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Climate Change Risk Premium, Stock Returns and Volatility Analysis in Relation to ESG Score

Master's Thesis

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Declaration of Authorship

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Prague, July 29, 2022

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Abstract

The purpose of this study is to provide the evidence in regards to how the ESG score integration in the investment strategies affects the stock portfolio performances. The 10 year long panel data on European stocks were used to test how does the corporate ESG score correlate with returns and volatility on corporate stocks and does it (if at all) hold any explanatory power if added to popularly used asset pricing models. Data sample was divided in two based on long and short ESG reporting periods, where on each the analysis was performed separately. Furthermore, both the single sort and double sort analyses were performed to isolate size and ESG effects. Using Fama-MacBeth regression the results seem to suggest that investors are already pricing in the climate related risks as shown by the negative risk premium associated with high ESG firms. Returns and volatility of corporate stocks tend to be lower with higher ESG score, although not uniformly nor very significantly. Comparing Leaders portfolio showed that high (European) ESG scorers underperfomed S&P 500 index both in terms of return and volatility.

JEL Classification	G11, G12, G24, G28, G32, Q51, Q54, Q56
Keywords	Climate finance, green finance, asset pricing, stocks, ESG, Fama & French, factors, stock returns, green stocks, brown stocks, stock volatility, regulations, investor

Title	Climate Change Risk Premium, Stock Returns and Volatility Analysis in Relation to ESG Score

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Abstrakt

Účelem této studie je prokázat jak integrace ESG skóru do investiční stratégie může ovlivňovat návratnost a stabilitu portfólia akciových titulů a zároveň odhalit případnou existenci související rizikové přirážky. Pro účely analýzy byly použity panelová data Evropských akcií v horizontu předešlých 10 let. Datový vzorek byl rozdělen na dva v závislosti na délce reportovacího období ESG skóru a na každý vzorek byla provedena zvlášť identická analýza. Pro izolování ESG efektu od efektu tržní kapitalizace jeř prokázaly silnou korelaci se autor navíc rozhodl provést analýzu na jednoduchém a dvojitém řazení protfolií. Výsledky modelu Fama-MacBeth ukazují, že investoři již oceňují do jisté míry rizika spojená s klimatem jež se projevuje jako záporné riziková přirážka u firem s vysokým ESG skórem. Návratnost a volatilita korporátních akcií prokázaly negativní korelaci s ESG skórem, ačkoliv ne vždy jednoznačně a statisticky významně. Ve srovnání portfolií Leaders a akciového indexu S&P 500 se ukázelo, že index překonal Leaders portfolio co do výnosu tak i stability cen akcií.

JEL Klasifickace: G11, G12, G24, G28, G32, Q51, Q54, Q56
Klíčová Slova: klimatické finance, zelené finance, ocenění aktiv, akcie, ESG, Fama & French, faktory, návratnost akcií, zelené akcie, hnědé akcie, stabilita akcií, riziková prémie

Název: Riziková prémie změny klimatu, analýzy návratnosti a volatility akcií ve vztahu k ESG skóru

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Contents

1 Introduction **1**

2 Related Literature Review **4**

2.1 Performance Comparison of Green & Brown Companies 4

2.2 ESG & Other Sustainability Measures – The Inconclusive Evidence 6

2.3 Pricing In The Climate Change & Public Awareness 8

2.4 Climate Change Risk Premium 10

2.5 Summary of Related Literature 12

3 Overview of Asset Pricing Models **14**

3.1 Capital Asset Pricing Model (CAPM) 15

3.2 Fama-French Three-Factor Model (FF3) 16

3.3 Carhart Four-Factor Model (CH4) 17

3.4 Fama-French Five-Factor Model (FF5) 18

4 On Building a Proxy For Sustainability **21**

5 Empirical Analysis **26**

5.1 Hypotheses Formulation 26

5.2 Data & Methodology 28

5.2.1 Data 28

5.2.2 Portfolio Construction 29

5.2.3 GMB 30

5.2.4 Model 31

6 Empirical Results **33**

6.1 ESG data & samples description 33

6.2 Portfolio performances – single sort analysis 35

6.3 Portfolio performances – double sort analysis 41

6.4 Fama & French factors, GMB factor 48

6.5 Climate related risk premium 51
6.6 Explanatory Power of GMB 53

7 Conclusion 55

Bibliography 65

A List of Countries Used In Estimation I

Acronyms

APT Arbitrage pricing theory

CAPM Capital asset pricing model

CH4 Carhart 4 factor model

CMA Conservative minus aggressive factor

CI Confidence interval

CO2 Carbon dioxide

CSR Corporate social responsibility

ERV Excess realized volatility

ESG Environment, Social and Governance

ES3 3 years long ESG data sample

ES6 3 years long ESG data sample

FF3 Fama and French 3 factor model

FF5 Fama and French 5 factor model

FMB Fama and MacBeth model

GLS Generalized least squares

GMB Green minus brown factor

GMB3 Green minus brown factor based on 33% sort

GMB10 Green minus brown factor based on 10% sort

HML High minus low factor

NYSE New York stock exchange

OLS Ordinary least squares

RMW Robust minus weak factor

SMB Small minus big factor

WML Winners minus losers factor

Master's Thesis Proposal

Author	**Timur Bahodirovich Barotov**
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Proposed topic	Climate Change Risk Premium, Stock Returns and Volatility Analysis in Relation to ESG Score

Motivation The global warming, which is scientifically proven to be caused by human industrial activity in the last centuries is bringing about one of the greatest challenges that the humanity may be soon facing. Likely, the climate change will lead to great changes and disruptions in the most areas of modern civilization, unless radically acted upon, which however is not what we currently observe.

The new government regulations, sustainability demands by customers, supply chain disruptions, physical geographical changes due to the global warming and much more may significantly alter the current business world and create considerably different environment for corporate success in the future.

The question then is, do investors recognize such risk at all? Current business environment is being increasingly influenced by sustainability requirements, however still not at the rate that would be expected given the gravity of the situation. The environmental considerations could be increasingly incorporated into the financial evaluation methods to account for all the new risks and opportunities that will potentially arise. Failing to incorporate the environmental considerations in the evaluation procedures could lead to increasingly imprecise projection analyses, inaccurately portraying the future economic landscape. Thus, it is indeed in investors' best interest to account for such effects.

Capturing the precise quantitative effects of the climate change is of great challenge due to the relative novelty and the future uncertainty of the topic. There seems to be currently more inconclusiveness than an agreement between the researchers trying to estimate the effects of company sustainability on the returns. This combined with the fact that most analysts underestimate the importance of the climate change underlines the importance of intensified research efforts in this branch of study.

The regulatory push augmented by investment activities shifting towards the greener production could significantly speed up the process of transitioning towards the greener future. Based on the extent to which the environmental conditions may be disrupted, the topic of green finance might soon become more than a mere "cherry on the cake".

Hypotheses

1. Hypothesis: Climate Change Risk Premium Exists
2. Hypothesis: High ESG portfolio performance is similar to the typical market benchmarks
3. Hypothesis: High ESG portfolios are more stable than the benchmark
4. Hypothesis: Adding an ESG factor enhances explanatory power of the model

Methodology Main approach would be to rank the stocks based on ESG score and build the quintile (tercile or decile) portfolios to examine the performance of each portfolio based on Thomson Reuters ESG ranking. Usually, bigger sample allow for larger amount of portfolios, but it may not be relevant for this study to have deciles instead of quintiles. The portfolios would be equally weighted and follow the long minus short strategy and construction of ESG factor should follow Fama and French approach of high factor portfolio and low factor portfolio, to be in compatibility with other classical factors. This way these portfolios will be easily implementable with the popular models from Fama and French. Nevertheless, Drei et al. (2019) and also Bennani et al. (2019) advocate use of long portfolios arguing that in real world huge number of portfolios are actually long only and thus, it would better describe the reality. It may be useful therefore, to include such portfolio analysis as part of robustness checks. Stock excess returns are mostly computed on a monthly bases. Comparing portfolios of lowest and highest ESG scores among themselves and with the market wide benchmark should yield the answers to the chosen hypotheses. Multiple asset pricing models (such as CAPM, F-F 3 factor, F-F 5 factor, Cahart etc.) would be used to assure greater control of results and flexibility in making conclusions about the hypotheses.

Another approach may be proxying the selected companies' greenness to assess the gross sustainability that is being achieved in the given sector. As there is no general approach to this task, one possibility is to use the environmental disclosures by the companies to source the data for a proxy variable. These are typically found in annual reports or other dedicated reports. This procedure allows to proxy for company's transparency, and actual impact it has on the environment. On this basis CAPM model may be employed with the specification as in (Alessi, Ossola and

Panzica, 2021) to estimate our proxy variable of the corporate "greenness". The authors further base the core estimation time-invariant, linear factor model on the assumption of approximate factor structure of excess returns in the absence of arbitrage opportunities. Although, time variant model would be preferrable. The risk premium is defined as the sum of expected returns on the factor, estimated as a first moment, augmented by the parameter of the respective factor, which among other things captures also the transaction costs. Factors included in the model are market premium, size premium, book-to-market factor premium and momentum premium. Very similar to what Fama and French (2015) proposed in their five-factor model. The core model as proposed is then applied on four-factor Cahart model, three-factor Fama-French model and the CAPM. Robustness checks are then applied in respect to the sample of stocks, definition of sustainability proxy variable and the definition of sustainability factors.

Data on environmental transparency can be found on Bloomberg Environmental disclosure data, which constitute the Environmental aspect of the company. The time series data on factors and the risk-free rates are readily available on Kenneth French's webpage. The limitations of sustainability data are relative novelty of the field of research and additionally, the sustainability data are not required to be audited, unlike the financial disclosures. Thus, the study conclusions might be slightly biased, for companies may report sustainability data in a manner benefiting their own public image.

Another approach could employ general statistical approach to the estimation procedure that is useful for estimating the climate risk-premium based on temperature shocks without the need for imposing specific models is described by (Breeden, Gibbons and Litzenberger, 1989). Other studies such as Kapadia (2011) or Vassalou (2003), have employed this approach, which can be used as benchmark for specifying the main equation. Moreover, the same authors' studies offer alternative approaches as means of robustness check of the original model. Going further, applying the practice of bootstrapping should underpin the robustness of error terms, as pointed out by Jiang, Kan and Zhan (2014).

Data may be limited to US as Balvers, Du and Zhao (2017) point out due to the accurate financial data and temperature data availability. Fama-French factors and returns on portfolios are available on Kenneth French's website, temperature data may be obtained from National Data Center of Climate, and macro-economic variables are available at the website of Federal Reserve Bank of Saint Louis.

Expected Contribution Expected contribution of this thesis is to add an argument either in favor or against the existence of climate-associated risk-premium, using the high-quality data provided by the Thomson Reuters data base, using various recognized financial pricing models.

Moreover, currently there seems to be no consensus on whether the ESG measure is enhancing the explanatory power of the popular financial models such as Fama-French, Cahart or CAPM or its effect is being explained by other variables already. Thus, to contribute into the debate this thesis employs various financial models to examine the statistical significance of the additional ESG variable.

Such analysis must not miss on the investigation of the relative profitability of sustainable stocks (i.e. high ESG stocks or Low CO2 stocks). It is after all of the central importance to all funds managers to be knowledgeable of both risk and reward aspects of the given stock class. Just as there is no consensus on the usefulness of including the ESG variable, there also seems to be no consensus on the performance of the greener portfolio as compared to the typical market benchmarks. Again, employing various models may help us better understand the links that may or may not exist between ESG variable and stock performance and stability.

Finally, investigating the volatility of the sustainable stocks may convince some analysts to re-evaluate their risk-reward expectations on these stocks.

The study should be of use both to the real-life portfolio managers and the researchers, who would be interested in diving deeper into certain topics that will be included there or cite the results to augment their scientific arguments.

Outline

1. Introduction
2. Literature Review
3. Climate Change Future Trends
4. Evaluation Methods
5. Corporate Sustainability
6. Data
7. Empirical Analysis
8. Conclusion

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Author Supervisor

Chapter 1

Introduction

The recent climate change that is consensually driven by human activity represents one of the greatest dangers to the future of human civilization. Climate change involves the full-scale effect of the greenhouse gasses on the climate including natural causes, whereas global warming is a description of increased surface temperatures induced by human activity only. The largest driver behind the ongoing, artificial climate change are the emissions of gasses that are capable of causing the greenhouse effect in the Earths' atmosphere, augmented by both natural causes and climate feedback effects. These gasses are mainly carbon dioxide (CO2) and methane, these two gasses combined account for more than 90% of total gas emissions (Olivier and Peters, 2019). These gasses are emitted mostly as a by-product of burning fossil fuels for energy consumption globally, with minor contributions from other sectors (manufacture, agriculture, transport etc.). The scientific community has already reached the consensus that the ongoing climate change is indeed largely caused by human activity (Cook et al., 2016) and it is not being disputed by any large scientific body.

The most recent data on current warming indicate approximately 1.2 °C. Under the Paris Agreement in 2015, 195 nations have collectively agreed and signed up to keeping the global warming by means of mitigation efforts well under the threshold of 2 °C. Nevertheless, even if the pledges made under the Agreement were to be met the global warming would still reach the threshold of approximately 2.8 °C as of the end of the current century. In reality however, the governments are often not meeting their pledges of Paris Agreement entirely and thus, the current realistic expectation is the rise of global temperature of 3 °C or more by the end of the century. Keeping the temperature rise bellow

1.5 °C would require halving the emission of gasses by 2030 and neutralizing them by 2050 according to Rogelj et al. (2018).

The situation is worsening by day and although the possible apocalyptic outcomes are far away from today the relevancy of this topic increases by day, which is also why the research topics related to climate change are quickly growing in popularity in recent years. Some investors do not want to fall back and have already taken steps to integrate the climate change in their financial decisions using for instance, ESG score as a proxy for business sustainability. The main point is to avoid potential risks associated with climate risks, should investors ignore these risks the efficiency and rationality of their decisions will deteriorate with time and with it also possibly returns on their investments.

The government policies and regulations, public opinion on the climate related matters and conscious investors and businessman are all major factors that may push the current business landscape to a more sustainable direction which would implicate a lot of changes for all the actors in the economy. Governments will be forced to act and regulate the polluters as per peer government pressures and to meet the voters demands. Voters are becoming increasingly informed about the climate related matters demanding the action in exchange for their votes. Customers may increasingly discriminate business products based on their sustainability pushing the firms towards greener narrative and more sustainable ways of production. Investors assessing all risks at all times will surely react accordingly and may tighten the funds flowing in the direction of increasingly riskier polluting businesses. This is all in theory. Interesting idea would be to see if investors are already acting upon the mentioned problems and whether this changes the investing methodology that should be applied when thinking about equity investing. Although far from perfect measure, ESG score is currently among the best proxies for corporate sustainability and ecology available to investors. In this respect, this study performs several analyses using this exact score to gauge on the relationship between the ESG score and returns on equity, volatility of the rated firms and the relevancy of this measure in modelling the returns. This and similar types of studies should help reader better understand how climate related changes in the world that are grossly proxied by the measures such as ESG are impacting the investment practice. The outcome of this study is thus yet another piece of puzzle that could in the end help (even if marginally) make better investment decisions for all types of equity investors, mainly though based in Europe or US, since the data used for analyses is of European origin.

