theoretical literature, their qualities, the quality of the journals, and the fact that they were peer-reviewed had high priority when conducting the literature review.

# 6 Empirical Results

*Section 6* presents the empirical results of the study. Firstly, the results related to the cross-sectional estimator are presented and then the results for risk premia.

## 6.1 Cross-Sectional Estimator

*Table 5* presents the results for the cross-sectional estimator $\widehat{v_k}$ and the annualized risk premium. As mentioned, the $\widehat{v_k}$ estimated with WLS. First, regarding the cross-sectional estimator, the greenness factor is statistically significant on a 1-% level for all linear factor models. In addition, except for the cross-sectional estimator related to the market factor in the CAPM-model, all estimators are significant on a 1%-level. While Alessi et al. (2021) found a significant negative $\widehat{v_G}$ throughout all linear factor models, for this study, it is only estimated to be negative for both the Carhart and Fama-French Models. An explanation could be that the greenness factor in the CAPM captures different effects related to other omitted variables, such as the ones included in the other two models.

The statistical implication for the cross-sectional estimator is the following, regarding the Carhart model: if the stock's beta increases by 1 unit, the constant alpha on average decreases by the coefficient $\widehat{v_G}$ -0.03%. Concerning its implication from an economical point of view relating to Alessi et al. (2021) hypothesis concerning $\widehat{v_G}$, the results mean that when the systematic risk of the firm, captured by the greenness factor, increases by one-unit, different market imperfections related to greenness are expected to, in general, decrease the excess return by -0.03%.

For the remaining factors available in the other models, they remain consistent regarding sign and significance. The market and the size factor are estimated to have a positive cross-sectional estimator, while the value and momentum factor are estimated to have a negative one. A robustness check for the cross-sectional estimator is presented in *section 8.*

*Table 5: Cross-Sectional Estimator and Risk-Premium.*

| Index $\widetilde{R}_I$ | | | |
|---|---|---|---|
| Risk Premium (OLS) | | Cross-sect. Estimator (WLS) | |
| **CAPM Model (1 factor)** | | | |
| $\hat{\alpha}$ | -5.570*** | $\hat{\alpha}$ | 0.006*** |
| | (-6.540, -4.600) | | (0.006, 0.006) |
| $\hat{\lambda}_{MkRf}$ | -2.648*** | $\hat{\nu}_{MkRf}$ | 0.043** |
| | (-3.015, -2.281) | | (0.003, 0.082) |
| $\hat{\lambda}_{G}$ | 0.023*** | $\hat{\nu}_{G}$ | 0.000*** |
| | (0.019, 0.026) | | (0.000, 0.000) |
| **Fama-French Model (3 factors)** | | | |
| $\hat{\alpha}$ | 3.757*** | $\hat{\alpha}$ | 0.005*** |
| | (3.610, 3.904) | | (0.005, 0.005) |
| $\hat{\lambda}_{MkRf}$ | -0.279 | $\hat{\nu}_{MkRf}$ | 0.040*** |
| | (-0.641, 0.084) | | (0.026, 0.053) |
| $\hat{\lambda}_{SMB}$ | -4.825*** | $\hat{\nu}_{SMB}$ | 0.279*** |
| | (-5.112, -4.539) | | (0.266, 0.291) |
| $\hat{\lambda}_{HML}$ | 4.379*** | $\hat{\nu}_{HML}$ | -0.218*** |
| | (3.917, 4.842) | | (-0.226, -0.209) |
| $\hat{\lambda}_{G}$ | 0.043*** | $\hat{\nu}_{G}$ | -0.002*** |
| | (0.040, 0.047) | | (-0.002, -0.002) |
| **Carhart Model (4 factors)** | | | |
| $\hat{\alpha}$ | 3.898*** | $\hat{\alpha}$ | 0.006*** |
| | (3.763, 4.033) | | (0.006, 0.006) |
| $\hat{\lambda}_{MkRf}$ | -0.432** | $\hat{\nu}_{MkRf}$ | 0.125*** |
| | (-0.785, -0.079) | | (0.115, 0.135) |
| $\hat{\lambda}_{SMB}$ | -4.631*** | $\hat{\nu}_{SMB}$ | 0.134*** |
| | (-4.918, -4.345) | | (0.124, 0.143) |
| $\hat{\lambda}_{HML}$ | 4.964*** | $\hat{\nu}_{HML}$ | -0.243*** |
| | (4.507, 5.421) | | (-0.249, -0.237) |
| $\hat{\lambda}_{MOM}$ | 6.416*** | $\hat{\nu}_{MOM}$ | -0.088*** |
| | (5.977, 6.855) | | (-0.097, -0.080) |
| $\hat{\lambda}_{G}$ | 0.038*** | $\hat{\nu}_{G}$ | -0.0003*** |
| | (0.034, 0.041) | | (0.000, 0.000) |

*Note: This Table summarizes the estimated annualized premium $\hat{\lambda}_k$ on the left-hand side, and the cross-sectional estimators $\hat{\nu}_k$ on the right-hand side for all the three Linear Factor Models. Also, the confidence intervals are reported on a 95% confidence level. The $\hat{\lambda}_G$ and the $\hat{\nu}_G$, is in absolute numbers and require multiplying by 100 to write in %. The other factors are already stated in %. Statistically significant outcomes are annotated by the following: *** (p<0.001), **(p<0.05), and *(p<0.1).*

