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Carbon emissions impact on stock performance for IT companies

An empirical study of the link between carbon emissions for information technology companies and stock performance

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This thesis is written as a final project for our Master of Science in Economics and business administration at the Norwegian School of Economics (NHH) with a major in Financial Economics (FIE).

Our primary objective was to do a meaningful and quantitative study that fills a gap in the current literature. As two finance students interested in sustainability, we felt compelled to contribute to this specific field of study.

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Abstract

This paper investigates whether carbon emissions have an effect on financial performance on companies in the information technology sector, by separating emissions in scope 1, 2 and 3. We want to examine if carbon footprint heavy portfolios have an inferior financial performance to the low carbon footprint portfolios. Using a dataset of stock prices and carbon intensities of 358 information technology companies between 2012 and 2021. We find that carbon footprint heavy stocks generate a lower risk-adjusted return, than the stocks with lower carbon footprint, that can be explained by a lower volatility in the Low carbon footprint stocks. However, we also find that historically it is the carbon footprint heavy stocks that generate the highest stock return. The relationship we identify can provide an incentive for investors to invest in low carbon technology stocks.

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Introduction

When large sectors like the oil and gas industry are reducing their emissions, or construction is becoming more sustainable, or financial services are pushing for faster transactions, they are all mentioning new digital solutions. The same goes for when the European Union is planning for its greener future (European Commission, 2022, p. 9). When we are envisioning a more sustainable future, the word “digitization” is repeated like a broken record.

Our personal motivation for this research question has been our common interest in sustainable investments and information technology. We have both observed how some of the largest companies in the world, measured in market capitalization, are IT companies and how this sector is increasing at a rapid pace every year. However, with growing digitalization of society, the climate impact of the IT companies rises. This implies that creative digital solutions can both help in mitigating the consequences of climate change, while at the same time growing emissions from these companies continue to harm the environment.

The most used method for selecting equities by ESG factors is the carbon emissions, which according to Wiedmann and Minx “is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product” (Wiedmann & Minx, 2008, p. 4). By selecting equities with smaller carbon footprints, investors anticipate that minimizing their exposure to climate risk will boost their risk-adjusted return. This approach, however, is contingent on whether equities prices adequately include climate concerns. We have seen previous studies done on sustainability and investing where the sustainability of the companies have been based on ESG ratings, e.g Xiong (2021) and Shanaev & Ghimire (2022). However, basing research on ratings from third parties offer its limitations. That is why we are looking at the actual carbon emissions companies are letting out in the three scopes. The purpose of this study is to determine if and to what degree the financial success of firms is correlated with their carbon exposure across different scopes. This thesis examines historical data from 2012 to 2021 for listed companies within The Global Industry Classification Standard (GICS) sector Information Technology. We investigate how listed firms with varying carbon footprints perform in the stock market, as well as how various carbon emissions may influence shareholder value. By constructing a total of six portfolios with high and low carbon emissions from scope 1, 2 and 3, we evaluate and compare the impact of the various compositions on financial performance.

Our findings indicate that investing in low carbon portfolios result in higher risk-adjusted returns than other options. This was true for all three scopes in the mean variance analysis. We observed that companies with lower emissions in scope 1 and 2, had lower expected return. However, the volatility was several times lower than for the portfolio with higher emissions. For companies with high emissions in scope 3 we observe lower expected return and higher volatility than companies with lower emissions. Our regression results show that all portfolios have significant abnormal return. For scope 1 the abnormal return are equal across high and low emission levels, and for scope 2 and 3 we see that the portfolio of high emissions has larger abnormal return.

Our contribution to the body of knowledge consists of expanding the field of study on companies' carbon emissions and its implications on the stock performance. Cohen, Fenn and Naimon compared in 1997 accounting and market returns of high emission and low emissions companies of the S&P 500 (Cohen et al. 1997). Their researched show no significant positive return from the portfolio of low emissions companies. However, in 2021 Xiong (2021) showed that green stocks with lower ESG risk ratings outperformed brown stocks with higher ESG ratings in the period of 2009 to 2020. Our results align more with Xiong and show that portfolios with low emissions has both abnormal returns and higher risk-adjusted returns than the equivalent portfolio of high emissions.