The first chapter investigates into the related literature of climate change associated topics in finance. How do “green” investments perform as opposed to “brown”? How does ESG fit into this picture, what are empirical results of other related studies? Do investors consider this problem already, or do they not pay enough attention to the related risks? Second chapter presents the most popular asset pricing models with detailed description of each that will be necessary to develop understanding of the results of this study. Then the different methods of proxying corporate sustainability are reviewed to give reader an idea how other authors approach this problem and how this study fits the literature. Then the parts necessary for empirical analysis are presented (data, factor construction, portfolio construction, model derivation). After the background for analysis was laid the results are presented with several charts and tables for better depiction of results and simpler understanding of the outputs. Afterwards, the study is concluded followed by an exhaustive list of literature cited in this study. Finally the appendices contain less relevant, yet still interesting tables and charts related to study, that are referenced in the study.

Chapter 2

Related Literature Review

2.1 Performance Comparison of Green & Brown Companies

In this chapter the literature review is conducted to find out how do more sustainable or greener companies perform in contrast to the brown or less sustainable companies. To tackle these and related questions the paper is mainly composed of three major areas of study: the asset valuation, sustainable finance, and equity investing. The literature on sustainable finance has so far focused predominantly on the corporate performance evaluation after introducing the sustainability measures in the company. As Early on the Porter (1991) shows by reviewing over 10 000 scholarly, government, book and web-based publications that companies' financial performance can be improved by means of improving the environmental performance, while not being necessarily accompanied by higher costs. Porter and van der Linde (1995) later also demonstrate the inefficiency that resides in the pollution due to the hidden costs such as flaws in product design or bad resource economy, augmented by negative regulatory and competitive implications for the polluters. Authors also emphasize the possibility of the competitive capabilities of "green" corporate strategy. Ambec and Lanoie (2008) in their systematic review demonstrate that the number of scientific empirical studies on challenging the paradigm of companies' greenness being necessarily more costly, yields the results contradicting this paradigm, showing the possibility of positive correlation between the environmental performance and financial or economic corporate performance.

Although the increasing amount of literature on performance of sustainable companies is available there seems to be no consensus reached concerning the performance of sustainable assets or pricing the environmental risk as a single macro factor. This inconclusiveness is a major factor of detest for investors that do their best to avoid the unnecessary risk and thus also the inconclusive evidence. Available academic literature yields mixed results based on the performance comparison of sustainable investments as compared to conventional (for example Renneboog et al. (2007) or Statman (2000)). Hartzmark and Sussman (2019) suggest that the sustainability is a positive predictor of future performance, meanwhile finding no evidence of highly sustainable funds outperforming the least sustainable funds. Given the evidence mentioned in ESG section of the study, this may be due to the long-term nature of incorporating the sustainability, thus longer-period data coverage would be required to witness any positive changes. Second reason for this effect may be that the funds are granted a return in proportion to the risks that their portfolio choice undertakes. Indeed sustainable firms are less risky than the highly polluting firms, which in theory yields negative risk premium for the greener companies. In another instance Bolton and Kacperczyk (2019) and Trinks et al. (2018) both produce conflicting evidence, where former ones suggest there are higher returns associated with the higher CO2 emission (one standard deviation increase in emissions associated with 2% increase in expected return p.a.), whereas latter suggest that divestment from fossil fueled companies does not hurt the portfolio performance. Some studies suggest the underperformance of green stocks on average, based on analysis of publicly traded companies, which may indicate investors' willingness to earn relatively less on an investment in order to hedge themselves against the long-term environmental risk. Hsu, Li and Tsou (2020) demonstrate that there is a spread (long-short portfolio, 5.2% p.a.) in average returns of high and low carbon firms, where investors expect higher returns on more risky assets (pollutants) due to the uncertainty about the development of environmental policy. Morgan Stanley (2019) with their financial analysis on the 11 000 mutual funds in the period from 2004 to 2018 report that median return of sustainable funds was comparable on average with the traditional funds, and they also exhibited lower volatility, making them more stable. Similarly, Eccles et al. (2014) presented the evidence that more sustainable companies are more likely to have a higher abnormal returns and lower volatility as compared to the less sustainable firms.

From this evidence it seems that strong polluters exhibit an extra risk premium for an increasingly risky nature of its core business due to environmental awareness. However, there seems to be no agreement among researchers on whether the sustainable portfolio performs better or worse than the traditional one. Thus, it may be plausible to believe that the truth is somewhere in the middle and that the answer depends largely on the details – as reported by Morgan Stanley (2019) where they show that there is no great difference on average, between sustainable and traditional funds returns. What is consensual, however, is a significant risk and volatility decrease in case of sustainable stocks.

2.2 ESG & Other Sustainability Measures – The Inconclusive Evidence

There are numerous ways in which one can proxy the corporate sustainability. Researcher usually makes a choice on which measure to use mainly based on the data availability rather than the true underlying nature of the measure. Some are simpler to access via many rating organizations (such as ESG), some are less accessible, such as some researchers have decided to go manually through the many of the company annual reportings to obtain the data on sustainability. Although ESG is not a perfect measure, taking into consideration also social and governance issues (not environmental in isolation) it has an advantage of relatively high popularity and recognition on top of being widely available throughout the paid databases. This chapter shows what literature has to say about this score as a sustainability proxy. For instance, in a Recent study Hoepner et al. (2018) demonstrate on proprietary database (1712 engagements across 573 targeted firms, 2005 to 2018) that engagement in environmental social and governance (ESG) issues lead to significant shareholder' downside-risk reduction. Although numerous studies find ESG measures relevant addition into the stock analysis, evidence suggests that it is still not being widely implemented. Cappucci (2018) provides with possible explanations for why the ESG information, although widely recognized is oftentimes in practice not being considered by asset managers. These ideas are focus on short-term performance of fund managers, poor data quality, differing measurement standards, increased costs and underperformance. Author furthermore argues that to fully reap benefits of ESG integration, the companies first go through the "valley" of lower returns as a result of the ESG integration-related costs which is not acceptable for many short-termed asset managers. It is particularly the remuneration of management in the firm that may motivate the short-term mindset, rather than the long-term corporate growth and gradual increase in value. Thus, positive quarterly results become more relevant to these managers and to the public than the actual value enhancing projects, that require time to implement and grow. Eccles, Kastrapeli and Potter (2017) deliver in their survey very similar results to Cappucci (2018) in their survey of 582 institutional investors across the continents. Main issues with ESG incorporation is the belief that it requires to sacrifice returns, short-term focus on returns (fiduciary duty) and lack of high-quality data. Moreover, Atz et al. (2020) contribute with their meta-analysis finding that sustainability is positively correlated with corporate financial performance (60±7% of studies were positive), whereas ESG investment performance is found to be indistinguishable from the conventional one (with only 1/3 of all studies indicating a superior performance). Moreover, author argues that this positive relationship between sustainability and financial performance is conditioned by the long-term period of implementation. They also found that the current ESG corporate disclosures are insufficient. More recent study conducted by Stotz (2021) applies a return decomposition to solve for a puzzling conflict between realized and expected returns on stocks. Empirically, author argues stocks with high ESG score tend to overperform those with low score, whereas in terms of future expectations high ESG stocks are performing worse than low ESG stocks. Stotz (2021) also found that high ESG stocks are discounted less intensely than low ESG stocks, contributing this difference to the demand of investors with ESG preferences rather than increased risk.

Couple of recent studies show that incorporating ESG information into global market neutral portfolio yields no changes to the returns because the ESG effect is already captured by other well-known equity factors (SMB, Momentum, Low Volatility/Low Beta) (Breedt et al., 2018), (Ngo and Tam 2020). Thus, the authors conclude the ESG should not be considered a unique equity factor and that the incorporation of ESG companies does not seem to hurt the portfolio returns. In a faint contrast to these findings, Becchetti, Ciciretti and Dalo (2016) found that the CSR risk factors, and other traditional risk factors used in asset pricing literature are uncorrelated, implying the necessary inclusion of these factors to the model. Similar results were yielded in a study by Akbar et al. (2021), where authors claim that incorporation of carbon risk factor does better job at explaining the variation in stock returns than the conventional five or three factor asset pricing models. These studies contrast previous ones in that the environmental measures are not well incorporated in the traditional asset pricing models. Adding more to this controversy, justifying the use of ESG, Maiti (2020) as well as Scholz (2020) found a positive evidence on the usefulness of incorporating the ESG factor in the asset pricing models. Maiti (2020) points at the statistical significance of ESG in his analysis, while showing the dominant performance of FF3 that includes size, market risk premium and ESG factors as opposed to plain FF3 model. In a similar manner Scholz (2020) shows that ESG factor significantly increases the explanatory power of CAPM, FF3 and FF5 plus the momentum factor asset pricing models, which is in direct conflict with the previously mentioned studies. Bennani et al. (2018) support preceding authors with their findings that ESG does increase explanatory power of the models utilized on European data, but not on US data. This, however, may be due to the stronger climate-related regulations in Europe as opposed to US. Moreover, authors show that the ESG investing was penalized between 2010 – 2013 and much more beneficial in more recent period 2014 – 2017 arguing that ESG investing can be viewed as both the alternative risk assessment model and as an investment style, in which case the ESG investing cannot be compared to the traditional investment styles which are purely centred around financial returns (since ESG investing is mainly motivated by extra-financial motives). Interestingly, it is often relatively older studies (2018) that find the ESG measure an irrelevant addition in asset pricing models as opposed to the newer studies (2020) that argue in favour of the opposite effect. Thus, one explanation may be that ESG related investment is relatively new, and the environmental crisis related topics began its significant acceleration just recently. In a scientific area that is new and largely unresearched such as the ESG and related research - it is not surprising that reaching a consensus will take much more time and effort.

2.3 Pricing In The Climate Change & Public Awareness

Before conducting any analysis it would be useful first to see whether investors are already aware of the climate related problems and whether or not they are acting upon them. In most recent studies there were attempts at constructing the portfolios capable of hedging against the climate change risks, where however, not many authors go as far as to quantify the respective risk premium. Amel-Zadeh and Serafeim (2017) report based on the review of investment professionals that ESG information is mainly perceived as risk indicator rather than the competitive positioning indicator. Also Atz et al. (2020) found in their meta-analysis that ESG investing provides downside protection, especially in the periods of socio-economic crises and that the risk management is one of the main reasons behind ESG investing. Hong et al. (2019) investigate how exacerbated droughts caused by climate change are affecting the food stock, suggesting lower returns on publicly traded food-supplying companies and thus, the underreaction of the sector to the climate change risks. Goergen et al. (2019) create measure of carbon risk the “carbon beta” via “Brown-Minus-Green” factor based on ESG databases. Monasterolo and De Angelis (2020) conduct research based on low and high carbon intensive assets on US and EU markets to see whether the Paris Agreement was effectively priced in. They found that after the Paris Agreement correlation between low carbon and high carbon indices drops, the overall systematic risk for low-carbon indices decreases consistently all while reaction of carbon intensive stocks is only mild. All in all authors conclude that investors began to increasingly invest in low carbon assets after the Paris Agreement, while the carbon intensive assets are not yet being penalized. Choi et al. (2020) using google search services show that in periods of abnormally warm weather, high carbon stocks tend to underperform as compared to firms with low carbon emissions, contributing such behaviour predominantly to retail and not institutional investors, with no sign of reversal in the long-term. Alok et al. (2020) show that money managers tend to overreact to the large climatic disasters if they are located within the disaster region, underweighting the disaster zone stocks contributing the bias to the salience of the event, rather than the superior information as opposed to the more distant fund managers. Engle et al. (2020) implement the procedure to dynamically hedge the climate risks based on textual analysis of newspapers. Authors document that the greener companies ‘stocks (high E-score), which are subject to the lower exposure of regulatory risk, tend to outperform when negative climate related news are released.

Investors do seem to appreciate the company’s efforts to mitigate its climate risk, which is then translated to the higher appraisal of the stock. For instance, Perez-Gonzalez and Yun (2013) show based on the firm weather data, CBOE contracts that the companies that hedge against the climate change receive higher valuations and even more so if those firms are climate-sensitive. Karydas and Xepapadeas (2019) also confirm the role of climate change risk premium, which is positive and increasing, employing the asset-pricing model with rare events and the time varying probabilities. In the survey conducted on institutional investors Krueger et al. (2020) report that these investors are aware and do recognize that the risks of climate change and its implied risks (particularly the regulatory and moral) have already begun to materialize. Surveyed investors also believe the equity market has not yet fully priced in the climate risk, but they also believe that the supposed changes to valuations are not very large. Divestment seemed to be the least frequent strategy to address the climate change, engagement (i.e. adapting and reshaping business) is the dominant strategy to protect portfolio against the climate change. Last but not least, authors conclude that the incorporation of climate risks is still in its early stages and point out that many firms do not even consider the basic approaches to hedge against these risks, where it is especially the larger institutions that are better prepared for the climate change, due to their very long-term investment horizon. Amel-Zadeh and Serafeim (2017) and Cappucci (2018) reinforce these results by showing that negative screening is the least suitable strategy of incorporating the ESG information and leads to lower performance in contrast to more suitable strategies such as positive screening or engagement in the company management. Similarly a meta-analysis and review paper show that ESG integration is a dominant strategy to divestment or screening strategies (Atz et al., 2020). All in all researchers suggest that investors should try and influence corporate management to adapt the climate related changes in the company to better position themselves for future development, rather than to divest from these companies or ignore them altogether.

2.4 Climate Change Risk Premium

The existence of significant risk premium on companies that are less sustainable could shed a light on the investor awareness and action upon the climate related risks. The academic community seems to recognize the existence of a climate risk premium showing that investors are to a certain degree already demanding the compensation for carbon risk exposure, although it seems to be a rather under-researched area as of now. Balvers, Du and Zhao (2017) for instance, employ the APT model using temperature shocks as systematic risk factor thereby finding the significant and negative risk premium with the growing effect on the equity pricing in recent years. The cross-sectional average cost of equity capital was associated with 0.22 % increase on an annual basis, which authors associate with 7.92 % loss of wealth in present value, due to the uncertainty of the future temperature changes. Lucia, Ossola and Panzica (2019) in another instance, found evidence of the existence of negative "greenium" (risk premium linked to greenness and transparency) based on European stock returns, proposing its use as a tool of assessing the portfolio exposure to the low-carbon transition risks. Authors explain that the negative risk premium implies investors are willing to accept ceteris paribus lower returns to hedge against the climate risks. Authors furthermore warn against "greenwashing", where companies often portray themselves as greener than they actually are. Oestreich and Tsiakas (2015) use EU Emissions Trading Scheme to prove the existence of statistically significant and large "carbon premium" on German stock returns data, which is according to authors mainly explained by free cash flows from the scheme. Similarly, Bolton and Kacperczyk (2019) produced evidence based on US stock data of statistically significant "carbon premium", while being unable to explain the premium using conventional risk factors. Moreover, Bolton and Kacperczyk (2020, 2021) show existence of carbon premium in all sectors across large continents (Asia, Europe, North America), which is reflected in higher stock returns on companies with higher carbon emissions. Authors argue that the carbon premium has been rising in recent years and that the widespread divestment of institutional investors, based on this carbon premium is being observed. Also Akbar et al. (2021) found statistically significant climate premium among bigger companies and the ones residing in developed nations, putting pressure on bigger firms to account for CO2 emissions. In contrast firms in developing nations or smaller companies generally, showed to be absent of the climate risk premium incorporation, thus being more prone to negative impacts of climate risks.