## 6.2 Risk Premium

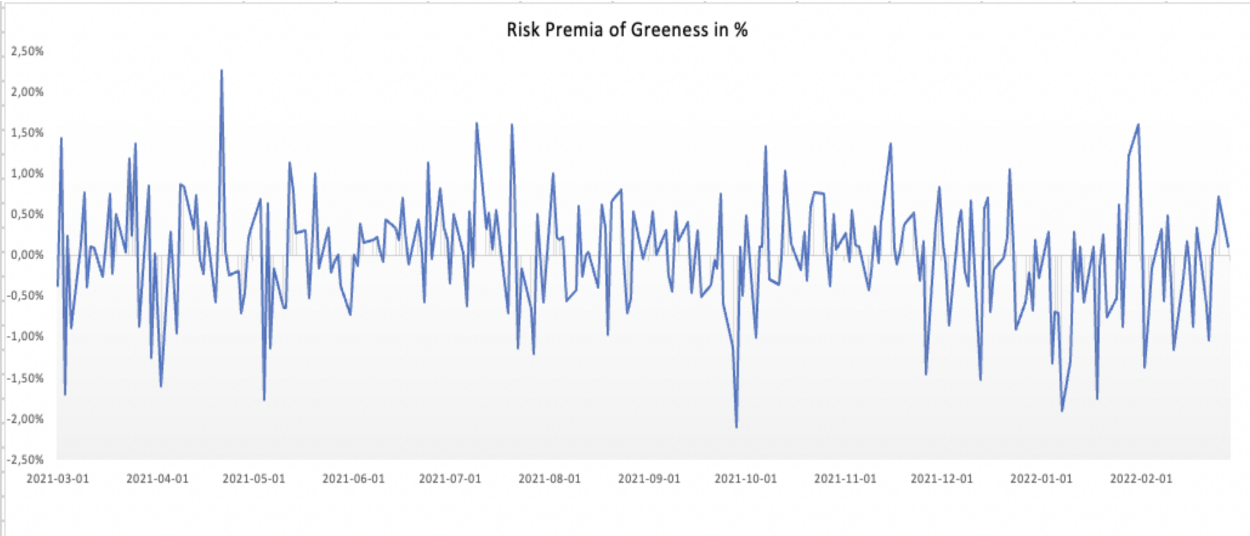
In respect to the annualized risk premium for greenness, it is found to be positively and statistically significant for all linear-factor models on a 1% significance level. This result differentiates itself from other studies, where the risk premium is usually found to be significantly negative or no significance at all.

In *Table 5*, for the Carhart Model, the coefficient is estimated at 3.76%, meaning that if the beta including the cross-sectional estimator increases by 1 unit, the annualized return on average increases by 3.76%, hence a positive risk premium. Regarding the Three-Factor Model and the CAPM, the coefficients were estimated at 4.31% and 2.25% respectively. Moreover, the economic implication can be explained as if there is an increased systematic risk related to the greenness factor, meaning an increase in the stocks' betas, the annualized return on average increases. In other words, when all factors are held constant, investors want to be increasingly compensated for this risk. However, in reality this increase in beta is likely coming from increase in demand for green stocks and not an increase in systematic risk on green assets, which will be further discussed in the analysis.

Furthermore, nearly all factors are found to be significant throughout the linear factor models, except for the market factor, which is found to be insignificant in the three-factor model. Although, all variables are consistent in its sign. Regarding the other factors, the factor models indicate a negative relationship between the market and size factor with coefficients of the Carhart model at -0.432% and -4.631% respectively. Additionally positive relationship is found for the momentum and value factor with the coefficients for the Carhart model being 6.416% and 4.964% respectively. Lastly, the constant is highly significant at a 1%-level for all models, suggesting the existence of an omitted factor. Robustness tests are presented in *section 8.*

Moreover*, Figure 1,* presents the estimated daily risk premium during the studied period. As can be seen, the risk premium is highly volatile, ranging from positive to negative.

*Figure 1: Carhart model - Daily Risk Premium*




Lastly, the results indicating evidence of a positive risk premium for greenness, leads to a rejection of the null hypothesis.

$H_0$=There is no significant risk premium on the European market for green stocks

Thus the alternative hypothesis is accepted:

$H_1$=There is a significant risk premium on the European market for green stocks

# 7 Robustness Tests

Firstly, in *Table 6*, a summary of the different robustness checks tested in this paper can be seen.

*Table 6: Summary Table Robustness Check*

| | **Robustness Check** |
|---|---|
| (R1) | Green and brown portfolio based on deciles |
| (R2) | Green and brown portfolio based on teraciles |
| (R3) | Results utilizing a different method to control for market cap |
| (R4) | Calculation of cross-estimator based on OLS robust standard errors |

*Note: This Table summarizes the robustness checks conducted for this study.*

*Table 7* presents the robustness test where the green and brown portfolios are sorted based on the top and bottom decile as well as teracile. First, the coefficients are highly statistically significant for nearly all factors for both portfolios. In terms of SMB, HML, and momentum factors are similar to the ones presented in *section 6*. However, while the market factor is negative throughout the models based on quintiles, here they are only negative in the CAPM.

More importantly, regarding the greenness factor, for the model based on teraciles, it is for the Carhart and Fama French model still significantly positive on a 1-%. This supports the results for the main model. However, for the CAPM it is insignificant with a negative coefficient.

Furthermore, regarding the decile-based portfolios, the risk premium for greenness is highly significant but negative. This result could argue against the robustness of the former one as it would have completely different implications for the risk premium for greenness. Nevertheless, the decile portfolio is more heterogeneous in terms of capitalization and which countries the firm operates in. Thus, we want to emphasize that it could perhaps capture other effects and is therefore not utilized as a main model.