Theory and literature review

In this section of the master thesis, we aim to build a solid theoretical foundation related to companies within the technology sector, associated carbon emissions and their financial performance. Further, we will explore previous literature on climate change and social responsible investing, as well as the technology sector. Additionally, we will discuss the UN´s Sustainable Development Goals and how the technology sector is working towards adopting these. From the research we present in this part, we have gained a larger understanding of the cost of carbon emissions and climate change. This has motivated our primarily investigation focus, and our research question will be represented in the last part of this section.

2.1 Previous Research

The research around the potential impact from climate change on investments has been growing in hand with the increased knowledge and awareness around global warming and the possible threat for humanity as a consequence of it. Several studies have found that holding green stocks can generate positive returns, and according to Chan and Malik (2022) investors that are willing to hedge against uncertainty in climate policy are willing to pay a higher price and accept lower future returns for Climate policy uncertainty stocks.

Previous research has found a positive return for environmental positive investing, especially around ESG investing. It is found that stocks with a good ESG score have higher returns, as well providing a better tail-risk protection than stocks that have a bad ESG performance. Companies that have achieved a good ESG score also show lower volatility in their stock performance, on average the volatility for these firms where 28.67% less than their peers in the same industry (Kumar et al., 2016, p. 3). In addition to this it has been discovered that funds holding green stocks have attracted significantly more fund flow than funds not holding green stocks (Xiong, 2021).

As global warming is becoming a bigger threat and concern among the general population, governments are starting to take action against carbon emissions by implementing carbon tax on a national level. Finland was the first country in the world to implement carbon tax in

1990 and an increasingly amount of country's have followed their steps in the recent years (Statista, 2022). According to a study done by the International Monetary Fund (2022) they found that stocks return preforms poorer when the carbon cost is higher, this relationship can provide an incentive for the companies to work towards decarburization as it is highly likely that they will experience higher carbon costs in the future because of government regulations.

These findings are applicable to us, as it has been proven that green stocks generate positive return, often investigated by looking at ESG and equivalent scores, while we want to investigate the real environmental effect from the portfolios when investigating financial performance.

2.2 Climate Change

Climate change is caused by an increase in carbon dioxide and other greenhouse gases in the atmosphere, which results mostly from emissions of fossil fuels (McKeever, 2021). The challenge posed by climate change is humanity's greatest peril, endangering development, poverty reduction, and global health. From 2030 through 2050, this threat is anticipated to cause around 250 000 more deaths annually due to malaria, diarrhea, hunger, and health stress (World Health Organization, 2021). Additionally, increasing temperatures drives the intensification of wildfires, storms, floods, and other extreme weather catastrophes (McKeever, 2021). To avert catastrophic health impacts and prevent millions of climate change related deaths, The Intergovernmental Panel on Climate Change has concluded that the world must limit temperature rise to 1.5°C degrees above pre-industrial level. Even if we manage to limit temperature rise to 1.5°C the consequences are unsafe and will cause severe damage (World Health Organization, 2021). To meet the target of 1.5°C we need to cut global emissions by 7.6% yearly between 2020 and 2030, if we do not manage to do this the world can miss the opportunity to get on track and not exceed 1.5°C (UN Environmental Programme, 2019).

Climate change has a negative impact on the financial markets since the impacts of a 1.5°C degree temperature rise would cause serious physical damage and will be financially costly for companies. Following the rising trend of sustainable investment and the promotion of other financial sustainability efforts, investors and policymakers are more aware of the significant consequences of climate change for the financial sector's stability (OECD 2021).

2.3 Sustainable Development

As mentioned in the previous sub-section, the climate change challenge is considered to be one of the biggest threats affecting humanity. Hence, it is urgent to deal with climate change by evolving sustainable development with the aim of transitioning to a low carbon emissions economy. To work towards tackling climate change and sustainable living, the United Nations Framework Convention was established in 1992 and took effect in 1994. Today, the UNFCCC have 198 member countries, a near-universal membership (United Nations Climate Change, 2022). According to the UNFCCC (2022), the ultimate objective of the convention is to stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic inference with the climate system within a time frame that is sufficient to allow ecosystems to adapt naturally to climate change.

In order to shift towards a more sustainable future The Sustainable Development Goals were adopted by the United Nations in 2015. The UN SDG´s are a joint of universal response to challenges like poverty and climate change, and to ensure that by 2030 all will enjoy peace and prosperity (United Nations Development Programme, 2022). The development through the 17 Sustainable Development Goals must balance social, economic, and environmental sustainability. The 193 Member states of the UN´s SDG have committed to prioritize progress for those who are furthest behind, and the goals are designed to end poverty, AIDS, hunger and discrimination against women and girls (United Nations Development Programme, 2022). The 17 Sustainable Development Goals are presented in Table 2.1.