All this evidence implies a significant and rising positive correlation between stock returns and carbon emissions. Although the environmental issues are being recognized by asset managers, evidence suggesting that the current market pricing of the climate risks is not accurate, implying the exploitable market inefficiencies (Choi et al., 2020), (Bernardini et al., 2019), (Jiang and

Weng, 2019), (Bolton, P. and Kacperczyk, M., 2019). As Ciciretti, Dalò and Dam (2019) points out, at certain periods of time there is an ongoing shift in demand of investors towards greener assets (perhaps as a result of significant regulatory actions). It is these periods, when the associated lower expected return on high ESG stocks (as many authors have already confirmed) might seem to be mitigated, or even overcompensated, so that the greener stocks yield above average returns on stocks. However, as authors point out, this effect is temporary and in the long term unsustainable. Finally they estimate that one standard deviation decrease in ESG score resulted in an increase of 13 basis points in monthly expected returns, implying negative ESG premium.

2.5 Summary of Related Literature

The topic of climate change and related investment changes seems to grow in popularity in recent years, especially in more developed countries. Performance wise there seems to be no simple rule or correlation to sustainability measures. Polluting companies tend to overperform more sustainable companies because these are riskier and thus have to compensate investors for all the additional risks related to the polluting nature of their business. However during certain periods sustainable companies may produce abnormal returns, especially when the news are flooded with negative climate related information. Studies do agree, however that incorporating and increasing ESG score within the company leads to lower volatility of the stock and a downside risk protection. Implementation of sustainability measures seem to lower expected returns of the company in the short run, with positive effects on return in the long run. Corporate and portfolio managers are often times remunerated in a manner that supports short-sighted behaviour concentrated on immediate results. Long term growth initiative may suffer because of this. Researchers do not seem to agree on whether the ESG measure should be used in modelling or not, producing contradicting results. Although ESG score is widely accepted measure of sustainable company development the data quality is very variant and different data providers produce different estimates on the same firms. Moreover, firms have incentives to exaggerate ESG score reflecting false image of their business. All these issues prevent investors form relying on and using these measures in a serious manner. Public awareness is increasing, however studies suggest the related risks are not being properly integrated in modelling the future business returns. Among the strategies that investors employ – the divestment was found least suitable and engagement the best, reshaping and adapting firm on new conditions, instead of abandoning it. All in all the climate related company risks is a growing area of research with increasing number of investors seeking to hedge against those risks. As the time goes on, modelling of the future asset returns will be increasingly inaccurate without considering climate related risks, especially in case of large conglomerates.

Chapter 3

Overview of Asset Pricing Models

One of the most intriguing questions in finance is what and to which extend do various economic factors influence the return on assets which could also help in explaining the cross-sectional differences in expected returns on those assets. Among the most popular approaches attempting to provide with an answer to this question are Sharpe's (1964) CAPM, various Fama-French (1993) model variations, utilizing number of different factors (such as size, momentum, value etc.), two pass regression as by Fama and MacBeth (1973) (FMB) or variety of inter-temporal and consumption models explaining expected return on assets as a linear function of corresponding betas, depending on the economic fundamentals.

In this part the author illustrates evolution of the asset pricing models, from its very basic design as first outlined by capital asset pricing model (CAPM) through the on-built versions of improved CAPM models – the Fama-French three-factor model, Carhart four-factor model to the latest improvement, the Fama-French five factor model. Each newer version of the model is ought to bring some improvements in explanatory power, although, at the same time, each of them contain certain specific anomalies that hinder the model's usefulness, and thus, it is difficult to pick the one that would definitively dominate others in terms of its performance. Even though there is no clear winner amongst these models, they certainly do a great service in supporting the creation of an informed decisions made by investors by helping to forecast the expected returns on the stocks or portfolios.

3.1 Capital Asset Pricing Model (CAPM)

The very first contribution in this respect was made by Markowitz (1952) in his dissertation thesis the Portfolio Selection, where he outlines the very basic theory of portfolio selection, on which the famous capital asset pricing model was based, describing the relationship between risk and return of a given investment (Bodie, Kane, and Marcus, 2014). The CAPM was created in 1960s by the William Sharpe, John Lintner, Jan Mossin and Jack Treynor. CAPM identifies the "fair" returns on an investment by considering different types of investment risks. The model introduces the beta variable, measuring the systematic or undiversifiable risk of an investment, relation between the efficient frontier and the capital market line, and four categories of risk. Two of them are the essential building blocks of the model – the systematic and unsystematic risks. Specifically, systematic risk measures the variability of an asset that is not diversifiable, and thus cannot be removed from the market portfolio, since the risk stems from the broad market conditions and the state of the economy as whole. Unsystematic risk is on the other hand diversifiable and specific only to the individual assets rather than the market or a broad economy. This is then incorporated into the model, taking the form of a common regression factor. Contribution of this model is rooted in the linear relationship between the expected return of a given asset and the associated risk that is composed of the systematic and unsystematic risks:

$$E(r_{it}) = r_{ft} + \beta_i[E(r_{mt} - r_{ft})] + \epsilon_{i,t}$$

where the left-hand side represents a return on an asset i, r_f stands for the risk-free rate, β_i for the measure relating the change in asset i's return to change in the market portfolio return. Or, as by words of Brealey, Myers and Marcus (2012), the CAPM may be defined as a "theory of the relationship between risk and return which states that the expected risk premium on any security equals its beta times the market risk premium". r_f typically being represented by an investment rate of return on government bonds, that bear little to no market-associated risk is therefore called a risk-free rate. Such asset has β close to zero. β_i effectively measures a correlation between stock i's and market portfolio's return, if it is larger than 1 then returns on an asset are more volatile than the market returns (market portfolio has $\beta_i = 1$ from definition). Less volatile assets are associated with β_i less than 1. Coming from the capital market line and efficient frontier as defined by Sharpe (1964), this model considers the volatility of asset returns as a proxy for risk, which is negatively related with the expected returns. Thus a higher expected rate of return on an asset is achievable only by incurring a higher risk (volatility) according to the CAPM. Ultimately, the goal of each investor is to optimise risk for maximum achievable return (or vice versa) and that's where this model is most useful.

3.2 Fama-French Three-Factor Model (FF3)

As showed before, CAPM is useful tool with an added value to investing analysis, nevertheless, the model is very simple, and it did not avoid critique (Womack and Zhang, 2003). As noted by Fama and French (2004), one of the most influential researchers on the given topic, the CAPM has never been an empirical success by the words of authors. CAPM seems to be yielding the results that are different from the resulting expected return. Nonetheless, Fama and French (1993) found in a study on 25 US equity portfolios that beta used in CAPM is able to explain approximately 70% of return of the market (actual return). Authors then proceeded with the creation of a new on-built model FF3 on the CAPM in an attempt to explain the rest 30% of market return that CAPM could not explain. They have added two additional variables that showed to bear significant explanatory power over the portfolio performance– the value and size factors. Fama and French (1992, 1993) demonstrated in their study that the value stocks are likely to yield abnormal returns as compared to growth stocks. Similarly, the firms with low market capitalization or size tend to outperform the larger-cap stocks. Thus, the creation of two new factors was inevitable: the small-minus-big (SMB) addressing the size risk premium and high-minus-low (HML) addressing the value risk premium. The rationale behind the new variables is the fact that smaller companies are at a greater risk of default, and thus, investors demand a premium on their investment for an extra risk they must bear. Analogically, the high value companies are less likely to fall and fundamentally better valued than growth companies that are often evaluated based on future expectation of its performance. This future guessing makes company overvalued and thus, to the lesser extent based on reality, which again is a risk factor for which a rational investor is ought to demand some kind of risk premium. As of that moment the augmented asset pricing model (FF3) included three factors in total: size of the firm, book-to-market value, and excess return on the market portfolio (also market risk premium), (Womack and Zhang, 2003):

$$E(r_{it}) = r_{ft} + \beta_1[E(r_{mt} - r_{ft})] + \beta_2 SMB_t + \beta_3 HML_t + \epsilon_{i,t}$$

where newly added factor SMB is calculated as the return on stocks with small market capitalization minus stocks with large market capitalization and HML as the return on high book-to-market value stocks minus return of low book-to-value stocks. β_2 represents a measure of risk exposure to the size risk and β_3 measures the exposure to the value risk. Numerous papers have found that in fact this model do perform better than the CAPM in predicting the excess returns on stocks. For instance, Womack and Zhang (2003) found that the CAPM has R^2 equal to 0.85, whereas the FF3 model yielded R^2 equal to 0.95 in their analyses. In another instance, Karp and Vuuren (2017) show that FF3 model outperforms CAPM when conducting study on 46 JSE stocks in the period of 2010 – 2015 (in their study the adjusted R^2 range was 11.3% - 50% for FF3 model and 3.1% - 6.3% for CAPM). However, some studies also point out the deficiencies of FF3 model and imply that it is in fact does not perform much better than the CAPM in explaining the return. Bartholdy and Peare (2004) showed that the R^2 of the FF3 is very low, approximately 5% compared to the R^2 of the CAPM of 2%. Or Lam (2005) points out that the FF3 model outperforms CAPM based on the 25 portfolios, but it does underperform the CAPM if the empirical analysis was based on 30 different industries.

3.3 Carhart Four-Factor Model (CH4)

The next evolutionary step in the asset pricing model was contribution made by Carhart (1997) who proposed expanding the FF3 model by adding a fourth factor – the momentum factor, arguing it would lead to improved performance of the model. Even before Carhart's contribution, Jagadaesh and Titman (1993) pointed out a tendency for either good or bad performance of stocks to persist over several months, also Fama and French (1996) communicated that the FF3 model of their creation was unable to explain the continuation of short-term returns. This tendency is known as momentum effect, where stocks tend to continue rising, if they have been rising for some time already, and vice versa with declining. Carhart, therefore, upgraded the model by adding a momentum factor to a FF3 model and evaluated the mutual funds' performances, not the individual stocks performances as in Fama and French. Similarly as with other factors before, the new factor winners minus losers (WML) is created by subtracting the excess returns on loser stocks that have been losing value from the winner stocks that were rising, based on 1 to 12 months of past returns (Bodie et al., 2014). Thus, CH4 takes form:

$$E(r_{it}) = r_{ft} + \beta_1[E(r_{mt} - r_{ft})] + \beta_2 SMB_t + \beta_3 HML_t + \beta 4 WML_t + \epsilon_{i,t}$$

where except for the usual variables, $\beta 4$ and WML have been added. Although adding a momentum factor looks appealing, not everybody was persuaded by its empirical performance as compared to CAPM or FF3. For instance in one study authors An-Sing and Shih-Chuan (2009) demonstrated that the FF3 performs better on Pacific Basin markets, than the CAPM, but the same cannot be said about the CH4. Authors went as far as to say that their study yielded no evidence that CH4 performed better than the CAPM and that the FF3 performed better than the CH4. Bello (2008) had an opposing view, where in his study he evaluated mutual funds instead of individual stocks and pointed out that the CH4 was a significant improvement as compared to the older FF3 model. Another study researched the role of CH4 model on American association of individual investors' portfolios, using Jensen's alpha, CAPM and CH4, stating that the CH4 had a highest explanatory power of all the tested models. Overall, it does seem that there are specific conditions under which CH4 yields very good results and in other situations it is perhaps better to rely on the older models. As pointed out, CH4 is better at explaining returns on mutual funds than the individual stocks.

3.4 Fama-French Five-Factor Model (FF5)

Another step in the model evolution was an addition of two additional factors by the creators of FF3 model, namely the profitability and investment factors. Fama and French (2015 a) recognize that the FF5 can perform better as compared to the older FF3 model to predict average stock returns. Authors found inspiration to add the new variables from the dividend discounted model, which infers that a value of the stock is equivalent to the discounted cash flows (or dividends) that an investor can expect the stock would yield during its life (Fama and French, 2015 a,b). Profitability factor attempts to explain the positive correlation between the profitability of company and the returns on stock. Investment factor is added to explain the negative relation between the internal investments (usually financed from its profits) and the average return on stocks. Thus, FF5 model is mathematically described as follows:

$$E(r_{it}) = r_{ft} + \beta_1[E(r_{mt} - r_{ft})] + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 CMA_t + \beta_5 RMW_t + \epsilon_{i,t}$$

where RMW stands for robust minus week (i.e. profitability factor) and CMA stands for conservative minus aggressive (i.e. investment factor). As with previous models, even here the consensus about the FF5 model performance is not uniform. Huang (2019) shows on Chinese stock market that the FF5 dominates traditional asset pricing models in explaining the individual stock returns. Another study investigating the performance of FF5, FF3 and CAPM models on Nordic stock data sample, yield the favourable results for FF5, stating that it has the best explanatory power of average stock return of all the models that were considered (Sundqvist, 2017). Indonesian stock market analysis conducted by Wijaya, Irawan and Mahadwartha (2018) resulted in insignificant relation between profitability and the return, but significant negative relation between both the size and investment factors and the average return. The model constructors themselves analysed the model on important international localities (US, Europe, Asia Pacific) finding proof on the tendency of average returns on stocks to grow in line with B/M ratio and profitability, whereas they observed negative relation between investment and the average returns in accordance with model expectations. However, in case of Japan they found the profitability and investment relation to returns to be somewhat weak. Authors continue with findings of anomalies that FF5 produces – model seems to be unable to explain the low average returns on small stocks, whose returns are behaving in a similar manner as returns of firms with high level of investment, despite low profitability (Fama and French, 2015a). Study by Blitz, Hanauer, Vidojevic and Vliet (2017) point at five anomalies produced by FF5 model. First of all FF5 is based on CAPM, which relates the systematic risk that is captured by beta and return on an asset, several papers exist showing evidence that there is no straight relationship between beta and returns. Secondly, FF5 fails to incorporate momentum factor, which is viewed unfavourably by the authors, because of the recognition that this factor has received. Next anomaly is concerns over the robustness of the new additional factors of FF5 as opposed to FF3 in cases when FF5 fails to explain the variables that are related to these two newly added factors. Fourth anomaly is the lacking economic rationale of the profitability and investment factors as opposed to the older factors which were justified by the risk-based explanations. And lastly, as with previous models, FF5 does not seem to reach consensual agreement on its performance.