*Table 7: Robustness Test 1 and 2*

| **Index $\tilde{R}_I$ (based on 10% Portfolio)** | | | | **Index $\tilde{R}_I$ (based on 30% Portfolio)** | | | |
|---|---|---|---|---|---|---|---|
| Risk Premium (OLS) | | Cross-sect. Estimator (WLS) | | Risk Premium (OLS) | | Cross-sect. Estimator (WLS) | |
| **CAPM Model (1 factor)** | | | | **CAPM Model (1 factor)** | | | |
| $\hat{\alpha}$ | 1.460*** | $\hat{\alpha}$ | 0.006*** | $\hat{\alpha}$ | 0.875*** | $\hat{\alpha}$ | 0.006*** |
| | (1.444, 1.476) | | (0.006, 0.006) | | (0.771, 0.978) | | (0.006, 0.006) |
| $\hat{\lambda}_{MkRf}$ | -0.649*** | $\hat{\nu}_{MkRf}$ | 0.041** | $\hat{\lambda}_{MkRf}$ | -1.958*** | $\hat{\nu}_{MkRf}$ | -0.288*** |
| | (-1.025, -0.272) | | (0.003, 0.079) | | (-2.320, -1.596) | | (-0.302, -0.273) |
| $\hat{\lambda}_{G}$ | -0.042*** | $\hat{\nu}_{G}$ | 0.005*** | $\hat{\lambda}_{G}$ | -0.001 | $\hat{\nu}_{G}$ | 0.000*** |
| | (-0.046, -0.038) | | (0.005, 0.005) | | (-0.004, 0.002) | | (0.000, 0.000) |
| **Fama-French Model (3 factors)** | | | | **Fama-French Model (3 factors)** | | | |
| $\hat{\alpha}$ | 1.543*** | $\hat{\alpha}$ | 0.006*** | $\hat{\alpha}$ | -1.020*** | $\hat{\alpha}$ | 0.006*** |
| | (1.508, 1.577) | | (0.006, 0.006) | | (-1.312, -0.728) | | (0.006, 0.006) |
| $\hat{\lambda}_{MkRf}$ | 1.944*** | $\hat{\nu}_{MkRf}$ | -0.043*** | $\hat{\lambda}_{MkRf}$ | 0.221 | $\hat{\nu}_{MkRf}$ | 0.607*** |
| | (1.561, 2.327) | | (-0.052, -0.034) | | (-0.128, 0.580) | | (0.583, 0.631) |
| $\hat{\lambda}_{SMB}$ | -5.121*** | $\hat{\nu}_{SMB}$ | 0.044*** | $\hat{\lambda}_{SMB}$ | -4.811*** | $\hat{\nu}_{SMB}$ | -0.292*** |
| | (-5.408, -4.835) | | (0.035, 0.053) | | (-5.100, -4.522) | | (-0.315, -0.268) |
| $\hat{\lambda}_{HML}$ | 3.146*** | $\hat{\nu}_{HML}$ | 0.066*** | $\hat{\lambda}_{HML}$ | 3.604*** | $\hat{\nu}_{HML}$ | 0.258*** |
| | (2.690, 3.602) | | (0.061, 0.072) | | (3.147, 4.061) | | (0.245, 0.270) |
| $\hat{\lambda}_{G}$ | -0.024*** | $\hat{\nu}_{G}$ | -0.003*** | $\hat{\lambda}_{G}$ | 0.0133*** | $\hat{\nu}_{G}$ | 0.005*** |
| | (-0.028, -0.020) | | (-0.003, -0.002) | | (0.010, 0.016) | | (0.005, 0.005) |
| **Carhart Model (4 factors)** | | | | **Carhart Model (4 factors)** | | | |
| $\hat{\alpha}$ | 2.713*** | $\hat{\alpha}$ | 0.005*** | $\hat{\alpha}$ | 5.414*** | $\hat{\alpha}$ | 0.006*** |
| | (2.431, 2.996) | | (0.005, 0.005) | | (5.063, 5.766) | | (0.006, 0.006) |
| $\hat{\lambda}_{MkRf}$ | 2.307*** | $\hat{\nu}_{MkRf}$ | 0.046*** | $\hat{\lambda}_{MkRf}$ | 0.058 | $\hat{\nu}_{MkRf}$ | 0.041*** |
| | (1.936, 2.679) | | (0.032, 0.060) | | (-0.291, 0.408) | | (0.022, 0.060) |
| $\hat{\lambda}_{SMB}$ | -4.891*** | $\hat{\nu}_{SMB}$ | 0.077*** | $\hat{\lambda}_{SMB}$ | -4.587*** | $\hat{\nu}_{SMB}$ | -0.071*** |
| | (-5.178, -4.605) | | (0.062, 0.091) | | (-4.876, -4.297) | | (-0.091, -0.051) |
| $\hat{\lambda}_{HML}$ | 3.897*** | $\hat{\nu}_{HML}$ | 0.539*** | $\hat{\lambda}_{HML}$ | 4.170*** | $\hat{\nu}_{HML}$ | 0.208*** |
| | (3.447, 4.346) | | (0.532, 0.545) | | (3.719, 4.622) | | (0.199, 0.218) |
| $\hat{\lambda}_{MOM}$ | 7.910*** | $\hat{\nu}_{MOM}$ | -0.392*** | $\hat{\lambda}_{MOM}$ | 6.797*** | $\hat{\nu}_{MOM}$ | -0.760*** |
| | (7.469, 8.352) | | (-0.404, -0.380) | | (6.354, 7.240) | | (-0.777, -0.743) |
| $\hat{\lambda}_{G}$ | -0.032*** | $\hat{\nu}_{G}$ | -0.005*** | $\hat{\lambda}_{G}$ | 0.006*** | $\hat{\nu}_{G}$ | -0.001*** |
| | (-0.036, -0.028) | | (-0.005, -0.005) | | (0.002, 0.009) | | (-0.001, -0.001) |

*Note: This Table reports as a robustness check, the estimated annualized premium $\hat{\lambda}_k$ and the cross-sectional estimators $\hat{\nu}_k$ for all the three Linear Factor Models. The left table corresponds to a portfolio constructed of the top and bottom 10% of companies with highest and lowest GHG emissions estimates, whereas the right table portfolios were constructed with the top and bottom 30%. Also, the confidence intervals are reported on a 95% confidence level. The $\hat{\lambda}_G$ and the $\hat{\nu}_G$, is in absolute numbers and require multiplying by 100 to write in %. The other factors are already stated in %. Statistically significant outcomes are annotated by the following: *** ($p<0.001$), **($p<0.05$), and *($p<0.1$).*

Furthermore, *Table 8 presents* the results from robustness tests 3. These robustness tests weight the portfolio returns differently by taking market capitalization into account when sorting the companies into the portfolios as in Fama & French (1993).