Table 2.1

The 17 UN Sustainable Development Goals

SDG 1	No poverty	End poverty in all its form everywhere.
SDG 2	Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
SDG 3	Good Health and Well Being	Ensure Healy lives and promote well-being for all at all ages.
SDG 4	Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
SDG 5	Gender Equality	Achieve gender equality and empower all women and girls.
SDG 6	Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all.
SDG 7	Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all.
SDG 8	Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
SDG 9	Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
SDG 10	Reduced Inequalities	Reduce inequalities within and among countries.
SDG 11	Sustainable Cities and Communities	Make cities and human settlement inclusive, safe, resilient and sustainable.
SDG 12	Responsible Consumption and Adoption	Ensure sustainable consumption and adoption patterns.
SDG 13	Climate Action	Take urgent action to combat climate change and its impacts.
SDG 14	Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
SDG 15	Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reserve land degradation and halt biodiversity loss.
SDG 16	Peace, Justice and Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
SDG 17	Partnerships for the Goals	Strengthen the means of implementation and revitalize the Global partnership for Sustainable Development.

2.4 Carbon Intensity

The CO2 pollution from a company's operations are divided into three scopes for measurement, scope 1, 2 and 3. Scope 1 and 2 are mandatory for companies to report, however scope 3 is voluntarily to report and harder to measure than Scope 1 and 2. Scope 1 measures emissions that are released into the atmosphere as a direct result of activities and operations at a firm level. The first scope is divided into four categories, stationary combustion, mobile combustion, fugitive emissions and process emissions. Scope 2 is a measurement of indirect emissions from the companies, from purchased energy. Lastly, we have scope 3 which is all other indirect emissions from the firm. This scope measures all emissions that occur in the value chain of the reporting company, both upstream and downstream emissions (Bernoville, 2022). In this research paper we will focus on all three scopes.

Table 2.2

Scope 1	Scope 2	Scope 3
Direct Emissions *Owned Assets*	Indirect Emissions *Energy Purchased*	All other Indirect Emissions *3rd party*
• Facilities • Equipment • Vehicles • Onsite Landfills	• Purchased electricity • Purchased heating • Purchased cooling	• Transportation • Distribution • Waste • Energy and fuel • Leased assets • Travel

Descriptive table emissions measured in each Scope.

Carbon emissions are responsible for around 81% of global GHG emissions and, and as the IT sector alone is responsible for between 2-3% of global greenhouse gas emissions. According to an analysis of the carbon disclosure of 30 of the world's largest technology companies, done by Tech Monitor, several technology companies struggle to reduce their Scope 3 emission, which is the emissions produced by the company's broader value chain, including suppliers and customers (Fitri, 2022).

2.5 Sustainable Finance

The topic sustainability has experienced a rapid growth in popularity over the past decades, and both firms and consumers are making more changes to become greener. For companies to keep up with the consumers, it is important that they implement sustainable solutions and products. Consumers changed shopping habits during the Covid-19 pandemic and adopted more sustainable habits, they shopped more locally and more seasonally. During the economic uncertainty now, as a consequence of the inflation and supply chain disruption, consumers are again finding more innovative ways to spend less money, and one way they are doing this is through adopting a more sustainable way of living and purchasing goods that are more durable or that can be reused or repaired easily (Archer et al. 2022). According to a survey done by McKinsey, 40% of companies in their survey expect to generate value from sustainability (Granskog, A., 2021, p. 3).

Sustainable Finance is from the European Commission defined as "*the process of taking environmental, social and governance (ESG) considerations into account when making investment decisions in the financial sector, leading to more long-term investments in sustainable economic activities and projects*" (European Commission, 2022). ESG investing has experienced a huge growth, and in 2021 ESG investing increased with 55% in assets under management in ESG-integrated products (Wu, J. 2022).

New innovations in technology is helping fund managers to preserve with the exponential increase in demand for sustainable investments. According to Wu (2022) the development of Artificial Intelligence, investors have the ability to analyze further information from the internet, such as the way information is captured, documented and disseminated, hence, access to more data than ever. This has resulted in a dramatic enhancement in corporate transparency since new data sources provide better insights into how companies are being run from an ESG perspective and makes it easier for investors to handpick between top rated ESG firms (Wu, J. 2022).