Chapter 4

On Building a Proxy For Sustainability

This chapter represents how some of the renown or high quality studies approached the problem of sustainable investing, their methodology and data sets used for analysis. Mostly authors rely on Fama-French models and methodology in regression analyses or in constructing the sustainability factors. Used proxies are usually CO2 emissions, ESG score, scope1-3 emissions and other corporate reports disclosures. Starting with Akbar et al., (2021) who argue that the scientific literature recognizes two distinct types of risks that exert an influence on the variations in returns on the investment in certain assets: the systematic (undiversifiable, market) risk and non-systematic (diversifiable, non-market) risk. The systematic risk is being represented by the beta factor, which results in greater asset volatility and thus the higher demanded premium on an investment in order to compensate for greater volatility which in finance is usually perceived as a risk measure. The climate risk is considered to be undiversifiable risk that has the potential to influence the whole market, that ought to be priced in on a fairly priced asset. In case the pricing model functions well and is able to capture most of the asset variance in expected returns, then the average values of the portfolio intercepts should be statistically converging to the null. Thus, the intercept is in the scope of time series regression thought to display the pricing errors, implying that the smaller value of intercept is desirable (greater intercept values would mean the model is less efficient in explaining the variance in the asset returns). Authors construct market value, size, book equity, operating profit, investment, book-to-market equity and climate change factors in accordance with the established approach by Fama and French (1993, 2015, 2017) for each region. Climate change risk factor was estimated as total CO2 corporate emission. The undue weight of small-cap stocks is accounted for by using the NYSE breakpoints for firm size and other variables, in accordance with Fama and French. These factors were then used as 2x3 sorting base of the portfolios constructed at the end of June(t). The dollar returns were estimated from the perspective of US investor by using 1-month US treasury bill rate as a risk-free rate. To evaluate portion of average returns explained by regression intercepts and also to identify the redundant factors, factor spanning tests were performed. Adding a new variable considering carbon associated risk requires for model performance examination to see if the variable has any substance in the equation. Authors used F-statistics as proposed by Gibbons, Ross and Shanken (1989), to test the hypothesis that the slope of all regressions is jointly zero.

In another study, Alessi, Ossola and Panzica (2021) explain that although there is a number of indicators available to measure company's environmental friendliness, the consensus has not yet been reached on which indicator is best suitable to proxy corporate environmental performance. The great source of information in this regard is corporate environmental disclosures, typically released as a part of an annual corporate report, or in separate reports (Corporate Social Responsibility, Sustainability, ESG release or Corporate Governance report). These disclosures serve investors as a prime source of assessing information about company's greenness and transparency. Authors decided to combine two measures: i) Environmental transparency (measured by quality of firm's disclosures) and ii) Greenhouse gas emissions. The corporate environmental transparency was proxied by Bloomberg Environmental disclosure score (E-Score), which is an index quantifying the completeness of corporate environmental disclosures. Authors assumed higher E-score implies higher transparency, since green companies are much more likely to engage in non-mandatory environmental disclosure than the brown companies, thus arguing that on average transparency should be correlated with greenness. To model risk premium authors made use of time-invariant linear factor model under the assumption of approximate factor structure for excess return and absence of arbitrage opportunities. Modelled factors were excess return on European, value weighted market portfolio, size factor, book-to-market equity and momentum factor. Risk-free rate was based on 1-month T-bill by Kenneth French. The reason why authors used CH4 instead of FF5 is that they argued

4 factors are enough to explain excess returns in time-invariant model in line with Gagliardini et al. (2019). To investigate the drivers of excess returns for portfolios authors employed CH4, FF3 and CAPM models, having an unbalanced panel of 942 stocks, lagged by one year to account for publication lags. Finally, to investigate whether greenness and transparency factors influence European stock returns they have tested for risk premium using linear factor model modified only by additionally adding the greenness and sustainability factors among the observable factors. Authors furthermore estimate risk premium for observable factors using individual stocks as in procedure suggested by Gagliardini et al. (2016), which is suitable for unbalanced panels and thus allows to estimate model on individual shares and not necessarily portfolios. Limitations of their study being the self-reporting nature of environmental disclosures, prone to biases since these are not required to be audited for majority of the companies. However, this should not interfere with estimation results too much, since investors are basing their decisions on the very same information that were gathered by the authors. Other biases include self-selection and differing ESG ratings across different data providers.

Bolton and Kacperczyk (2020) explain that corporate carbon emissions are grouped into three categories or scopes where scope1 accounts for direct production-related emissions, scope2 accounts for indirect emissions resulting by its purchase and consumption of electricity, production materials, waste management or outsourced activities and scope3 accounts for upstream and downstream indirect emissions. While scope1 and scope2 data are widely available in company reports, scope3 emissions are usually estimated based on input-output matrices. Using these, authors estimate carbon risk premium (long-green, short-brown portfolios) with respect to the total level of corporate emissions, annual change in those and lastly in relation to the emission intensity (i.e. carbon emission per unit of revenue). Control variables included size, book-to-market equity, leverage, return on equity, momentum, Herfindahl concentration index, property plant and equipment, beta, volatility, sales and capital-expenditure-to-total-assets. Authors investigate the determinants of carbon emissions (i.e. the difference in characteristics of companies that do report and do not report the carbon emissions). Secondly, authors relate the emission levels, growth and intensity to the stock return in cross-section, using pooled OLS and year/month fixed effects. Since emissions tend to cluster according to the specific industries authors further include the industry specific fixed effects, employing Trucost industry classification. Authors also include the several robustness checks to avoid for instance, look ahead effect, when the data on emission in year t are regressed on the return in the same year t (it takes some for information to arrive and be absorbed by the market). Thirdly, authors using the time-series regression model try to find out whether the carbon premium is linked to some traditional risk factors. They found that carbon premium cannot be explained by those known risk factors, which implies that the level of carbon emissions contains independent information on cross section of average stock returns. Next authors test whether the observed carbon premium could be explained by divestment hypothesis (i.e. institutional investors are divesting from high carbon stocks which results in under-diversification). They find that limited risk sharing caused by divestment cannot alone explain the return premium on high carbon and growth of emissions. Furthermore authors test whether the results are disproportionately driven by the most significant few carbon emitting sectors and whether periods of higher awareness of investors about carbon risk could affect carbon premium.

Ciciretti, Dalò and Dam (2019) employ CAPM, FF3 and FF5 models and augmented versions of these that included momentum (Carhart 1997) and ESG risk factor in the spirit of Becchetti et al. (2018). In order to assess the contribution of the ESG variable and related betas in explaining variation in the cross-sectional average expected return authors employed approach by Chordia, Goyal, and Shanken (2017). Their method was based on the two pass procedure inspired by Fama and MacBeth (1973) applied not on the portfolios but on individual stocks instead. In second stage the cross-sectional regression of both the firm characteristics and betas were included. Authors furthermore dealt with finite-sample issues in estimation process and used the obtained results to estimate the measures of relative contribution of betas and characteristics.

Hubel and Scholz (2020) used ASSET4 database to fetch ESG data combined with EIKON database to obtain closing prices, risk-free rates or total returns on constituents of STOXX Europe Total Market Index, that is covering majority of market capitalization across the 17 European states. They have constructed ESG factors following Fama and French (1993) approach, unconditionally sorting stocks into six portfolios based on market capitalization and environmental rating, median size and terciles of the environmental ratings served as breakpoints. They proceeded with creating four monthly value-weighted return portfolios: small size + low environmental score, big size + low environmental score, big size and high environmental score and small size and high environmental score. As ESG ratings are updated annually, they have decided to sort portfolios on yearly basis. These variables were then used to create a factor: $ENV_t = 0.5(SL_T + BL_t) - 0.5(SH_t + BH_t)$, that proxies time variant market evaluation of the environmental risks given by the difference in return between "brown" and "green" firms. This factor, together with social and governance factors created in the same fashion were then plugged in to the FF5 model augmented by CH4 momentum factor.

Chapter 5

Empirical Analysis

5.1 Hypotheses Formulation

The main forces driving the transition to sustainability are constituted by government regulations, corporate reputation among customers and conscientious consumer. Firms are accommodating their activity with respect to the regulations, which usually aim at increasing the costs of operating unsustainable business. The transition to sustainability is usually costly and requires upfront investments into firm capital which prevents most firms from transitioning with ease. Subsidies such as employed in European Union are increasingly devised aiming to aid this transition. Firms are further motivated to transitioning by consumer increasing awareness resulting in altruistic behaviour of some portion of consumers who choose to avoid products and services of firms that are known to be a significant polluters of the environment. That's where corporate prestige is at stake, further motivating firms to transition or at least to create an image of business transition to more sustainable operation. This is unfortunately often the case where the biggest part of corporate investment in the sustainability is simply a marketing. Arguably, one of the strongest forces to alter the corporate decision is the philosophy of an investor who often owns strategic stakes at the companies. It is investors, especially big institutional ones that may significantly speed up the transition by choosing to allocate resources to rather sustainable businesses. If unsustainable businesses lose the investors, then the business will probably not be able to compete long and soon will cease to exist or at least will significantly decrease scale of its operations. That is why it is an important part of the transitioning to sustainable future to properly study and develop the green finance and back the transition efforts with data and empirical evidence. Should the data prove that unsustainable companies are increasingly riskier in face of intensifying regulations and reputation costs and that the costs of transitioning are lower by the day thanks to the innovation there will be a strong argument for institutional investors to rationally abandon or at least decrease stakes in unsustainable businesses to mitigate the portfolio risks. Should the institutional finances flow in the direction of sustainable companies and innovations in the green technology the transition to clean future is just a matter of time.

This philosophy was the main motivation behind forming the hypotheses of this study. Mainly, to inspect whether the greener companies are really as some critics suggest less profitable than the brown companies. It is important that the innovations and subsidies make the transition cheaper, otherwise business reality will prevent institutional investors from investing in the greener companies and thus speeding up the transition. But before that the author attempts to answer a simpler question of whether the investors do even consider the matter in the real time and do price in the risks related to the climate change in any significant manner which could be demonstrated by the existence of associated risk premium. However, the profit maximization is just a half of the story behind the investment decision making, the other half is risk considerations. Big institutional investors care strongly about risk minimization of their portfolio allocation. The bigger the portfolio the more diversified and less risky the portfolio must become. Thus, showing that sustainable companies are in fact less volatile than the unsustainable ones may add an argument in favour of decreased risk profile of greener businesses. Lastly, it is topic of a great dispute among the researchers as to whether the ESG factor should be added in the typical asset pricing models (such as Fama-French type) or not. Some show the evidence of the model being unaffected by adding the variable, explaining that the effect of the variable is already explained by other typical variables in the asset pricing models. Other show significant contribution of the variable and its indispensability in such models.

Thus, the hypotheses are summarized as follows:

(i) Investors are aware and do actively partake in climate-related risk management, implying the existence of significant climate change risk premium.

(ii) Sustainable firms stock returns are on par with unsustainable ones.

(iii) Sustainable firms stock prices exhibit lower volatility than less sustainable ones.

(iv) More sustainable companies exhibit similar performance to typical market benchmark which encompasses stocks independent of their sustainability.

(v) More sustainable companies are relatively more stable than the market benchmark encompassing stocks independent of their sustainability.

(vi) Adding a sustainability factor, specifically ESG factor in the empirical model increases the explanatory power of the model.

5.2 Data & Methodology

5.2.1 Data

ESG Scores & Stock Prices

Every database offering a comprehensive ESG score data is a paid service with no free databases available according to the best knowledge of the author. The database used in this study is Thompson Reuters Eikon with funded access by Charles University. The product is owned by the Refinitiv, founded in 2018 and formerly owned by both Blackstone Group LP and Thomson Reuters to be later acquired by the London Stock Exchange Group. Eikon is a software platform offering an access to a number of products provided by Refinitiv, used by financial professionals to help them at monitoring and analysing financial information. The platform provides an access to real time market data, fresh news, analyst recommendations, fundamental data, various analytics etc. It furthermore provides data on asset classes such as forex, fixed income, equities, commodities, funds or real estate and money markets.

Eikon database was therefore used to download monthly stock closing prices and annual ESG score data on all available publicly traded companies in the Europe. Data was downloaded for period of January 2012 – February 2022.

The data were filtered to not include extra small-cap companies, setting a minimum market capitalization threshold to \$50 million, with no upper limit on size. Author satisfied himself that the minimum threshold will not influence the results, since firms with market capitalization of \$50 million and bellow rarely do report ESG score. For the purposes of this analysis monthly stock closing prices were transformed into matrix of month over month log-returns for each month. Indeed, ESG score reporting occurs more often as the firm gets bigger in size. Based on this criterion the initial data sample size was n = 2361. As expected, significant number of corporations had incomplete number of years with available ESG score, being unfit for estimation purposes and were thus omitted. The reason is that not all firms are long-term reporters of the ESG score and may have decided to begin with the reporting only a couple of years ago, which provides insufficient amount of data for inclusion in the analysis. Also, small number of stocks that either had extreme values of returns or that had too many missing monthly prices, have been filtered out.

Fama-French 3 Factors

In order to proceed with Fama-MacBeth (FMB) regression the typical three factors used in Fama and French regressions are necessary. For this study the European Fama and French 3 Factors developed markets factors and returns were downloaded and reduced to the estimation period of January 2012 – March 2022. Later in the study also Fama and French 5 Factors on European developed markets were used to construct FF5 model. WML factor was not available on the website (just like GMB of course), so it was constructed by the author. The data is freely available at the website of Kenneth R. French.

5.2.2 Portfolio Construction

In this study the data sample was transformed into two different, but overlapping samples based on ESG scores availability and each analysis was applied separately on each portfolio, which provides unique results from two different time-perspectives, enhancing the analysis. First sample contained firms which reported ESG score in the each of the last 3 years ("ES3" or "ESG 3FY") amounting to N1 = 1682 firms, with 336 stocks per portfolio. Second sample contained firms with ESG score reporting period of at least 6 of the most recent years ("ES6" or "ESG 6FY"), disregarding other firms, which resulted in N2 =

1036 firms with 207 stocks per portfolio. The advantage of the first sample is higher number of stocks to analyse whereas second sample's advantage is that it is based on longer ESG average. This implies that the ES6' portfolio sorting is more precise where for instance, Leaders are truly long-term committers to high ESG scores and did not hold this status only a couple of years, which should help better explain investor behaviour towards high scorers as opposed to low scorers.

Five portfolios in total were created per each data sample ("Leaders", "High Scorers", "Average", "Low Scorers" and "Laggards") based on the average ESG scores of the companies. In case of ES3 portfolio the average of last 3 years' ESG scores was used to sort the firms and in case of ES6 portfolio the average of last 6 years' ESG scores was used. The companies were sorted in the following manner: companies located in the fifth quintile of ESG scores with highest scores were included in the Leaders portfolio, companies located in fourth quintile of ESG scores were included in the High Scorers portfolio and so on in the same manner until first quintile or the lowest ESG scorers are sorted into the Laggards portfolio. This portfolio sort is different from for example, MSCI – ESG rating sort, where companies are sorted into 3 groups (Leaders, Average, Laggards) with respect to the fixed ESG score threshold and then into couple of subgroups within each group. This sorting was, however, unsuitable for purposes of this study, because for instance, in lower ESG sort the companies were regarded as Laggards if they scored between 0-14.3 according to MSCI sort. This would yield too few companies from the sample obtained and would potentially lead to imprecise results. The constructed portfolios were in accordance with the common practice of equally-weighted portfolios as there is no apparent necessity to weigh on the returns with respect to the company size.