*Table 8: Robustness Test 3*

| Different weighting of market cap | | | |
|---|---|---|---|
| Time-Invariant | | WLS | |
| **CAPM Model (1 factor)** | | | |
| $\hat{\alpha}$ | 1.341*** | $\hat{\alpha}$ | 0.005*** |
| | (1.323, 1.358) | | (0.005, 0.005) |
| $\hat{\lambda}_{MkRf}$ | -1.943* | $\hat{\nu}_{MkRf}$ | -0.050*** |
| | (-2.306, -1.580) | | (-0.085, -0.015) |
| $\hat{\lambda}_{G}$ | -0.00003** | $\hat{\nu}_{G}$ | 0.005*** |
| | (-0.000, 0.000) | | (0.005, 0.005) |
| **Fama-French Model (3 factors)** | | | |
| $\hat{\alpha}$ | 3.450*** | $\hat{\alpha}$ | 0.007*** |
| | (3.110, 3.791) | | (0.007, 0.007) |
| $\hat{\lambda}_{MkRf}$ | 0.023 | $\hat{\nu}_{MkRf}$ | -0.788*** |
| | (-0.338, 0.383) | | (-0.807, -0.768) |
| $\hat{\lambda}_{SMB}$ | -4.939*** | $\hat{\nu}_{SMB}$ | 0.163*** |
| | (-5.229, -4.648) | | (0.144, 0.182) |
| $\hat{\lambda}_{HML}$ | 3.790*** | $\hat{\nu}_{HML}$ | -0.312*** |
| | (3.322, 4.259) | | (-0.324, -0.300) |
| $\hat{\lambda}_{G}$ | 0.0002** | $\hat{\nu}_{G}$ | 0.000*** |
| | (0.000, 0.000) | | (0.000, 0.000) |
| **Carhart Model (4 factors)** | | | |
| $\hat{\alpha}$ | -2.661*** | $\hat{\alpha}$ | 0.006*** |
| | (-3.083, -2.241) | | (0.006, 0.006) |
| $\hat{\lambda}_{MkRf}$ | -0.069 | $\hat{\nu}_{MkRf}$ | -0.468*** |
| | (-0.420, 0.283) | | (-0.481, -0.455) |
| $\hat{\lambda}_{SMB}$ | -4.655*** | $\hat{\nu}_{SMB}$ | -0.036*** |
| | (-4,946, -4.364) | | (-0.049, -0.023) |
| $\hat{\lambda}_{HML}$ | 4.258*** | $\hat{\nu}_{HML}$ | 0.846*** |
| | (3.797, 4.718) | | (0.839, 0.854) |
| $\hat{\lambda}_{MOM}$ | 6.849*** | $\hat{\nu}_{MOM}$ | 0.045*** |
| | (6.398,7.298 ) | | (0.033, 0.056) |
| $\hat{\lambda}_{G}$ | 0.0001*** | $\hat{\nu}_{G}$ | -0.0004*** |
| | (0.000, -0.000) | | (-0.000, -0.000 |

*Note: This Table reports as a robustness check, the estimated annualized premium $\hat{\lambda}_k$ and the cross-sectional estimators $\hat{\nu}_k$ for all the three Linear Factor Models, where the portfolios were first created based on market capitalization. The estimated returns consists of 1/3 for each market cap category: Mega & Large, Mid, and Small. Also, the confidence intervals are reported on a 95% confidence level. The $\hat{\lambda}_G$ and the $\hat{\nu}_G$, is in absolute numbers and require multiplying by 100 to write in %. The other factors are already stated in %. Statistically significant outcomes are annotated by the following: *** (p<0.001), **(p<0.05), and *(p<0.1).*

The portfolios are first created based on market capitalization and then weighted by market value as described in the methodology section. The average portfolio return is then added together and divided by three before the return on the green portfolios is subtracted by the return on the green portfolios:

$$f_{G,t} = \frac{1}{3}(r_{G,s} + r_{G,m} + r_{G,l}) - \frac{1}{3}(r_{B,s} + r_{B,m} + r_{B,l}) \quad (15)$$

As can be seen in the table, the risk premium for greenness is still indicated to be positive for both the Fama French model and Carhart model, which supports the results in *section 6*. However, for the CAPM, the risk premium is instead negative on a 10 %-significance level. The coefficients are smaller compared to the main model.

*Table 9* summarizes the result of robustness test 4, where the cross-sectional estimator $\widehat{v_G}$ has been estimated by OLS robust standard errors as opposed to the WLS estimator. This is because, as mentioned in *section 4*, a result where WLS and OLS strongly diverge can be a sign of unbiasedness related to the WLS-results. Comparing *Table 5* with *Table 9,* certain differences can be noted where the cross-sectional estimator has a different sign yet is highly statistically significant. As a result, this can thus indicate that the estimates for the cross-sectional estimator utilizing WLS can be biased.

*Table 9: Robustness Test 4*

| | Carhart Model | FF3 | CAPM |
|---|---|---|---|
| $\hat{\alpha}$ | 0.006*** | 0.005*** | 0.006*** |
| | (0.006, 0.006) | (0.005, 0.005) | (0.006, 0.006) |
| $\hat{v}_{MkRf}$ | -0.024*** | -0.040*** | -0.0343*** |
| | (-0.026,- 0.023) | (0.026,0.053) | (-0.036,- 0.033) |
| $\hat{v}_{SMB}$ | 0.011*** | 0.279*** | |
| | (0.010, 0.014) | (0.266, 0.291) | |
| $\hat{v}_{HML}$ | -0.030*** | -0.218*** | |
| | (-0.031, -0,028) | (-0.226, -0,210) | |
| $\hat{v}_{MOM}$ | -0.001*** | | |
| | (-0.003, 0.000) | | |
| $\hat{v}_G$ | 0.000*** | -0.002*** | 0.006*** |
| | (0.000, 0.000) | (-0.002, -0.002) | (0.006, 0.006) |

*Note: This Table summarizes the results for robustness test 4. The estimated annualized premium $\hat{\lambda}_k$ and the cross-sectional estimators $\hat{v}_k$ for all the three Linear Factor Models are shown. Hereby the cross-sectional estimators $\hat{v}_k$ were estimated on OLS robust standard errors. Also, the confidence intervals are reported on a 95% confidence level. $\hat{v}_G$, is in absolute numbers and require multiplying by 100 to write in %. The other factors are already stated in %. Statistically significant outcomes are annotated by the following: *** (p<0.001), **(p<0.05), and *(p<0.1).*

# 8 Analysis & Discussion

Firstly, when looking at all the regressions including the robustness test, the outcome found in this paper show mixed results. Most of the risk premiums for green stocks discovered are positive for the portfolios that include 20% and 30% of the greenest and brownest companies. However, the risk premium is negative when looking at the top 10% green and brown companies' portfolios. Another potential reason, than the one stated in the robustness test, for the different results of negative and positive premiums is that the overall risk premium for green stocks is close to zero. Therefore, this does not ultimately mean that substantially different results were found. Instead, the difference comes from the different portfolios investigated (10%, 20%, and 30%), resulting in a positive and negative risk premium. Hence, if the size of the risk premium were larger (positively or negative), the difference in the risk premiums for the different portfolios would potentially all show the same sign.