Based on the findings of several studies, it has been proven that sustainable investing and superior investment returns are positively correlated. Institutional investors are observing that risk related to ESG issues can have a measurable effect on a company´s market value as well as the reputation of the company (Bernow et al. 2017). However, other studies show no correlation between sustainable investing and superior investment returns. This makes it hard to conclude that there if there is a link between sustainable investing and financial performance.

2.5.1 Socially Responsible Investing (SRI)

Socially Responsible Investing (SRI) is a steadily growing market segment, it is an investing strategy that considers not only the financial returns from an investment but also its impact on socially responsible factors such as environmental impact (CFI Team, 2022). The number of investors that incorporates SRI screens into their investment decisions are increasing, and according to a survey from Morgan Stanly in 2019, 85% of individual investors are interested in sustainable investing. Social responsible investing strategy incorporates investing in companies that are making a positive sustainable or social impact, and excluding companies that have a negative impact, like companies that produce weapons and health threatening products (O´Shea et al., 2022). Based on the findings of Kempf and Osthoff (2007) a socially responsible investment strategy leads to higher abnormal returns.

2.5.2 Environmental, Social and Governance (ESG)

According to McKinsey&Company (2017) more than one out of four assets under management globally are now being invested according to the premise that environmental, social and governance (ESG) factors can materially affect a company´s financial performance. Environmental, Social and Corporate Governance (ESG) refers to a set of standards for a company's sustainable and ethical ways of operating. A company that performs well on the environmental pillar operates in a way that is minimizing the company´s harm on the environment. The social pillar addresses the impact and associated risk from workforce, human rights, community and product responsibility and governance is measured from management, shareholders and CSR strategy. Over the last years, the number of companies that are reporting and measuring ESG variable have experienced huge growth with more than 90% of the S&P 500 companies now publishing ESG reports in some form (Pérez et al, 2022, p. 1).

The rising profile of ESG is showing a great impact on investments, inflows into sustainable funds rose from $5 billion in 2018 to $50 billion in 2020. From the end of the first quarter of 2022 sustainable investment funds experienced a small decrease of 13.3%, however compared to the broader market the fall is less significant as this was 14.6 percent, and global sustainable assets are now up to around $2.5 trillion (Pérez et al, 2022, p. 2). Environmental, social and governance factors are becoming higher priority for governments, regulators and servers alike and government policies is a driver for why investors are paying more attention to ESG factors (Gimber &Stadtelmeyer-Petru, 2022, p. 1). As the Paris Agreement has created significant momentum for tackling climate change, with a goal of limiting global warming to maximum 2 degrees Celsius compared to pre-industrial levels, companies have more responsibility than before for their contribution to the climate challenge. Policy changes include new taxes and regulations, as well as benefits for companies working on climate-friendly projects (Gimber &Stadtelmeyer-Petru, 2022, p. 2).

Table 2.3

Environmental	Social	Governance
Renewable fuels	Working conditions	Ethical standards
Greenhouse gas emissions (GHG)	Human rights	Board independence
Energy efficiency	Stakeholder relations	Conflicts of interest
Climate risk	Health and Safety	Pay for performance
Water management	Employee relations	Board diversity and governance
Recycling processes	Diversity and inclusion	Stakeholder engagement
Emergency preparedness	Impact on local communities	Shareholder rights

Overview of the environmental, social and governance pillar included in ESG.

As explained by ESQ, the Environmental pillar of ESG focus on how an organization or business preforms with regard to the physical environment, taking areas into account such as energy use, pollution, natural resource utilization, how animals are treated, and the lists goes on. For companies to boost customer engagement and accessing capital, it is valuable to take initiative towards building a culture of sustainability (McCarthy, 2022). If companies are not taking appropriate action to decrease carbon emissions or protects against environmental incidents, they can face governmental or regulatory sanctions, criminal prosecution and damage their reputation which risk harming shareholder value (S&P Global, 2019).

2.6 Information Technology

The information technology (IT) sector is made up of organizations, sole traders and partnerships that sell IT services and related goods. The IT market includes services such as computer networking, broadcasting, system design and information distribution technologies. This sector also includes the selling of commodities that is used in providing IT services, like computers and other telecommunication equipment.

The technology sector has largely thrived over the last couple of years. The fast-growing sector is experiencing increase in pressure to reduce its carbon emissions, and is currently accountable for 2% to 3% of global carbon emissions (Silverglate, P., 2022, p. 7). As the industry is growing and the online community is growing along with the digital technology becoming a bigger part of everyone's life, the CO2 emissions are expected to continue growing for the technology sector (Fitri, 2022).