5.2.3 GMB

In order to conduct analysis on approximated climate risk premium this study uses famous Fama and MacBeth (1973) two pass-pass regression approach. There is therefore a necessity to create new climate factor that will be used to augment classical FF3 model to inspect whether there is any ongoing climate related re-pricing of assets based on ESG score and also to inspect whether this factor holds any explanatory power in financial models. The green minus brown (GMB) factor was constructed in line with Fama and French (1993) methodology of single sort so that the new variable is comparable with the way classical factors were constructed. Each sample was separately sorted based on ESG score on equally-weighted basis, either to three portfolios (GMB3) or 10 portfolios (GMB10), where average returns over the given estimation period were computed and difference in average returns between top portfolio and bottom portfolio in each sort were used to produce GMB factor. It could also be interesting to construct E, S and G factors separately to include in the models as in Lioui (2018) or Hubel and Scholz (2020). This way the climate risk premium could be tested better, however the available data services did not provide such data.

5.2.4 Model

The original paper by Fama and MacBeth (1973) has currently over 17 750 citations (June 2022), making this methodology one of the most influential paper in asset pricing. In this study the FMB approach is used to estimate ESG related risk premium in its standard two-pass regression form.

In the first stage the factor loadings (betas) corresponding to the individual chosen factors (SMB, HML, MRP and GMB) are calculated by regressing these factors against the stock returns of each company on a monthly basis over the sample period of 10 years. In this study, the factors used in analysis are basic factors used in FF3 augmented by GMB factor calculated based on ESG score over the period of 10 years of stock returns. These factor loadings reveal the relationship between the given company's stock returns adjusted for risk-free rate and the FF3 factors for each stock individually.

In second stage the factor loadings from the first stage are regressed again, this time against average asset's return over whole period in a sample to determine the risk premium of each factor. The property of FMB is that it produces standard errors that are corrected only for cross-sectional correlation, leaving time-series autocorrelation unaddressed. This, nevertheless, should not pose a problem in case of stocks since it is established that stock financial data exhibit weak time-series autocorrelation in shorter period holdings, with increasing autocorrelation for longer periods Fama and French (1988). Shanken and Zhou (2007) and Kan et al (2013), provide among others the analytical and simulation evidence of the model's proficiency. Interestingly, J.Bai and G. Zhou

(2015) demonstrate in their study, that while number of assets is an important determinant of the risk premia estimate accuracy, the time series sample size is also very important, contrary to the popular belief that only number of assets is of importance. Authors, moreover, demonstrate that adjusted OLS or GLS estimators of risk premia reduce biases significantly for samples with small time series dimension. The standard FMB regression is computed using ordinary least squares (OLS) estimator. Thus on a multi-factor sample the FMB model would take form:

$$E(r_{it} - r_{ft}) = \alpha_i + \beta_1[E(r_{mt} - r_{ft})] + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 GMB_t + \epsilon_{i,t}$$

where $E(r_{it} - r_{ft})$ is excess log return on stocks, $E(r_{mt} - r_{ft})$ is market risk premium, SMB is small minus big factor, HML high minus low factor and GMB the newly constructed GMB factor that either corresponds to portfolio sort based on decile division (GMB10) or tercile division (GMB3), where i subscripts different stocks and h = tercile sort, decile sort.

$$E(R_k^{Avg}) = \gamma_0 + \gamma_1\beta_1 + \gamma_2\beta_2 + ... + \gamma_k\beta_k + \epsilon_k$$

where $E(R_k^{Avg})$ stands for average stock return over the estimation period, $\gamma_1,\ldots,\gamma_k$ are the risk premia and $\beta_1,\ldots,\beta_k$ are factor loadings taken from the first equation by applying OLS. Commonly the studies maintain that the disturbances are independently and identically distributed in time (iid), around the mean equal to zero and that they are independent of the explanatory factors. The iid condition should be satisfied due to the statistical behaviour of stock returns data with weak cross-sectional correlations.

Chapter 6

Empirical Results

6.1 ESG data & samples description

In this section the reader is presented with an in-depth view on the ESG data samples used for analyses. Firstly the descriptive statistics are presented for each portfolio on an annual basis and also the distribution of data samples. Usual descriptive statistics are applied such as minimum, maximum, mean, median and standard deviation. Data samples are overlapping in that ES6 contains the stocks from ES3 sample that have been evaluated in at least 6 of the most recent years.

In the following Table 6.1. the descriptive statistics of two distinct ESG samples were used for estimation purposes in the period from February 2016 - February 2022. Statistics display minimum, mean, median, maximum and standard deviation of ESG scores in each year of the distinct portfolios.

Table 6.1: Descriptive statistics - ES3, ES6 samples

	ESG 3FY Sample				ESG 6FY Sample					
Year	**22/21**	**21/20**	**20/19**		**22/21**	**21/20**	**20/19**	**19/18**	**18/17**	**17/16**
Min	2.3	0.4	0.3		5.0	0.4	0.3	0.7	1.0	0.7
Mean	57.9	54.9	51.4		63.4	61.4	58.8	56.2	53.4	51.7
Median	59.3	56.1	52.0		65.7	63.6	61.2	57.8	54.4	52.3
Max	95.1	94.2	94.4		95.1	94.2	94.4	94.2	92.2	93.6
Std	18.3	19.4	20.6		17.6	18.1	19.1	19.4	20.1	20.7

It is not very surprising that the mean consistently grows as the data are closer to our date, possibly because companies that do attempt to report ESG scores will do so in order to benefit from it and will thus attempt to maximise this score with time. Hand in hand with the mean moves the median, in line with the previous explanation. Interestingly, the more recent the data the more does the standard deviation tend to decrease in both samples, meaning that as the time goes on the companies deviate less from the mean ESG score and cluster more around the sample average. This may be due to the increasing marginal costs of moving above the average score, but relatively low effort and cost required to move towards the average score. This increased clustering around the mean is well depicted by the distribution charts (Figure 6.1. and 6.2.) below. These figures show in a histogram the frequency of distribution of ESG scores in distinct data samples with the bucket size equal to 5 ESG score points.

Figure 6.1: Distribution of ESG score - ES3 sample

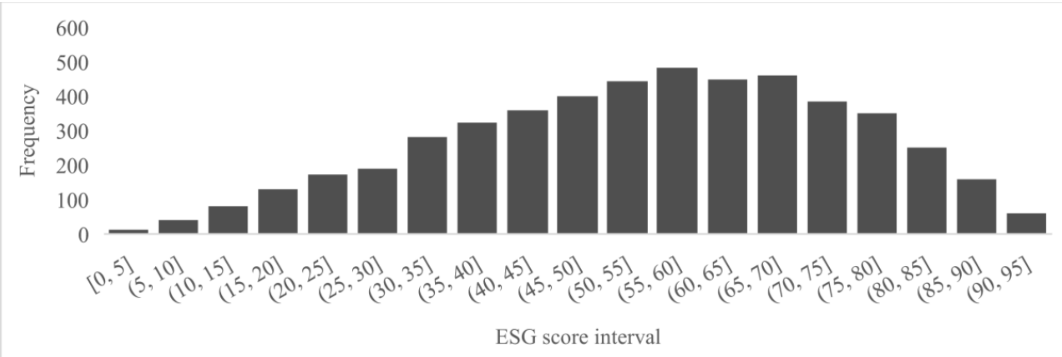
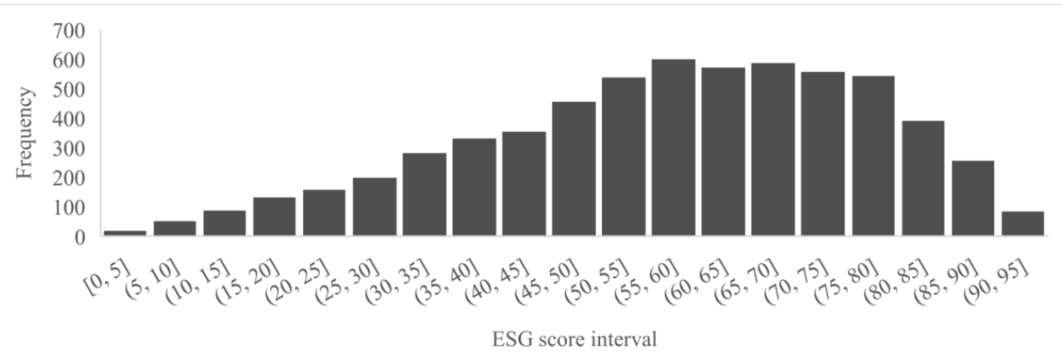


Figure 6.2: Distribution of ESG score - ES6 sample



6.2 Portfolio performances – single sort analysis

Now that the portfolio construction is complete in a manner described before, it is time to estimate average returns (Avg.Ret.) and excess realized volatilities (ERV) per each portfolio for both samples ES3 and ES6. The monthly prices per each company's stock in each portfolio were used to compute log returns on a monthly basis over three different time periods (1, 2 and 3 years for ES3 sample and 2, 4, 6 years for ES6 sample). Considering returns over longer time horizon would probably yield more precise and reliable results. However in this study shorter time periods were purposefully chosen so that their length do not exceed the length of the period (3 and 6 years) from which the average ESG score was computed in a given sample. To better showcase this point imagine if the company was sorted into Leaders portfolio based on the average of last 3 years' ESG score and the computation period for average return exceeds 3 years, for instance, suppose it is 7 years. Also suppose that the company was performing far worse in terms of ESG score in the first 4 measurement years and then it was pushed by shareholders to maximize ESG score as fast as it could so that in the last 3 years its score was suddenly very high. Calculating returns for this company based on 7 years period would thus provide misleading results, because it would consider returns of a company that is now considered a Leader also in periods where it could have been considered a Laggard.

Computation of average returns over a given period was made simply by taking the difference of logarithmic prices of sequential months and then averaging those to obtain the Avg.Ret for periods of 1, 2 and 3 (and also 4 and 6) years. The computation of excess realized volatility was slightly more difficult, where first the difference of logarithmic prices of sequential months was squared and then summed altogether to obtain realized variance over the given period for a given portfolio. Afterwards this sum was divided by the number of years over which the realized variance is computed (realized variance is annualized in relation to the length of the period over which it is computed) and square root was applied to obtain realized volatility. To finally obtain the excess realized volatility (ERV) the realized volatility is further decreased by a realized volatility of a benchmark in the given period, which in this study it is realized volatility of S&P 500. Monthly and annualized realized volatilities of S&P 500 was constructed in a similar fashion as the portfolio volatilities.

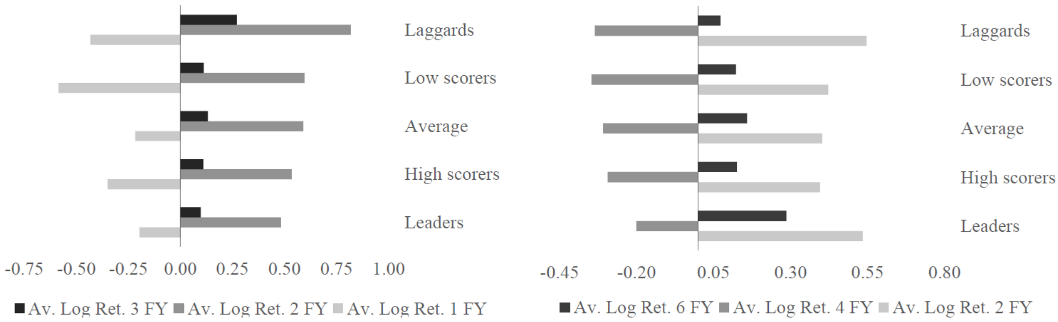
Table 6.2. below summarizes the resulting average returns and excess realized volatilities per each period in ES3 sample and also in addition the average market capitalization (Avg.Mkt.Cap), average ESG score (Avg.ESG Score) and average number of ESG reports that were publicized during the whole sample time period (10 years) of the respective companies in the sorted portfolios. Results suggest negative average returns for all portfolios in the last 12 months (1FY), which is not surprising given the current market situation, where high inflation expectations, war in Ukraine and post-pandemic supply chain issues all greatly contribute to the decline of virtually all stock markets around the world. Interestingly, with higher ESG portfolio the returns tend to decrease relatively less. This is in line with the expectations, where the most fundamental rule of risk/reward implies that the more risky assets are those that are more volatile and in a de-risking market environment such as it is nowadays it would be reasonable to expect investors to flee to a higher degree from the riskier investments (i.e. those with lower ESG score). This effect is clearly present as can be seen in the column Avg.ERV 1FY. Considering average over both 2020 and 2021 (Avg.Ret.2FY + 3 FY) altogether show relatively high returns that were caused by the post-pandemic intense monetary stimulation. There we see again a negative correlation between ESG score and both returns and ERV. Laggards managed to secure highest returns among all portfolios by a high margin, whereas Leaders secured the lowest. Similar implications could be drawn from Avg.Ret.3 FY and ERV3FY. The average log returns of the two samples are also graphically depicted in the Figure 6.3. below.

Table 6.2: Empirical Results: ES3 sample

n = 1682	ESG 3 FY Sort								
Stock Portfolios	Avg. Ret. 1FY	Avg. Ret. 2FY	Avg. Ret. 3FY	Avg. Mkt. Cap [mil. USD]	Avg. ESG Score	Avg. # of ESG rep.	Avg. ERV 1FY	Avg. ERV 2FY	Avg. ERV 3FY
Leaders	-0.197	0.483	0.097	29 074	80.12	9.3	0.136	0.200	0.186
High Scorers	-0.349	0.535	0.110	10 857	66.65	8.3	0.170	0.229	0.219
Average	-0.217	0.591	0.132	5 830	55.77	7.1	0.164	0.245	0.228
Low Scorers	-0.586	0.596	0.113	3 159	44.19	5.8	0.193	0.247	0.235
Laggards	-0.432	0.818	0.271	2 383	26.94	5.0	0.181	0.231	0.220
Lead - Lagg	0.235	-0.335	-0.174				-0.045	-0.032	-0.035
t - test (Lead/Lagg)	1.121	-2.178*	-1.367				-3.939***	-2.085*	-2.55*
Lead - S&P500	-1.156	-1.005	-0.939		Lead - S&P500 (Rvol)		0.014	0.131	0.104
t - test (Lead/S&P)	-7.612***	-9.023***	-9.309***		t - test (Lead/S&P)		1.760	13.626***	11.243***

In the bottom part of the Table 6.2. the hypothesis testing was performed in order to investigate in a deeper manner whether there is statistically signif-

Figure 6.3: Returns per portfolio sorts - ES3 & ES6 samples

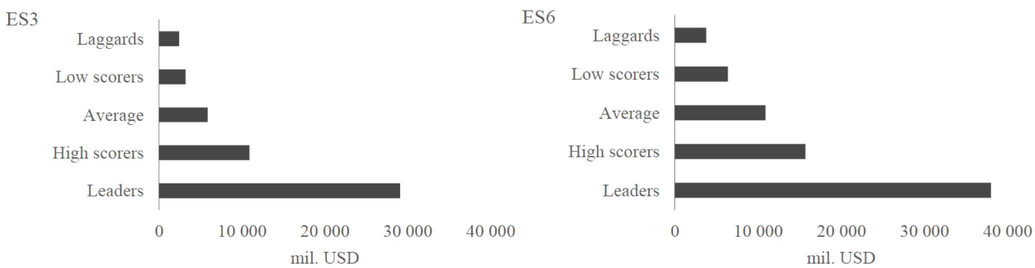


icant difference observed between returns on Leaders portfolio and Laggards portfolio. Results from Avg.Ret.1FY show positive coefficient of 0.235, that is however, not statistically significant. Therefore, we can not a draw conclusion based on these data that there is any difference in returns between the portfolios. The conclusion is slightly different for Avg.Ret.2FY showing statistical significance at 10% confidence interval with coefficient equal to -0.335. In other words, Laggards do indeed outperform in this time period the Leaders by 0.355 percentage points on average. For period of three years the result is statistically insignificant and thus, no conclusion can be drawn. Now to investigate ERVs, the results are overall more significant and unified. In all periods ERV is negative, but not very significant number. Greatest statistical significance was observed in 1FY period, but also at 10% confidence interval at 2 and 3FY periods.