Secondly, if then analyzing a scenario which would assume an overall risk premium of roughly zero, it would suggest that the market has not priced climate risk from March 2021 to February 2022. No risk premium would potentially indicate that green stocks do neither under nor outperform brown stocks. Hence, climate risk would not impact investors' behavior. Investors' willingness to accept lower expected returns for utilizing a green stock or hedging against climate risk (as with a negative risk premium) would be obsolete. However, this is an implausible scenario relating to past literature, as considerable evidence has shown that the market does price climate risk. Such studies are by Fama & French (2007), Hong & Kacperczyk (2009), Engle et al. (2020), Pástor et al. (2021), or Alessi et al. (2021) (for more information, refer *to section 3.2* Empirical Literature Review). Also, with today's increasing relevancy of climate change, including all future risks arising from an environmental perspective and financial market perspective, it is doubtful that the market does not price such a risk or is that inefficient.

Thirdly and more importantly, the observations can lead to a much more interesting explanation when concluding that this study found a positive risk premium, when considering the main model. Even though only the 20% and 30% portfolios mostly show a positive premium, the robustness tests support the findings of a positive risk premium over no risk premium or negative risk premium for green stocks in 2021. In contrast, most (less) of the literature has found a negative (positive) risk premium and therefore has priced climate risk. The positive but close to zero risk premium found in this paper shows a shift in the risk premium for green stocks. With this, the previously observed negative risk premium found during the 21st century by the formerly mentioned literature did not only get smaller in 2021 but turned positive. Such a change indicates that green stocks slightly outperformed brown stocks during 2021, and investors were generating higher expected returns for green than brown stocks. These finding of green stocks outperforming brown stocks for smaller periods aligns with Pástor et al. (2021) or Nofsinger and Varma (2014). From a market efficiency perspective, a positive premium in general, would contradict the idea that investors accept a lower expected return as compensation to hedge climate risk. A positive premium in a silo perspective would also mean that green stocks were to be considered riskier, and therefore investors would be accordingly compensated for the additional risk. Indeed, with evidence that climate risk is priced in the market from past literature, this idea does not explain the risk premium shift.

Fourthly, an abrupt increase in demand for green assets would plausibly better explain the risk premium shift. With this, green investors' taste for green assets suddenly increased, and potential market shocks turned non-green investors to create a demand for green assets to hedge climate risk. The following events in 2021 of high relevancy, in terms of creating noise or regulations, could have been contributed to launching and intensifying such shocks that affect the past equilibrium dimension more than usual: UN *Climate Change Conference COP26* (13.11.2021), *Greta's Thunberg* "blah blah blah" speech (28.09.2021), EU reaching *Climate Deal* with binding goals (21.04.2021), EU's publication of the *Taxonomy Delegated Act* (09.12.2021), EU's proposal of the *Complementary Climate Delegated Act* (02.02.2022), *Friday for Future* event (24.09.2021), publication of the *UN Climate Report* (09.08.2021), UN WMO's publication about weather extremes (31.08.2021), or the German flood natural disaster (15.07.2021). Also, the regulatory landscape around non-financial reporting has tightened. New regulations such as the *Taxonomy Delegated Act* (01.01.2022) with the *Sustainable Finance Disclosure Regulation (SFDR)* becoming effective or the EU's proposition of the *Complementary Climate Delegated Act* (02.02.2022) further emphasize the importance of acknowledging climate risk. It also enforces the realization that brown firms' cash flows are specifically at risk due to implementations such as the *EU Emissions Trading System (EU ETS)*. Hence, the overall increase in demand for green stocks at the expense of brown stocks potentially directed to a change in equilibrium, creating a temporarily positive premium in

2021. Nofsinger and Varma (2014) reported such a phenomenon in the past and found positive premiums in market crises. Görgen et al. (2020), and Pástor et al. (2021), also found temporary positive risk premiums, or betas for specific years, that do not align with the overall betas for the whole period. Nevertheless, all these studies found it only for specific shorter periods, wherein a negative risk premium was detected in the long run on average. Therefore, in combination with previous studies, it can be expected that a new equilibrium will eventually be found, and the new investors' taste for green assets will balance out to zero, assuming the presence of market efficiency to a certain degree. Hence, this would indicate that a negative premium for green stocks will be observed again as the concept of riskier brown assets accordingly compensate investors, and investors willing to earn less for hedging climate risk by investing in green assets withstand. This is in line with some of the findings by Pástor et al. (2021).

Finally, this ultimately raises the question of why a lower, or in our case a negative, risk premium was found for green assets in the 10% portfolios, in contrast to the other positive premiums (20% and 30% portfolios). The 10% portfolio risk premiums essentially differ by comparing the greenest and brownest stocks returns' and are therefore much more concentrated than the other portfolios. Theoretically, if the demand increases for investors that want to hedge climate risk, someone could assume that these investors would then invest in the greenest stocks. Hence, this would then indicate that the positive risk premium should potentially be more significant with the 10% portfolios. Yet, it is the one that actually is negative. A consideration explaining this outcome would be that investors' classification of green stocks could differ from the one in this paper. To the author's knowledge, it is the first time that the real greenness of a company can be quite accurately identified through the new GHG estimated by Bloomberg. Hence, this study is not perfectly comparable with previous studies, and therefore the impact of a different portfolio selection on the results is unknown. Also, the question would always arise if the investors' are aware of Bloomberg's GHG estimates and if they associated the same companies with the same greenness or brownness level as done in this paper. Therefore, if investors would have a different understanding of green companies and need to invest in a very green company to hedge climate risk, and if this is the reason for such a shock, the just mentioned reasoning could explain. Nevertheless, this would also ignore investors' taste in greenness, as it would assume that they would want to invest in the greenest stocks. This would undoubtedly raise another question of how far these GHG estimates by Bloomberg are incorporated within the stock market, yet this is a question for another day.