According to the International Data Corporation (IDC 2022), the IT industry will surpass $5.3 trillion by 2022. After the speed bump of 2020, the industry will revert to its previous annual growth rate of 5 to 6 percent. The United States is the largest technology market in the world, accounting for 33 percent of the global market in 2022, or nearly $1.8 trillion. Referring to an analysis done by Tech Monitor, Western telecommunications companies have generally managed to decrease their carbon footprint, whereas cloud providers experience that as their business grow so has emissions. The main struggle for several technology companies is to reduce emissions in Scope 3 and it is said that Scope 3 emissions reveal the reality of the technology industries environmental footprint (Fitri, 2022).

2.7 Portfolio Theory

Modern Portfolio Theory (MPT) is an investment theory that allows investors to assemble an asset portfolio that maximizes expected return for a given level of risk, a theory formed by Harry Markowitz (1952). According to the theory the investor is risk averse and must be compensated for a higher level of risk through higher expected returns. Portfolio construction is commonly viewed as the allocation of the overall portfolio to safe assets such as money-market account or Treasury bills versus to risky assets such as shares of stock and the determination of the composition of the risky portion of the complete portfolio (Bodie et al., 2018, p. 157). Over the resent years, many institutional investors, particularly in Europe and North America, have now adopted approaches that consider ESG factors in portfolio selection and management (Bernow et al., 2017, p. 2). Based on the findings from Boffo and Patalano (2020) when testing for the Markowitz efficient frontier, risk adjusted performance vary depending on the ESG index analyzed. We will apply Markowitz portfolio theory to create the portfolios needed to investigate the final research question.

2.8 Research Question

With the intention of measuring the financial impact from a company's carbon footprint, we will conduct a portfolio study that includes technology companies with high and low carbon emissions. As the technology sector is growing at a fast pace, with increasingly higher emissions yearly, we wanted to focus our research around the information technology industry (Fitri, 2022). When reviewing previous literature, we observe that the focus is often around the companies ESG score and how this is affecting stock returns, whereas we wanted to look at the real environmental impact from the operations. Previous research around carbon emissions and stock returns mainly concludes that there is a positive correlation between low carbon emissions and higher expected returns, however, there is still research suggesting that carbon emissions does not affect stock returns. Therefore, we want to investigate whether investing in portfolios consisting of low carbon intensity will have a positive effect on expected returns compared to high carbon intensity, with a focus on scope 1, 2 and 3 emissions. Leading us to our final research question:

How does carbon emissions from each scopes affect financial performance of IT companies in the stock market?

In order to answer our research question, we are mainly interested in looking at financial performance in our portfolios. The financial factors we are focusing on are, expected returns, Sharpe ratio and standard deviation. To do this, we will put together six portfolios where each portfolio is composed of high and low carbon footprint companies for scope 1, 2 and 3. By doing this we can further investigate how company's financial performance is effected by their carbon footprint, and which of the three scopes that has the most impact on financial performance. With the aim of excluding industrial factors we will only focus on the information technology sector. This provides us with a dataset of 358 companies performance from January 2012 to December 2021.

Hypothesis

In this section of the thesis, we will describe the hypothesis development and the testing mythology used.

Based on findings from previous research, it has been presented higher systematic risk in companies with a high carbon footprint. Specially, it has been seen that financial markets are pricing the Paris Agreement by decreasing the systematic risk and increasing the portfolio weights on of low-carbon indexes, however, stock market reactions for carbon intensive indexes are mild (Monasterolo & Angelis, 2020, p. 5). The goal of the Paris Agreement is to limit global warming to a level below 2°C degrees, preferably 1.5°C degrees compared to pre-industrial levels. In order to reach this goal, it is necessary that companies must be held accountable for their environmental impact which will additionally affect the investors. Hence, we want to further investigate the financial impact of investing in low carbon footprint companies leading us to the following research question

How does carbon emissions from each scopes affect financial performance of IT companies in the stock market?

To answer our research question, we will first focus on the impact value of carbon emissions. This is to determine if carbon emissions have significant impact on financial performance for companies in the technology sector. To accomplish this, we will conduct a mean variance analysis to get an overview of portfolio performance. Furthermore, we will implement a regression to test specifically on the technology sector, to discover how carbon emissions are effecting stock performance. In or regression model, we will have six separate portfolios, consisting of high and low carbon footprint for scope 1, 2 and 3. By doing so, we can investigate financial performance in Low and High, carbon footprint portfolios. The reason we are separating the scopes are to investigate if the three scopes have different impact on financial value, and if so, which of the scopes have the most significant impact on information technology company’s financial performance.