Overall, these results suggest that there might be some weak evidence of outperformance of Laggards in relation to Leaders and there is relatively strong evidence suggesting that Leaders are less volatile than the Laggards. On the bottom line of the Table 6.2. there is comparison of both performance and realized volatility (Rvol) of Leaders against the benchmark, namely S&P 500. Leaders significantly underperformed in each period the benchmark, which could imply that these companies are on average less risky than those included in S&P index. In all but first period S&P index proved to be significantly less volatile than the Leaders portfolio, which is not what would be expected in relation to the performance of Leaders vs S&P index.

Average market capitalization shows signs of high and positive correlation with ESG score, which is intuitive. Bigger companies are generally wealthier and have more money to spend on public relations related campaigns and their perceived image by the public is of great importance to them. Significantly bigger companies are observed in Leaders portfolio, that are on average 13x bigger than their counterparts sorted in Laggards portfolio. This is clearly depicted in the Figure 6.4. below. Also, Leaders on average scored 3x higher than the Laggards and had frequency of reporting ESG score almost twice as big. That is also expectable as companies with high ESG score will make sure public learns and hopefully appreciates their efforts in this regard.

Figure 6.4: Market capitalization with respect to portfolio sorts



From the relative distribution of big companies between the portfolios arise reasons for concern. From the previous analysis it was clear that high scoring companies have on average lower returns and are less volatile. However, it is important to inspect to what degree is this effect caused by ESG score and to what degree is it caused by size of the company. It is empirically established relation, that bigger companies tend to be less risky and slower to grow. This translates into relatively lower volatility and lower mean returns on their stock. There is a huge difference in size of the companies sorted in the Leaders portfolio and rest of the other portfolios. To tackle this issue author decided to also perform double-sort analysis, where effects of ESG score and size would be analysed in a more isolated manner. This analysis is located later in the study, first the same analysis as above, based on longer ESG observations (ES6) period will be presented.

Looking at the Table 6.3. below the average returns for Laggards and Leaders over 2 year period seem to be almost equal with relatively lower returns of the middle portfolios, following the negative correlation between ESG score and average returns. ERV is in case of Leaders portfolio however lower than Laggard's with somehow unexpected values for middle portfolios without

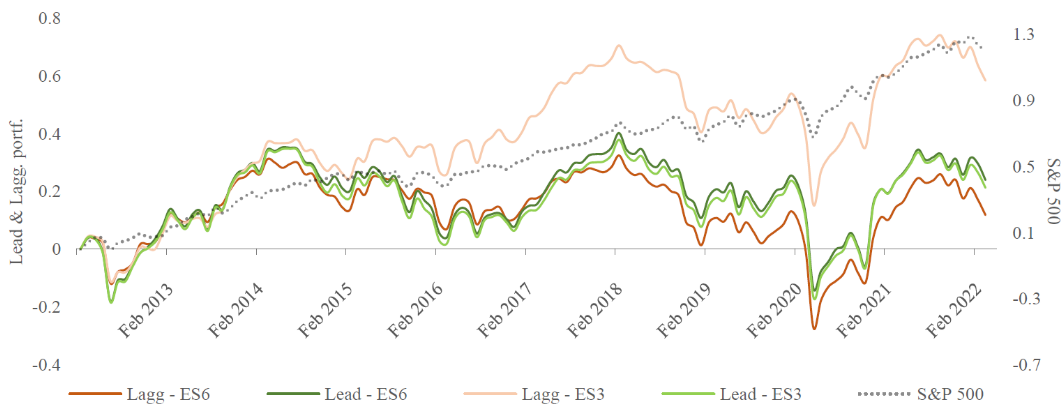
Table 6.3: Empirical Results: ES6 sample

n = 1036	**ESG 6 FY Sort**								
Stock Portfolios	Avg. Ret. 2FY	Avg. Ret. 4FY	Avg. Ret. 6FY	Avg. Mkt. Cap [mil. USD]	Avg. ESG Score	Avg. # of ESG rep.	Avg. ERV 2FY	Avg. ERV 4FY	Avg. ERV 6FY
Leaders	0.535	-0.200	0.288	38 004	81.34	9.9	0.172	0.154	0.152
High Scorers	0.396	-0.293	0.126	15 667	68.92	9.8	0.212	0.192	0.193
Average	0.403	-0.308	0.159	10 881	58.90	9.6	0.246	0.221	0.218
Low Scorers	0.423	-0.346	0.123	6 360	48.38	9.2	0.223	0.201	0.199
Laggards	0.547	-0.335	0.073	3 747	30.00	8.7	0.196	0.185	0.179
Lead - Lagg	-0.012	0.135	0.214				-0.024	-0.031	-0.028
t - test (Lead/Lag)	-0.124	1.039	1.993*				-1.103*	-1.771	-1.788
Lead - S&P500	-0.965	-1.100	-0.814		Lead - S&P500 (Rvol)		0.105	0.074	0.016
t - test (Lead/S&P)	-6.913***	-9.033***	-8.509***		t - test (Lead/S&P)		9.165***	7.950***	1.839

clear relationship. Four year period presents negative returns for all portfolios, probably owing to post-2017 stock markets volatility over fears of monetary tightening, economic downturn and trade wars between US and China on top of recent events. Interestingly the ERV for the same time period did not seem to be heightened, it seems no bigger than the ERV of 2 years or 6 years period. Inspecting the 6 year period which is the longest and should therefore be most accurate in terms of ESG committers and non-committers shows the reversed results of what expectation would be. The results suggest Leaders were significantly outperforming Laggards having more than 4x larger average returns. In fact Leaders outperformed every portfolio in the sample by high margin while at the same time being the least volatile according to ERV. Investigating the statistical significance of difference between Leaders and Laggards portfolio returns and excess realized volatilities, all results but the average returns in 6 year period yield statistically insignificant differences. Average return over 6 year period show significant result of 0.214 at 10% significance level showing that Leaders on average outperform Laggards by 0.214 percentage points in this period. Leader portfolio again significantly underperformed benchmark in all periods like in ES3 analysis. Also similar to previous analysis the Leaders proved to be more volatile than the benchmark, yielding significant results for all but the last period. As before, there is a significant size effect present that must be differentiated from ESG effect to draw any meaningful insights by means of double sort analysis. It may be useful to chart some of the portfolio returns in the charts in a cumulative manner.

In the Figure 6.5. there is charted cumulative average log returns of Leaders and Laggards portfolios from both ESG samples and compared with the broadly

Figure 6.5: Cumulative return of Leaders and Laggards vs S&P 500



used stock market benchmark S&P 500 index. Performance of Leaders portfolio was very comparable no matter the sample. This may be due to the fact that the companies that were sorted into Leaders portfolio in both samples are mostly identical since these tend to be biggest and tend to be most committed to ESG reporting. Interestingly, Laggards portfolio from ES6 sample seem to be mostly performing worse than both green portfolios but not by a high margin. The highest performance was observed with Laggards of ES3 sample, that significantly outperformed all three portfolios and in a period from 2013 – Feb 2019 it seems to have even outperformed S&P 500 index. There is, therefore, huge discrepancy between Laggards portfolios originating from ES3 and ES6 samples. It may be that companies included in the Laggards portfolio in ES6 sample are the companies that are systematically not committed to the ESG score and this may be used as a proxy to the company's ambitiousness and its efforts to invest in itself. These companies are not favoured by investors, and they are not huge in size as seen in Figure 6.4., therefore weak performance is not attributable to the size effect, as it is actually the opposite the size effect in case of Laggards should play in favour of their performance as compared to Leaders portfolio, which is comprised of huge companies. It may be therefore that these companies have bad reputation and are not expected to grow as much as other and that is why they underperform other portfolios. This cannot be said about Laggards from ES3 sample as their efforts to push ESG score higher are less proxying the negative attributes as in case of ES6 Laggards.

6.3 Portfolio performances – double sort analysis

The previous section presented with results in regards to how profitable on average would be an investment in different ESG portfolios and how volatile are those portfolios. The problem with single sort analysis is the strong correlation between market capitalization and ESG score. This important size effect may be wrongly mistaken for ESG effect, where higher ESG firms also tend to be the bigger ones.

To investigate how these two effects interact to influence the returns and volatility - the two samples ES3 and ES6 each, were first sorted into three size portfolios: big, medium and small. In each of these three size portfolios the stocks were sorted again into 5 portfolios according to their ESG score, the portfolios are named same as in the single sort analysis. It is important to note again, that these ESG portfolios are created in relation to other stocks in the sample and their breakpoints are not given by any fixed absolute value, but rather relative one. Therefore, it may be the case that in the portfolio of big firms, Laggards will on average have relatively high score or conversely in a portfolio of small companies the Leaders could on average score what Laggards would score in a portfolio of big companies.

In the Figure 6.6. below the double sorted portfolio returns are depicted with the help of heat map, where the greener the colour the higher returns and more red it is the more negative returns are, with yellow marking value close to a median. First looking at 1 year period the returns are clearly positively correlated with the size, where bigger firms tend to earn more than smaller ones. This effect is observable among all the periods and is most likely attributable to the ongoing de-risking and post-pandemic problematic environment in the stock markets where bigger firms perform much better under such circumstances than smaller ones. Interestingly, it is the opposite of what empirically the statistics would suggest – usually smaller companies tend to outperform the bigger firms to compensate investors for risks associated with small business. Therefore in this time period, size appears to be highly relevant and is a significant predictor of returns. There is also observable ESG effect, where Laggards in all periods seem to outperform Leaders. Just as size appears to be positively correlated with returns so does the ESG score seem to be negatively correlated with returns in the given periods. ESG effect seems to be present in all time periods among all three size portfolios (big, medium and small).

Figure 6.6: Returns heatmap: size vs ESG sorts - ES3 sample

Returns 1FY *(ES3)*	Size: Big	Size: Med	Size: Small
Leaders	0.28%	-0.44%	-1.69%
High Scorers	-0.08%	-0.71%	-0.63%
Average	0.31%	0.19%	-1.14%
Low Scorers	0.37%	-0.13%	-0.98%
Laggards	0.08%	-0.12%	-0.65%

Returns 2FY *(ES3)*	Size: Big	Size: Med	Size: Small
Leaders	0.76%	0.33%	-0.50%
High Scorers	0.74%	0.37%	0.07%
Average	0.97%	0.88%	-0.02%
Low Scorers	1.08%	1.07%	0.41%
Laggards	1.32%	1.36%	0.18%

Returns 3FY *(ES3)*	Size: Big	Size: Med	Size: Small
Leaders	0.36%	-0.17%	-1.24%
High Scorers	0.33%	0.20%	-0.46%
Average	0.70%	0.42%	-0.61%
Low Scorers	0.73%	0.64%	-0.40%
Laggards	1.03%	1.07%	-0.46%

Table 6.4. below shows results of statistical analysis, where Leaders portfolio of ES3 sample were compared with Laggards portfolio in each of the size portfolios. Results suggest that there is statistically very significant ESG effect inside of each size portfolio, where in every single of them Laggards outperform Leaders portfolio in terms of stock returns performance. This is very interesting as analysis applied on single sort portfolios yielded statistically weak and often times insignificant results as seen in Table 6.2. The outperformance of Laggards becomes more and more pronounced as companies get smaller. Moreover, Laggards proved to be significantly less volatile than Leaders in both Medium and Small sized portfolios. Only Big sized portfolio over 1 year measurement period reports Leaders to be less volatile than Laggards. This is in contrast with results produced from single sort analysis (Table 6.2.) which suggest that ERV of Laggards is consistently and statistically significantly higher than ERV of Leaders, although magnitude by which the two numbers differ is rather small.

Table 6.4: Double Sorted Average Returns ERV, ES3 Sample

Avg. Return ES3	t-test	Lead-Lag
Big		
1FY	-14.387***	-0.161
2FY	-13.048***	-0.159
3FY	-14.868***	-0.159
Med		
1FY	-12.132***	-0.177
2FY	-11.585***	-0.173
3FY	-13.400***	-0.170
Small		
1FY	-10.339***	-0.195
2FY	-10.062***	-0.257
3FY	-11.381***	-0.265

ERV ES3	t-test	Lead-Lag
Big		
1FY	-3.844***	-0.051
2FY	-0.829	-0.014
3FY	-1.219	-0.018
Med		
1FY	-0.159	-0.003
2FY	3.294***	0.072
3FY	3.511***	0.068
Small		
1FY	1.616	0.056
2FY	2.961***	0.120
3FY	3.192***	0.116

Now to investigate how other variables behaved – not surprisingly there is a clear positive correlation between size and ESG score as depicted in the Figure 6.7. in the recent three year period. As noted, bigger firms have more resources to dedicate to ESG related efforts and it is also bigger firms who would suffer the most from lawsuits or damaging affairs arising from either of the environmental, social and governance topics. The figure furthermore shows how big is the difference in market capitalization across the size portfolios. Leaders in big sized portfolio have by far the largest market capitalization of 52 billion USD on average, with small portfolio containing firms with on average market capitalization bellow one billion USD. There should, therefore, be a significant empirical effect that should favour smaller and medium portfolios to significantly outperform big portfolio but that is not the picture this analysis paints as explained before. Last heatmap in Figure 6.7. reports how dedicated are on average companies in different portfolios to ESG reporting in the most recent three year period. Very similar to average ESG score there is a clear positive relationship between number of reports and the size and average ESG score. Companies with high ESG score have no reason to hide the reports as it improves their public relations.