Furthermore, with new regulations being proposed in Europe, especially within the EU, to improve the quality of environmental reporting and to include more firms, studying the relationship between firms and the environment will become even easier. Incorporating GHG Scope 3 for future studies would thus be interesting. For now, GHG estimates can act as a great substitute. While this study concerns European firms, for future studies the GHG estimates could be used to study markets where the environmental reporting is not as widespread and with the same quality of reporting as in Europe. Hence, the other markets mentioned in *section 2* such as the US and Australia, seems to be an appropriate market to study next as GHG reporting is still only partly implemented. Furthermore, the authors had a few different ideas of where this study could go when conducting this study, but they did not end up in the final paper. For example, using the gap between the reported GHG and estimated GHG as a factor to research whether investors correct for the new information or study what factors potentially could explain the size of the gap. Additionally, as soon as more periods are available to measure the effect of the Bloomberg GHG emission estimates, the actual impact of using a potentially very accurate measure of greenness can be investigated within a longer period. The Bloomberg GHG estimate score opens another book with many different variations of potential studies attempting to measure the effect of "real greenness" and therefore contributes by bringing a new perspective.

# 9 Conclusion

In summary, this paper investigates the existence of a risk premium for being green on the European market during the period of March 2021 to February 2022 utilizing daily returns. A greenness factor is constructed based on the difference in excess returns on a green and brown portfolio. The portfolios are constructed via a ranking of the top and bottom quintile, based on estimated Bloomberg GHG emissions normalized by revenue. To the authors knowledge, this is the first study conducting a study based on these estimates. An unbalanced panel data of 1,602 individual European stocks were used to perform cross-sectional regressions with the OLS estimator. The study performs a time-invariant model, where a highly statistically significant positive risk premium for greenness is found, contradicting the results of numerous earlier pieces of literature such as those by Gros et al. (2016) or Alessi et al. (2021). However, these results can also be explained through the evidence for a positive risk premium found by Engle et al. (2020) or Görgen et al. (2020). As Pástor et al. (2021) illustrate, the temporary positive risk premium is derived from an abrupt increase in investors' demand for green assets that forces a new equilibrium readjustment. Several robustness tests are carried out, which both validate and contend the results. Returning to the research questions defined in *section 1*:

*Does the European market price climate risk with a negative risk premium for green stocks in the period from March 2021 to February 2022?*

The authors of this study thus conclude that, no, a risk premium for greenness cannot be found in the European market. In this case, a positive one was instead found during the studied period.

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# Appendix

*Appendix 1: Distribution by GHG Confidence Score*

| Confidence Score | Green Portfolio | Brown Portfolio |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 3 | 0 | 1 |
| 4 | 1 | 1 |
| 5 | 4 | 6 |
| 6 | 14 | 9 |
| 7 | 30 | 36 |
| 8 | 126 | 106 |
| 9 | 129 | 136 |
| 10 | 6 | 16 |
| **Sum** | **310** | **311** |

*Note: The table presents the confidence score related to the separate firms GHG estimates by Bloomberg. The scores have been retrieved at a Bloomberg terminal. The scores range from least Bloomberg being least confident in the estimates accuracy (0) to most confident in the estimate's accuracy (10). As can be seen from the table, a large amount receive a high confident score, where 84.19% (82.96 %) of the firms included in the green (brown) portfolio receive a score of 8 or above.*

*Appendix 2: Country Distribution of Total Sample*

| Country | Total Sample | Green Portfolio | Brown Portfolio |
|---|---|---|---|
| *Austria* | 29 | 1 | 9 |
| *Belgium* | 45 | 6 | 9 |
| *Bosnia Herzegovina* | 1 | 0 | 0 |
| *Britain* | 293 | 88 | 42 |
| *Bulgaria* | 3 | 0 | 1 |
| *Croatia* | 9 | 1 | 5 |
| *Cyprus* | 1 | 0 | 1 |
| *Czech Republic* | 5 | 1 | 2 |
| *Denmark* | 44 | 14 | 9 |
| *Estonia* | 3 | 0 | 1 |
| *Finland* | 53 | 9 | 8 |
| *France* | 162 | 43 | 19 |
| *Germany* | 203 | 30 | 33 |
| *Greece* | 22 | 2 | 12 |
| *Hungary* | 3 | 1 | 2 |
| *Iceland* | 9 | 0 | 2 |
| *Ireland* | 32 | 5 | 4 |
| *Italy* | 89 | 14 | 19 |
| *Latvia* | 1 | 0 | 1 |
| *Lithuania* | 1 | 0 | 0 |
| *Luxembourg* | 24 | 3 | 7 |
| *Macedonia* | 2 | 0 | 0 |
| *Malta* | 6 | 1 | 2 |
| *Monaco* | 3 | 0 | 3 |
| *Netherlands* | 52 | 11 | 5 |
| *Norway* | 54 | 6 | 15 |
| *Poland* | 41 | 0 | 17 |
| *Portugal* | 14 | 0 | 3 |
| *Romania* | 13 | 0 | 10 |
| *Slovenia* | 7 | 0 | 3 |
| *Spain* | 63 | 13 | 16 |
| *Sweden* | 128 | 36 | 7 |
| *Switzerland* | 115 | 24 | 16 |
| *Turkey* | 70 | 1 | 28 |
| *Ukraine* | 2 | 0 | 0 |
| SUM | 1602 | 310 | 311 |