Further, we will test the following two-sided null hypothesis against the alternative hypothesis:

H0: IT companies in the Low S1, S2 and S3 portfolio`s **will not** generate higher risk-adjusted return than the IT companies in the High carbon footprint portfolio, when
H1: IT companies in the Low S1, S2 and S3 portfolio **will** generate higher risk-adjusted return, than the IT companies in the High carbon footprint portfolio

H0: Reducing emissions in Scope 3 **will not** have the most impact on stock returns.
HA: Reducing emissions in Scope 3 **will** have the most impact on stock returns.

The reason we expect the IT companies with a lower carbon footprint to generate higher risk-adjusted returns is because we assume that the Low portfolios will have a lower systematic and unsystematic risk, which is captured in the Sharpe Ratio. These assumptions are based on findings from previous research that have found that ESG firms and green stocks have lower volatility and generates higher return, thus, providing a higher risk-adjusted return (Kumar et al., 2016, p.4).

Further, we expect decarburization of scope 3 emissions to have the greatest impact on stock performance for information technology companies. The majority of carbon emissions for IT companies comes from scope 3 and is often a struggle to reduce, as these are indirect emissions from the company´s broader value chain, including customers and suppliers. Hence, we expect that IT companies who reduce scope 3 emissions to experience a greater impact on their stock returns, than IT companies that reduce emissions in scope 1 and 2.

To answer our research question, we will test our two-sided null hypothesis against the alternative hypothesis. In the following section, we will present the data material and the methodology that were used in order for us to investigate our research question and test our hypothesis.

Data

In the following section of the thesis, we present the data material used to analyze differences in the impact from the three scopes on financial performance, in addition to this, any assumptions made will be explained and reviewed. Furthermore, we present the data from Refinitiv Eikon and how we constructed the portfolios. The sample period is from financials and scope values from 2012 to 2021 and consist of 358 observations.

4.1 Refinitiv Datastream

Refinitiv Datastream is an analytical data source that enables detailed explanations between data series, which provides data covering 175 countries from international organizations for a worldwide perspective (Refinitiv, 2022, p. 1). Datastream has an unmatched database consisting of 39 million individual instruments across all major asset classes. Refinitiv provided us with carbon emissions data and financial performance factors for companies in the technology sector. When cleaning the data, we only included companies that are included in Global Industry Classification Standard (GICS) for companies in Information Technology.

4.1.2 Global Industry Classification Standard (GICS)

The Global Industry Classification Standard (GICS) is a common global classification standard used by thousands of market participants across all major groups involved in the investments process. GICS consists of eleven sectors, 24 industry groups, 69 industries and 158 sub industries, a four-tiered, hierarchal industry classification system (Refinitiv, 2022). In 1999 the classification system was created by Standard and Poor´s Financial Services LLP (S&P) and MSCI. The data we have used to answer our research questions includes only companies that goes under GICS Information Technology sector. When we exclude all other industries in our dataset, we are left with 6315 information technology companies.

4.2 Fama-French Data Library

The Fama-French three-factor model was the first model established in 1992 by Eugene Fama and Kenneth French that extends the capital asset pricing model (CAPM) by adding two more components to explain asset returns. To better explain the returns of particular equities, Fama and French later added two additional elements to the three-factor model and produced the five-factor model.

The Fama-French five-factor model is regarded as a thorough model for describing individual stock returns. It is frequently employed in combination with the three-factor model and has shaped current portfolio theory. We felt it was important for our study to expand the Fama and French five risk factor analysis of North American companies to count for IT companies around the world instead. The stock data is obtained using Refinitiv. The monthly stock data is collected for a 10-year sample period from January 2012 to December 2021. Each year, we managed a distinct portfolio of IT firms. Due to varying global reporting requirements, the number of firms covered annually would range from 3 306 in 2021 to 4 768 in 2019. To standardize and facilitate a fair comparison, the entire data set is represented in dollars.