Figure 6.7: Other statistics heatmap - ES3 sample

Avg. ESG Score 3 FY (ES3)

Portfolio	Size: Big	Med	Small
Leaders	86.31	73.93	68.05
High Scorers	77.23	61.58	54.20
Average	70.42	53.57	44.64
Low Scorers	61.54	43.32	35.63
Laggards	42.50	27.31	21.12

Market Cap. [bil. USD] (ES3)

Portfolio	Size: Big	Med	Small
Leaders	51.99	3.02	0.71
High Scorers	26.84	2.89	0.61
Average	23.34	2.69	0.66
Low Scorers	21.05	2.54	0.68
Laggards	13.79	2.47	0.54

Avg. # of Reports 3 FY (ES3)

Portfolio	Size: Big	Med	Small
Leaders	9.90	8.63	7.04
High Scorers	9.52	7.50	6.88
Average	9.09	6.11	4.89
Low Scorers	8.89	5.72	5.33
Laggards	7.27	4.63	4.92

Next is the ERV of double sort. Expectation would be that there is significant negative correlation between size and volatility. In case of ESG it is less clear, but literature suggests also a negative relationship between ESG score and volatility. Double sort will help dissect the two effects to inspect those in isolation. Figure 6.8. below suggests a clear differentiation in volatility depending on ESG score, with higher score the ERV is on average lower. Size effect does not seem to be significant as small companies seem to be having consistently higher ERV among all ESG portfolios than medium sized portfolio. The size effect is also negated by the fact that Laggards have approximately the same ERV no matter size of the portfolio in each period. Inspecting the same over 2 year period shows consistently low ERV for big companies portfolio and Laggards across all size portfolios. However, unlike first period heatmap it shows the highest ERV for medium and small portfolio among leaders. From this chart we observe some degree of size effect but little to no ESG effect. Finally looking at the last figure (Avg.ERV 3FY) size effect is present in that the biggest companies have the lowest ERV, however, ESG effect is not observed at all. Significant ERV is observed again among the leaders in medium and small sized portfolios. This may have connection with increased trading due to recent economic environment and inflow of investors into bigger and safer stocks.

Figure 6.8: ERV heatmap: size vs ESG sorts - ES3 sample

Avg. ERV 1FY *(ES3)*

Portfolio	Size: Big	Med	Small
Leaders	11.36%	15.25%	14.56%
High Scorers	12.67%	15.23%	15.00%
Average	14.01%	15.73%	15.33%
Low Scorers	14.66%	17.37%	17.05%
Laggards	16.34%	16.55%	16.25%

Avg. ERV 2FY *(ES3)*

Portfolio	Size: Big	Med	Small
Leaders	16.91%	24.87%	23.94%
High Scorers	15.72%	21.61%	20.89%
Average	17.64%	21.79%	21.21%
Low Scorers	18.36%	22.03%	21.82%
Laggards	17.05%	17.45%	17.03%

Avg. ERV 3FY *(ES3)*

Portfolio	Size: Big	Med	Small
Leaders	23.42%	37.21%	36.78%
High Scorers	16.48%	26.10%	24.99%
Average	20.58%	26.45%	25.51%
Low Scorers	20.46%	26.83%	26.97%
Laggards	17.81%	25.25%	25.25%

Double sort portfolio analysis based on 1,2 and 3 year period yielded significant size and ESG effects for returns and ERVs, although not consistently throughout all the portfolios and periods. To take this analysis a step further the presence of these effects are also investigated in the double sort portfolios based on 2,4 and 6 years periods of the ES6 sample. Looking at the Figure 6.9. the heatmap immediately gives up the size effect, where returns are significantly higher the bigger companies in the portfolio are. ESG effect is also observable, but the effect is not consistent. Big and small companies portfolio show the ESG effect, where medium portfolio show reversed ESG effect. Slightly more consistent ESG effect is observable on 4 years period returns with again, strong size effect where smallest companies in the sample underperform. Finally, looking at the last figure, it is evident that across the periods of all lengths there is significant size effect with ESG effect present, that is increasing in its consistency as the period lengthens. Bigger companies outperform smaller ones and simultaneously in this sample leaders outperform laggards in all periods.

Figure 6.9: Returns heatmap: size vs ESG sorts - ES6 sample

Returns 2FY *(ES6)* — Portfolio	Big	Med	Small
Leaders	1.23%	0.68%	0.24%
High Scorers	0.91%	0.68%	0.16%
Average	0.93%	0.48%	-0.18%
Low Scorers	1.13%	0.50%	-0.20%
Laggards	0.57%	0.28%	-0.56%

Returns 4FY *(ES6)* — Portfolio	Big	Med	Small
Leaders	0.56%	-0.12%	-0.43%
High Scorers	0.35%	-0.18%	-0.73%
Average	0.37%	-0.34%	-1.21%
Low Scorers	0.29%	-0.08%	-1.10%
Laggards	0.16%	-0.52%	-1.51%

Returns 6FY *(ES6)* — Portfolio	Big	Med	Small
Leaders	0.83%	0.38%	0.14%
High Scorers	0.81%	0.36%	-0.17%
Average	0.63%	0.21%	-0.78%
Low Scorers	0.72%	0.25%	-0.79%
Laggards	0.60%	0.16%	-1.07%

In the Table 6.5. below double sort statistical analysis on ES6 sample is reported. Returns on Laggard stock companies seem to be consistently outperforming Leaders returns, just as in ES 3 sample. Interestingly, none of the portfolio returns in the Medium sort portfolio proved to be statistically significant. In small sort the Leaders seemed to be outperforming slightly the Laggards in 4 and 6 years period with 2 years period yielding insignificant results. These results are far more informative than those of single sort in the Table 6.3., which barely showed any statistical significance in both returns and volatility cases. Volatility difference between Laggards and Leaders for medium and small sorts proved to be statistically insignificant. In big sort portfolio though, the Leaders were clear winners in stability as opposed to Laggards.

Figure 6.10. below shows the average ESG score distribution across portfolios that is not unexpected, however the laggards score significantly higher score, than in ES3 sample. The figure also shows that in this sample (ES6), unlike ES3, the average reporting commitment is very high with all portfolios averaging above 9 out of 10. In other words the companies in ES6 are mostly long-term ESG committers. Last heatmap shows the distribution of capital among the portfolios is more extreme in this sample than in ES3. It shows that ES3 was purified mostly of smaller cap stocks to obtain ES6 sample.

Table 6.5: Double Sorted Average Returns ERV, ES6 Sample

Avg. Return ES6	t-test	Lead-Lag
Big		
2FY	-9.256***	-0.140
4FY	-11.626***	-0.138
6FY	-13.728***	-0.136
Med		
2FY	1.363	-0.010
4FY	2.440	-0.004
6FY	1.695	-0.005
Small		
2FY	1.649	0.008
4FY	3.131***	0.011
6FY	4.178***	0.012

ERV ES6	t-test	Lead-Lag
Big		
2FY	-9.256***	-0.140
4FY	-11.626***	-0.138
6FY	-13.728***	-0.136
Med		
2FY	-0.283	-0.009
4FY	-0.798	-0.020
6FY	-1.154	-0.024
Small		
2FY	0.906	-0.483
4FY	0.512	0.023
6FY	0.479	0.020

Figure 6.10: Other statistics heatmap - ES6 sample

Avg. ESG Score 6 FY ***(ES6)***

Portfolio	Size: Big	Med	Small
Leaders	77.77	61.90	51.64
High Scorers	70.93	58.34	47.66
Average	68.32	56.14	48.16
Low Scorers	64.17	54.51	46.95
Laggards	61.59	54.33	39.92

Avg. # of Reports 6 FY ***(ES6)***

Portfolio	Size: Big	Med	Small
Leaders	10.00	9.69	9.00
High Scorers	9.74	9.49	9.21
Average	9.72	9.34	9.06
Low Scorers	9.69	9.28	9.04
Laggards	9.50	9.15	9.26

Market Cap. [bil. USD] ***(ES6)***

Portfolio	Size: Big	Med	Small
Leaders	110.41	7.87	1.89
High Scorers	36.79	5.92	1.33
Average	23.11	4.46	0.82
Low Scorers	15.03	3.37	0.43
Laggards	10.67	2.50	0.17

The volatility as seen in Figure 6.11. just like returns in sample ES6 is visibly significantly influenced by size of the companies. The heatmap shows that smaller companies are more volatile than the big and medium companies, in line with the related empirical expectations. This effect is consistent with also both 4 year and 6 year periods. Abstracting the size effect, ESG seems to have weak influence on the volatility. There are some patterns that may suggest volatility is lower with higher ESG scoring companies, but it is not evident at first sight. Laggards tend to have higher volatility than Leaders. Interestingly though, average scoring companies tend to have highest volatility in the small size sort. Not the laggards.

Figure 6.11: RV heatmap: size vs ESG sorts - ES6 sample

Avg. ERV 2FY *(ES6)*

Portfolio	Size: Big	Med	Small
Leaders	9.70%	21.20%	26.71%
High Scorers	16.11%	19.75%	27.88%
Average	13.54%	17.83%	39.61%
Low Scorers	12.96%	20.85%	29.46%
Laggards	15.27%	22.08%	21.60%

Avg. ERV 4FY *(ES6)*

Portfolio	Size: Big	Med	Small
Leaders	9.13%	18.54%	23.79%
High Scorers	13.95%	17.34%	24.88%
Average	12.11%	17.36%	34.12%
Low Scorers	12.49%	18.84%	27.22%
Laggards	14.35%	20.52%	21.41%

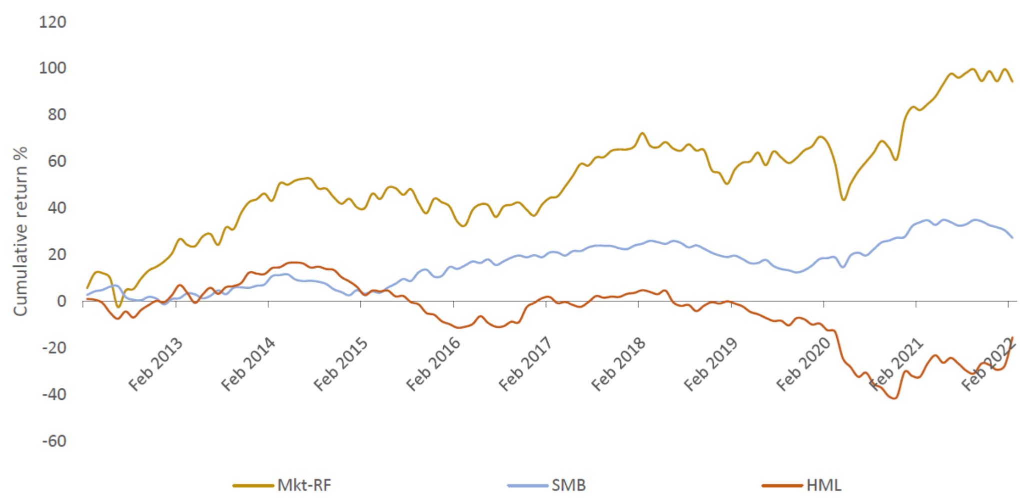
Avg. ERV 6FY *(ES6)*

Portfolio	Size: Big	Med	Small
Leaders	9.62%	18.10%	22.86%
High Scorers	14.18%	17.31%	24.62%
Average	12.55%	17.48%	32.82%
Low Scorers	12.70%	18.20%	25.98%
Laggards	14.48%	20.52%	20.82%

6.4 Fama & French factors, GMB factor

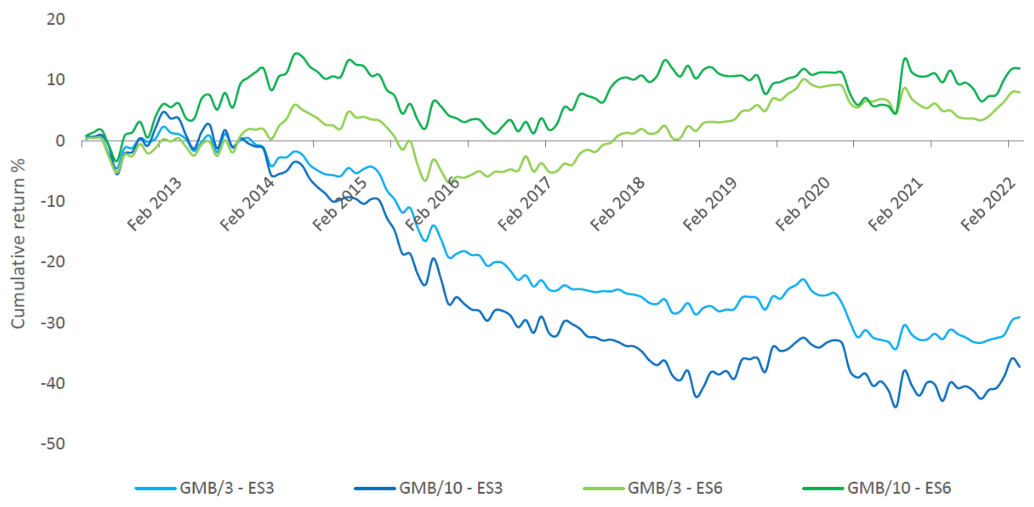
This section shows how FF3 factors and newly constructed GMB factor used in analysis are behaving in the given time period. Market risk premium (Mkt-RF) shows how equity markets performed in contrast to the bond markets where investors typically expect equity markets to outperform bond markets and thus the Mkt-RF to be positive mostly. Small minus big (SMB) is the factor tracking the empirically observed relationship between market capitalization of firms and performance on their stocks, which is significantly and negatively correlated. Thus the typical investor would expect SMB to be above zero most of the time. High minus low (HML) or value premium, maps the spread in returns between companies with high book/market value ratio and those with low value of this ratio. According to older sources the investor should expect high value companies to outperform low value companies in the longer time horizon, however this idea is somehow debatable and not clearly established as numerous low value companies or so called growth companies tend to significantly outperform the value stocks, especially during the times of low interest rates during bull markets. Analogically the newly constructed factor green minus brown (GMB) is tracking how high ESG scorers are faring in contrast to low ESG companies in two different periods (ES3, ES6), based on two different sorts (tercile and decile sort). Studies reviewed seem to be inconclusive as to if high scorers outperform low scorers, thus this also may be debatable as to what development should investor expect to see.

Figure 6.12: Cumulative returns of FF3 factors - span of 10 years



In the Figure 6.12. above is the graphical depiction of typical FF3 factors and its development in time. Indeed as expected market risk premium is positive in most of the time period showing stocks outperformed bonds and investors fared much better allocating their funds into equity market than bond markets. This observation may be caused among other things by a long period of very expansive monetary policy observed in Europe to combat deflation and falling productivity since 2008 financial crisis. Also the SMB factor behaves as expected with smaller companies outperforming the bigger companies on average. Finally, HML shows that academics may have been wrong about high value companies outperforming low value companies as in this period for most of the time – opposite effect is observed.

Figure 6.13: Cumulative returns of GMB factors - both ES3 and ES6 samples



The Figure 6.13. above depicts the constructed GMB factors and their development in time. These factors independently of whether they were calculated based on tercile sort or decile sort behave very similarly, the biggest differentiator is the sample used for computation. Sample ES3 that contains approximately 50% more stocks than sample ES6 and is ordered based on ESG score from only 3 recent years produced GMBs strongly in favour of laggard companies. Cumulative returns over the observed period reached negative 40% and more. Low scoring firms outperformed more in decile sort rather than tercile, which may be due to the size effect, where in decile sort the compared sorts are extremely high ESG scores (that tend to be big companies) an extremely low scorers (that tend to be smaller companies). Sample ES6 that does not contain stocks with shorter ESG reporting horizon in recent years shows entirely different result. High scorers outperformed low scorers most of the time. More so if the GMB was based on decile sort. Tercile sort showed outperformance of up to 10% and decile sort even up to 15%. There may be numerous reasons as to why the result is so contrasting. One explanation may be that in ES6 sample the companies that are younger and unstable were filtered out and so mostly the established, stable companies remain in the sample where laggards do not exhibit significant outperformance as they did in ES3 sample. The other reason may be that consistently low ESG score (based on 6 year average) could have proved to be a good proxy for company's future growth expectations, which are low and thus these tend to underperform as compared to high scorers in ES6.