*Appendix 3: NACE Sectors of Total Sample*

| NACE Sectors | NACE Industry code | Total Sample | Green Portfolio | Brown Portfolio |
|---|---|---|---|---|
| ***High Emitting Sectors*** | | | | |
| Crop and animal production, hunting and related service activities | A1 | 9 | 0 | 3 |
| Mining of coal and lignite | B5 | 3 | 0 | 2 |
| Extraction of crude petroleum and natural gas | B6 | 8 | 0 | 6 |
| Mining of metal ores | B7 | 24 | 0 | 18 |
| Mining support service activities | B9 | 15 | 0 | 4 |
| Manufacture of coke and refined petroleum products | C19 | 23 | 1 | 15 |
| Manufacture of chemicals and chemical products | C20 | 63 | 1 | 33 |
| Manufacture of rubber and plastic products | C22 | 25 | 1 | 8 |
| Manufacture of other non-metallic mineral products | C23 | 37 | 1 | 24 |
| Manufacture of basic metals | C24 | 23 | 0 | 16 |
| Manufacture of fabricated metal products, except machinery and equipment | C25 | 19 | 0 | 2 |
| Electricity, gas, steam and air conditioning supply | D35 | 61 | 1 | 38 |
| Waste collection, treatment and disposal activities; materials recovery | E38 | 4 | 0 | 0 |
| Land transport and transport via pipelines | H49 | 10 | 0 | 3 |
| Water transport | H50 | 19 | 1 | 17 |
| Air transport | H51 | 14 | 0 | 13 |
| ***Total High Emitting:*** | | 357 | 6 | 202 |
| ***Other Sectors*** | | | | |
| Forestry and logging | A2 | 1 | 0 | 1 |
| Fishing and aquaculture | A3 | 7 | 1 | 0 |
| Other mining and quarrying | B8 | 2 | 0 | 0 |
| Manufacture of food products | C10 | 48 | 0 | 5 |
| Manufacture of beverages | C11 | 26 | 1 | 3 |
| Manufacture of tobacco products | C12 | 6 | 1 | 0 |
| Manufacture of textiles | C13 | 6 | 0 | 2 |
| Manufacture of wearing apparel | C14 | 13 | 8 | 0 |
| Manufacture of leather and related products | C15 | 5 | 3 | 1 |
| Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials | C16 | 6 | 2 | 0 |
| Manufacture of paper and paper products | C17 | 34 | 3 | 10 |
| Printing and reproduction of recorded media | C18 | 3 | 0 | 0 |
| Manufacture of basic pharmaceutical products and pharmaceutical preparations | C21 | 43 | 12 | 4 |

| | | | | |
|---|---|---|---|---|
| Manufacture of computer, electronic and optical products | C26 | 76 | 25 | 4 |
| Manufacture of electrical equipment | C27 | 41 | 5 | 2 |
| Manufacture of machinery and equipment n.e.c. | C28 | 114 | 22 | 13 |
| Manufacture of motor vehicles, trailers and semi-trailers | C29 | 55 | 6 | 4 |
| Manufacture of other transport equipment | C30 | 24 | 7 | 3 |
| Manufacture of furniture | C31 | 4 | 0 | 0 |
| Other manufacturing | C32 | 40 | 14 | 5 |
| Repair and installation of machinery and equipment | C33 | 3 | 1 | 1 |
| Water collection, treatment and supply | E36 | 6 | 0 | 4 |
| Construction of buildings | F41 | 36 | 14 | 1 |
| Civil engineering | F42 | 40 | 1 | 6 |
| Wholesale and retail trade and repair of motor vehicles and motorcycles | G45 | 14 | 5 | 0 |
| Wholesale trade, except of motor vehicles and motorcycles | G46 | 40 | 15 | 3 |
| Retail trade, except of motor vehicles and motorcycles | G47 | 101 | 33 | 3 |
| Warehousing and support activities for transportation | H52 | 26 | 4 | 3 |
| Postal and courier activities | H53 | 9 | 2 | 1 |
| Accommodation | I55 | 14 | 0 | 12 |
| Food and beverage service activities | I56 | 15 | 1 | 0 |
| Publishing activities | J58 | 74 | 20 | 2 |
| Motion picture, video and television programme production, sound recording and music publishing activities | J59 | 8 | 3 | 0 |
| Programming and broadcasting activities | J60 | 10 | 9 | 0 |
| Telecommunications | J61 | 42 | 12 | 1 |
| Computer programming, consultancy and related activities | J62 | 56 | 22 | 1 |
| Information service activities | J63 | 31 | 11 | 2 |
| Legal and accounting activities | M69 | 8 | 1 | 0 |
| Activities of head offices; management consultancy activities | M70 | 8 | 2 | 0 |
| Architectural and engineering activities; technical testing and analysis | M71 | 16 | 4 | 0 |
| Scientific research and development | M72 | 22 | 5 | 2 |
| Advertising and market research | M73 | 13 | 6 | 0 |
| Other professional, scientific and technical activities | M74 | 2 | 1 | 0 |
| Veterinary activities | M75 | 2 | 1 | 1 |
| Rental and leasing activities | N77 | 4 | 2 | 0 |
| Employment activities | N78 | 10 | 6 | 0 |

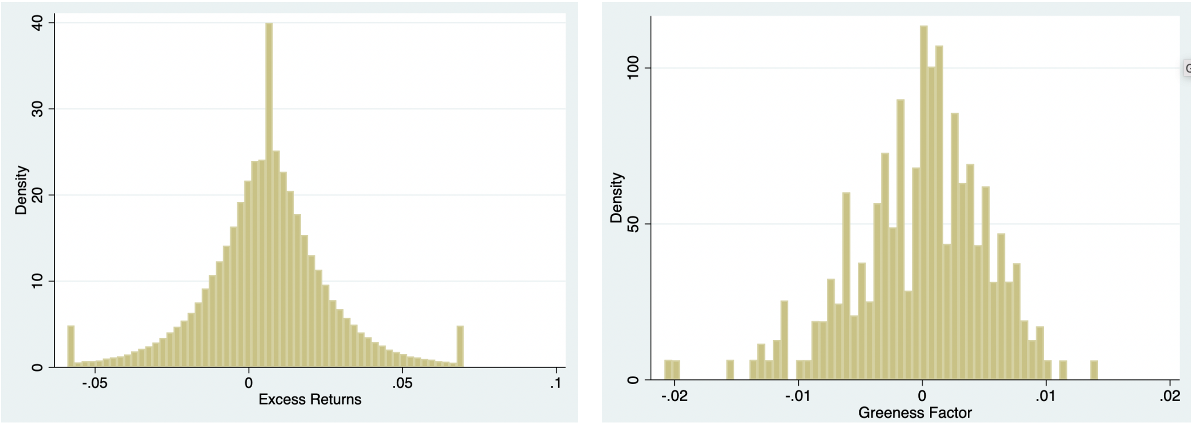
| | | | | |
|---|---|---|---|---|
| Travel agency, tour operator and other reservation service and related activities | N79 | 4 | 0 | 3 |
| Security and investigation activities | N80 | 7 | 1 | 1 |
| Services to buildings and landscape activities | N81 | 7 | 2 | 0 |
| Office administrative, office support and other business support activities | N82 | 6 | 1 | 0 |
| Education | P85 | 2 | 0 | 0 |
| Human health activities | Q86 | 24 | 2 | 2 |
| Residential care activities | Q87 | 4 | 0 | 0 |
| Creative, arts and entertainment activities | R90 | 2 | 0 | 0 |
| Gambling and betting activities | R92 | 13 | 6 | 1 |
| Sports activities and amusement and recreation activities | R93 | 10 | 1 | 2 |
| Other personal service activities | S96 | 2 | 0 | 0 |
| ***Total other:*** | | 1,245 | 304 | 109 |