4.3 MSCI World Information Technology Index

In order to apply the CAPM in our regression, we had to employ a market return, which we created by using the monthly returns from the MSCI World Information Technology Index as we have created our portfolios based on technology companies worldwide. The MSCI Index is designed to capture the large and mid-cap segments across 23 Developed Markets countries. According to MSCI (2022) the index is based on the MSCI Global Investable Market Indexes (GIMI) methodology, which is a comprehensive and consistent approach to index construction that allows for global views and cross regional comparisons across all market capitalization size, sector and style segments. All the securities that the Index contains are classified in the Information Technology sector as per the Global Industry Classifications Standard, the same standard we have used to retrieve information technology companies in our dataset for the portfolio construction (MSCI, 2022).

4.4 Portfolio Construction

In order for us to conduct our analysis and investigate how companies in the information technology sector are financially affected by carbon emissions, we composed mutually exclusive portfolios by creating two portfolios for each scope, with high and low carbon footprint companies. The "high" portfolios consist of companies in the technology industry that are among the 20% companies with the highest carbon footprint. The "low" portfolio companies are the 20% that have the lowest carbon footprint out of all the technology companies in our dataset. We have calculated each company´s carbon footprint by dividing each the carbon emissions from each scope on revenues to exclude company size as a factor that can affect the final result, the calculation is illustrated in formula 4.1.

$$Carbon\ Footprint\ = \frac{Carbon\ Emissions\ Scope\ X}{Revenue} \tag{4.1}$$

By construction the portfolios with this partitioning, we can determine whether there exist any reasonable differences in financial performance for company's carbon emission scoring, and if so, which of the scopes have the highest impact on financial performance.

For technology companies, scope 3 emissions are the industry's biggest carbonization challenge as it is emissions the companies can influence but have no direct control over (Fitri, 2022). Technology companies often have carbon hotspots in Scope 3, which might include the materials and services they purchase, manufacturing equipment or how the products are used by the consumers once it is sold and no longer under the company`s control (Fitri, 2022). Based on the carbon emission data in our portfolio, Scope 1 has an average carbon emissions score of 71 340.408 whereas Scope 2 emissions has 430 274.759 and lastly Scope 3 with 3 603 061.503, hence, it is clear that Scope 3 is the biggest challenge for the tech industry. These are the total carbon emissions score, when we are looking at the score´s relative to company size, we will divide the carbon emissions with regard to total revenue. To illustrate this, figure 4.1 shows average carbon emissions across all sub sectors for technology companies, for all three scopes.

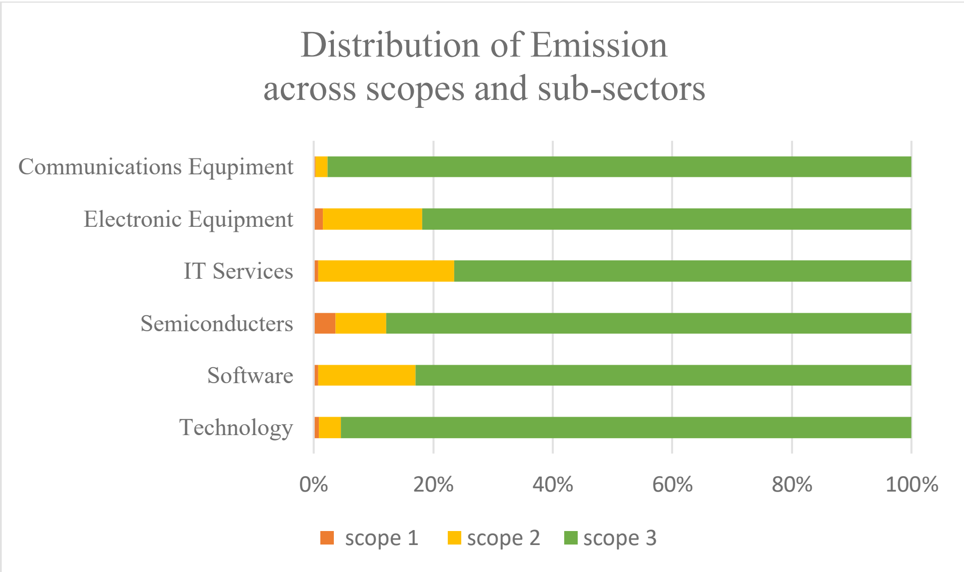
Table 4.1

Sub-sector	Scope 1	Scope 2	Scope 3
Technology Hardware, Storage & Peripherals	65.75	278.55	7 263.17
Software	12.66	271.40	1 382.73
Semiconductors & Semiconductor Equipment	522.15	1 207.89	12 488.47
IT Services	38.13	1 194.67	4 002.77
Electronic Equipment, Instruments & Components	96.44	1 002.49	4 954.58
Communications Equipment	184.56	1 285.12	60 951.83
Total (kgCO_2/Revenue in millions)	**919.69**	**5 240.13**	**91 043.56**

Table 4.1 illustrates the average carbon footprint for each scope across all sub sectors included in the technology industry, that are included in our portfolio.