6.5 Climate related risk premium

The Table 6.6. below shows the results of two-pass FMB regression using GMB 1/3 and GMB 1/10 factors on both ES3 and ES6 samples to test for existence of risk premium effect. GMB 1/3 produce promising result that is very significant and negative amounting to -0.192 suggesting there is a significant and negative risk premium to green stocks on average. In other words in the given sample over the given period investors applied positive risk premium (they asked for higher returns to compensate for higher risks) on Brown stocks (i.e. stocks with low ESG score). Similarly GMB 1/10 factor, that is constructed similarly as GMB 1/3, however it considers firms with more extreme ESG scores with higher average spread between the two portfolios showed also statistically significant and negative result amounting to -0.197, which is a tiny bit lower than GMB 1/3. This result is in line with expectations because higher spread between the portfolios should logically lead to more significant risk premium effect. Just like in case of GMB 1/3, also in this case of GMB 1/10 the factor is telling that investors require positive risk premium on Brown companies and apply negative risk premium on Green companies, penalizing those with lower ESG score for all the associated extra risks that they do not face in case of companies with high ESG score. Now inspecting other FF3 factors, HML reports significantly negative risk premium of -0.807, which interprets as companies that are considered value companies (lower growth prospects, but higher stability, usually also bigger in size and established business model) bear negative risk premium – which in other words penalizes growth stocks for all the added risks associated with these companies (high risk, unproven business model, high volatility). Therefore – smaller value or growth stocks would yield investors higher returns in the given period to compensate them for the additional risk associated with high growth. Also SMB was examined using FMB regression and unsurprisingly the coefficient is statistically significant and positive using ES3 sample and even more so in case of ES6 sample. This would suggest that smaller firms are being associated with positive risk premium as opposed to the bigger firms, which is in line with empirical observations.

Table 6.6: Fama-MacBeth Regression on different types of GMB factor on both ES3 and ES6

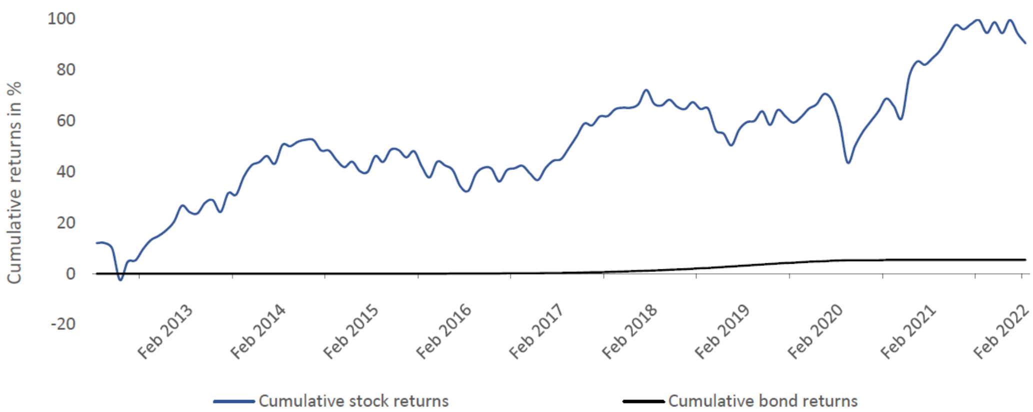
	Dependent Variable: ARET			
	Factors Used & Sample			
	GMB/3 (ES3)	GMB/10 (ES3)	GMB/3 (ES6)	GMB/10 (ES6)
‘GMB/3‘	−0.192***		0.077*	
	(0.029)		(0.046)	
‘GMB/10‘		−0.197***		−0.062
		(0.041)		(0.063)
HML	−0.807***	−0.812***	−0.805***	−0.812***
	(0.041)	(0.041)	(0.041)	(0.041)
SMB	0.135***	0.151***	0.139***	0.139***
	(0.036)	(0.036)	(0.035)	(0.035)
MRP	−0.008	−0.024	−0.028	−0.007
	(0.070)	(0.069)	(0.070)	(0.070)
Constant	0.447***	0.460***	0.465***	0.446***
	(0.073)	(0.073)	(0.073)	(0.073)
Observations	1,372	1,372	1,372	1,372
R^2	0.238	0.239	0.240	0.238
Adjusted R^2	0.236	0.237	0.237	0.236
Res.St.Err. (df = 1367)	0.931	0.930	0.930	0.931
F Stat. (df = 4; 1367)	107.019***	107.317***	107.627***	106.823***

*p<0.1; **p<0.05; ***p<0.01

Now looking at MRP there is no statistical significance to this factor, which is puzzling. The factor is computed as average return on broad market portfolio subtracted by the average return on treasuries portfolio and given the insignificant result it could suggest that there is no clear evidence of investors penalizing stock market securities with positive risk premium for all the stock market associated risks that are absent in the bond market as opposed to bonds. This may have something to do with the fact that for most of the period the

European bonds return data show on average 0.05% return (5.44% cumulatively) as opposed to stock market showing average monthly returns of 0.75% (cumulatively 90.6%) as shown in the Figure 6.14. below. However it is not clear to the author why this result is statistically insignificant.

Figure 6.14: Cumulative returns: European equity vs bond markets



6.6 Explanatory Power of GMB

In order to investigate explanatory power of the GMB variable the studied models (i.e. CAPM, FF3, CH4, FF5) are all used on the sample data with and without the GMB variable. The results from these models will produce not only coefficients on the estimation factors and their significance on estimation sample, but also R^2, which is used as a proxy for explanatory power of the researched variable. Should the R^2 be significantly higher after adding GMB factor in the model and should the factor be statistically significant the inference would be that GMB factor adds to explanatory power of the model and that it is relevant to add. The sample used for this analysis is neither ES3 nor ES6, but the original sample from which the two were created, filtered for stocks with missing data.

In order to estimate CH4 model it is necessary to create WML variable (winners minus losers) as it is one of the base variables in CH4 models in addition to MRP, SMB and HML. The WML factor was created in line with the instructions by Kenneth R. French. Thus, first the data sample was divided into big and small portfolios (with respect to the market capitalization of companies). Afterwards within each portfolio the "winners" and "losers" were identified by taking 10% of the highest return companies and 10% of lowest return companies within each portfolio respectively. Monthly WML was created using difference of equal-weighted averages of returns for two winner portfolios and average returns of two loser portfolios as per following formula:

$$WML = (BigHigh + SmallHigh)/2 - (BigLow + SmallLow)/2$$

The Table 6.7. below summarizes the findings of multiple regression analyses. These results suggest that most models yield no additional significant explanatory power from inclusion of either of GMB factors. CAPM is the only model where GMB factors are statistically significant. Weak statistical significance is also observable with FF5 model augmented by GMB/10 factor. In line with authors mentioned in literature review these results suggest that GMB factor based on ESG score is wholly explained by SMB and HML factors, since adding these and other factors to the model render GMB factors obsolete. Therefore it may be concluded that GMB factors based on ESG score are not relevant inclusion in the following asset pricing models and do not increase explanatory power as witnessed by constant R^2 in all but CAPM models.

Table 6.7: Explanatory power of GMB factors across different asset pricing models

Model	Factor								R^2
	MRP	SMB	HML	WML	RMW	CMA	GMB/3	GMB/10	(adjusted)
CAPM	1.129***								0.936
CAPM + GMB/3	1.185***						-0.448***		0.948
CAPM + GMB/10	1.187***							-0.337***	0.950
FF3	1.059***	0.593***	0.206***						0.978
FF3 + GMB/3	1.065***	0.567***	0.212***				-0.049		0.978
FF3 + GMB/10	1.075***	0.524***	0.221***					-0.094	0.979
CH4	1.050***	0.614***	0.111**	-0.074***					0.979
CH4 + GMB/3	1.056***	0.590***	0.117**	-0.074***			-0.044		0.979
CH4 + GMB/10	1.066***	0.546***	0.126***	-0.074***				-0.093	0.980
FF5	1.050***	0.611***	0.336***		0.256***	-0.020			0.980
FF5 + GMB/3	1.057***	0.577***	0.346***		0.259***	-0.023	-0.065		0.980
FF5 + GMB/10	1.065***	0.533***	0.361***		0.262***	-0.034		-0.105*	0.980

Chapter 7

Conclusion

This diploma thesis investigated into the usefulness of ESG score as a proxy of company sustainability and how this proxy relates to stock returns and volatility based on different samples formed with respect to different lengths of ESG score reporting periods and different portfolio sorting methods. The single-sort analysis on ES3 sample yielded results suggesting there is a weak evidence of Laggards portfolio outperforming Leaders in 2 year measurement period, whereas in other periods (1 and 3 year) results proved to be insignificant. On the other hand in each period of ES3 sample the ERV of Leaders portfolio proved to be significantly lower than that of Laggards, showing that high ESG firms are more stable in this sample. In the same sample the Leaders portfolio performances was also compared to the benchmark S&P 500 performance yielding results that suggest Leaders significantly underperform S&P 500 index in all periods. In case of volatility the index proved to be less volatile than the Leaders portfolio. These results are to be taken with a grain of salt in the light of recent shocking events on the world scene (pandemic related impacts and war in Ukraine). Investigating the longer sample ES6 should abstract some of the recent effects. Analysis on ES6 sample reported only a weak outperformance of Leaders portfolio against Laggards in 6 years period with otherwise statistically insignificant results. Same with the volatility, only 2 year period yielded results suggesting that Leaders portfolio are more stable on average than Laggards portfolio. Comparing Leaders to the benchmark index, the index proved to be outperforming significantly the Leaders portfolio in all periods. Also, the index proved to be more stable in 2 and 4 year periods than the Leaders portfolio. Comparison of Leaders portfolio to the index proved to be very consistent across both ES3 and ES6 samples, yielding very comparable results. The literature seems to be divided on the topic of performance of sustainable and unsustainable portfolios in terms of returns. Overall the results in this study proved no strong relationship in this regard, mostly statistical significance was not even achieved. On the topic of volatility there seems to be more agreement among researchers that lean in favour of sustainable firms being more stable. In line with this is the ES3 sample analysis showing that indeed Leaders portfolio is more stable than Laggards portfolio at all periods. Nevertheless ES6 sample yielded statistically insignificant results in this regard.

Double-sort analysis was purposed for differentiation of ESG and size effects that are strongly correlated as bigger firms usually report higher ESG score. Overall the double sort heatmap analysis suggest that ES3 sample returns are strongly impacted by size effect but weakly also by ESG effect, where Laggards seem to be outperforming Leaders and bigger companies (in light of recent events) outperform smaller companies. Indeed Laggards consistently outperformed Leaders cross all portfolios in ES3 sample and in a big portfolio in ES 6 sample, as shown by statistical results. Medium and small portfolios in ES6 sample do not support this result though. In the longer sample ES6 the heatmaps suggest that returns are again strongly influenced by size effect with bigger firms still outperforming smaller firms and higher ESG scorers outperforming lower ESG scorers. This proved to be true only in case of small companies portfolio in ES6 sample, where Leaders outperformed Laggards. In regards to volatility ES3 heatmaps show significantly lower volatility of bigger companies, although with no significant difference between medium sized and small sized companies. ESG score seemed to be rather insignificant in this regard. Statistical results suggest overall higher stability of Laggards portfolios rather than Leaders. ES6 sample heatmpas reported strong size effect with big companies being significantly more stable and with medium companies also being more stable than smaller ones. ESG effect is also observable with Leaders usually being less volatile than Laggards. Statistical results proved this to be right, but only in case of big companies portfolio. Medium and small companies yielded no statistically significant results. All in all results suggest that abstracting size effect ESG effect is still significant although not always intuitively so and not consistently, across all periods.

The ESG measure was also used in FMB regression to prove the existence of climate pricing via the existence of negative ESG-related risk premium, which was confirmed, meaning investors do consider climate related issues to some degree. This is in line with the reviewed literature that suggests heavily polluting companies' stocks are discounted for a fact that it bears an extra risks. Furthermore the ESG score was used to test whether it is a relevant add-on in the different most popular asset pricing models such as capital asset pricing model, Fama-French 3 factor model, Carhart 4 factor model and Fama-French 5 factor model. The results show that addition of "green-minus-brown" (GMB) factor in the model was associated with better model performance only in the case of capital asset pricing model. The reason is that ESG effect is mostly captured by the SMB and HML factors and thus it seems to be unnecessary to include this variable in the Fama-French and Carhart models. The literature seemed to be divided on the usefulness of inclusion of ESG score into these asset pricing models. Authors were divided into two groups where one reported usefulness of inclusion of this and related measures in asset pricing models and second group that reported no usefulness in adding the sustainability and ESG variables into the model. This study yielded results supporting the second group, where adding ESG in more sophisticated models proved to be meaningless with one exception - the Fama-French 5 factor model reported GMB factor statistically significant and negative on 10% confidence interval, although the adjusted R^2 of the model was not enhanced by this variable.

As occasionally mentioned in the study many of the produced results (especially in returns and volatility) proved to be counter intuitive and in conflict with the empirical observations. This is however not a reason for concern over the data quality or methodology, because as author mentions the times during which analysis was conducted are extraordinarily chaotic and strongly influenced by exogenous major events. Lastly as pointed out by authors partaking in the related literature the pricing of climate related risks is still largely imprecise, unsystematic and inconsistent. There is no perfect measure to measure corporate climate-change related risks and there is a shortage of systematically reported measures that could capture these effects. This will inevitably lead to inconclusive and imprecise results yielding results that must be always taken with a grain of salt. It is precisely this uncertainty and chaos that is a factor of detest for institutional and other financial investors who refuse to rely on the existing academic results as a tool to price in the climate-related risks based on existing measures.

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Appendix A

List of Countries Used In Estimation

1. Albania
2. Andorra
3. Austria
4. Belarus
5. Belgium
6. Bosnia and Herzegovina
7. Bulgaria
8. Croatia
9. Cyprus
10. Czech Republic
11. Denmark
12. Estonia
13. Faroe Islands
14. Finland
15. France
16. Germany
17. Gibraltar
18. Greece
19. Guernsey
20. Hungary
21. Iceland
22. Ireland
23. Italy
24. Jersey
25. Latvia
26. Liechtenstein
27. Lithuania
28. Luxembourg
29. Macedonia
30. Malta
31. Moldova
32. Monaco

33. Netherlands
34. Norway
35. Poland
36. Portugal
37. Republic of Montenegro
38. Republic of Serbia
39.
40. Romania
41. Russia
42. San Marino
43. Slovak Republic
44. Slovenia
45. Spain
46. Svalbard and Jan Mayen
47. Sweden
48. Switzerland
49. Ukraine
50. United Kingdom
51. Vatican City State