*Appendix 4: Distribution by Market Capitalization*

| Market Cap | Total Sample | Green Portfolio | Brown Portfolio |
|---|---|---|---|
| MEGA | 26 | 13 | 3 |
| LARGE | 247 | 65 | 33 |
| MID | 490 | 129 | 87 |
| SMALL | 839 | 103 | 188 |
| Total: | 1602 | 310 | 311 |

*Note: The table presents a summary of the distribution of companies in market capitalization terms within the total sample, the green portfolio, and the brown portfolio.*

*Appendix 5: Histogram of Excess Returns and Greenness Factor*




*Note: The left figure shows the histogram representing the distribution of the excess returns in the total sample, which was winsorized at 99%. The right figure shows the histogram representing the distribution of the greenness factor.*

*Appendix 6: Collin-test*

| Variable | VIF | SQRT VIF | Tolerance | R-Squared |
|---|---|---|---|---|
| Excess Returns | 1,01 | 1 | 0,9912 | 0,0088 |
| MktRf | 1,77 | 1,33 | 0,5659 | 0,4341 |
| SMB | 1,41 | 1,19 | 0,7115 | 0,2885 |
| HML | 1,63 | 1,28 | 0,614 | 0,386 |
| MOM | 1,6 | 1,27 | 0,6249 | 0,3751 |
| Greenness Factor | 1,51 | 1,23 | 0,6609 | 0,3391 |

| | Eigenvalue | Cond Index |
|---|---|---|
| 1 | 2,071 | 1,000 |
| 2 | 1,421 | 1,208 |
| 3 | 1,198 | 1,315 |
| 4 | 0,858 | 1,554 |
| 5 | 0,732 | 1,682 |
| 6 | 0,364 | 2,385 |
| 7 | 0,356 | 2,414 |

*Note: The tables present the output from Stata utilizing the collin command for stock i, in this case the stock 1&1 AG. In Stata, this test is carried out for every separate company as "collin excess return MktRf SMB HML MOM Greenness if companyid==x." Alongside these results, the mean VIF (1.490) and Conditional Number (2.420) are also generated. The conditional number is used for a trimming of the sample which is discussed in section 4*

Appendix 7: Summary Statistics of Portfolios

| Portfolio | | Mean | Median | Max | Min | SD | Obs |
|---|---|---|---|---|---|---|---|
| Green | $\tilde{R}_G$ | 0.0060 | 0.0068 | 0.0232 | -0.0104 | 0.0052 | 324 |
| Brown | $\tilde{R}_B$ | 0.0064 | 0.0064 | 0.0398 | -0.0082 | 0.0057 | 324 |

*Note: This table summarizes the statistical characteristics of the green and brown portfolios.*

## *Appendix 8: Summary Statistics of the Linear Factor Models*

| Factor | Mean | Median | Max | Min | SD |
|---|---|---|---|---|---|
| $f_{MkRf}$ | 0.024 | 0.120 | 6.120 | -4.590 | 1.093 |
| $f_{SMB}$ | -0.014 | -0.020 | 1.400 | -1.400 | 0.375 |
| $f_{HML}$ | 0.055 | -0.025 | 2.360 | -2.780 | 0.745 |
| $f_{MOM}$ | 0.040 | 0.060 | 1.690 | -2.310 | 0.639 |

*Note: This table summarizes the statistical characteristics of the factors in the linear factor models (without the greenness factor).*

## *Appendix 9: Correlation Summary Table of the Linear Factor Models for the Portfolios*

| Factor \| Portfolio | Green $\tilde{R}_G$ | Brown $\tilde{R}_B$ | $f_{MkRf}$ | $f_{SMB}$ | $f_{HML}$ | $f_{MOM}$ |
|---|---|---|---|---|---|---|
| $f_{MkRf}$ | 0.682 | 0.235 | 1.000 | | | |
| $f_{SMB}$ | -0.216 | -0.042 | -0.208 | 1.000 | | |
| $f_{HML}$ | -0.331 | 0.173 | -0.149 | -0.290 | 1.000 | |
| $f_{MOM}$ | 0.270 | -0.013 | 0.309 | 0.162 | -0.260 | 1.000 |

*Note: This table summarizes the correlation characteristics of the portfolios. On the left, the table shows the correlations between the individual factors from the Linear Factor Models and the excess returns of the green and brown portfolios respectively.. On the right, the correlations between each of the factors of the Linear Factor Models are displayed.*

*Appendix 10: White test, Carhart model*

| chi2(20) = 36472.78 | | | |
|---|---|---|---|
| Prob > chi2 = 0.0000 | | | |
| Source | chi2 | df | p-value |
| Heteroskedasticity | 36472.79 | 20 | 0.0000 |
| Skewness | 8604.27 | 5 | 0.0000 |
| Kurtosis | 5357.25 | 1 | 0.0000 |
| Total | 50434.30 | 26 | 0.0000 |

*Note: The test tests the null hypothesis of homoskedasticity against the alternative hypothesis of unrestricted heteroskedasticity. As can be seen in the table, homoskedasticity for the main Carhart model can be rejected and thus heteroskedasticity is prevalent.*