The numbers presented in table 4.1 are calculated by the average carbon emissions for each sub-sector in our data set, divided by the average revenue, for each scope (A1). This figure only takes 2021 emissions into account. Based on the data presented in table 4.1 it is clear that scope 3 has the highest emissions, also when company size is factored in. The sub-sector Software preforms the lowest carbon footprint out of all others, with Microsoft Corp as the biggest company included in this portfolio. Despite the fact that the Software sector has the lowest carbon footprint, with Microsoft Corp as the most profitable company, the company has struggled to contain its elective emissions against a backdrop of booming growth. The total emissions for Microsoft Corp, over scope 1, 2 and 3 has experienced a growth of 29% since 2017 (Fitri, 2022). Communications Equipment has the overall highest carbon footprint, and exceeds all in scope 2 and 3. With a scope 3 of 60 951.83 total CO2 divided by revenue (tCO2/Revenue), communications equipment companies stands for over 60% of the total carbon footprint for scope 3 across all six sub sectors. Communications Equipment companies are responsible for manufacturing the hardware, devices and equipment and includes companies providing telephone, cable and data services (Astro Machine Works, 2022). The most profitable communications equipment company in our portfolio is Cisco Systems Inc, a company that provides innovative software-defined networking, cloud and security solutions. The only sub sector to exceed the communication equipment in a scope is semiconductors and semiconductor equipment companies for scope 1. A semiconductor is a substance with electrical features, they conduct electricity under certain circumstances (Zola, 2021).

Figure 4.1



This figure illustrates the distribution of carbon emissions across scope 1, 2 and 3 for all sub-sectors in the technology industry, that are included in our portfolio.

Figure 4.1 illustrates how the carbon emissions in distributed over all three scopes, noticeably it is scope 3 that dominates emissions across all sub-sectors for the technology companies in our portfolio.

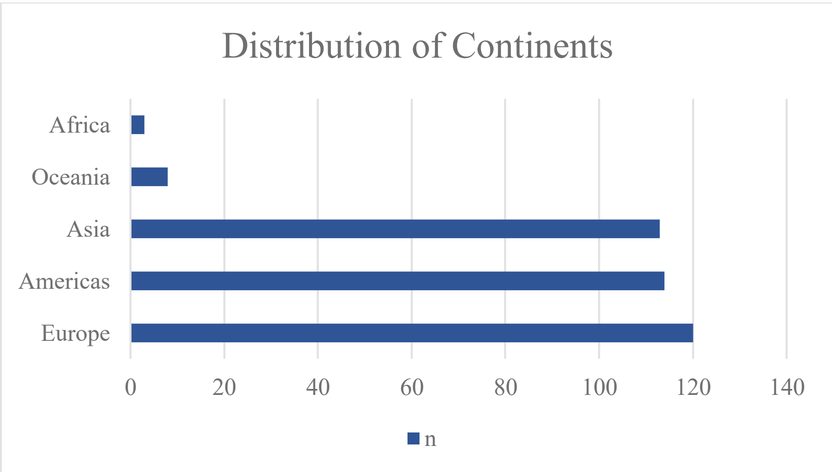
4.5 Reliability and Validity

In order to ensure research quality and check the reliability and validity of our data we conduct several test of our data. It is essential to establish quality of our research, and to do so, a good research design is a crucial element in this process (Kalu & Bwalya, 2017, p. 43).

Accuracy of measure is a concern, how carbon emissions are documented may jeopardize the validity of or research. We have gathered carbon emissions data from Refinitiv Eikon that follow Green House Gas (GHG) protocol for all emission classifications by type. The gases that are relevant are; Carbon Dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCS), perfluorinated compound (PFCS), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3) and is presented as ton of CO2 (Refinitiv, 2022). The final CO2 score presented in this thesis consists of the total carbon emissions score in ton divided by company revenue in US dollars. Scope 3 is not mandatory to measure, which can make the results for scope 3 less reliable as some companies in our portfolio has not reported scope 3 measures every year.

The dataset is composed of companies worldwide and does not have a balanced distribution among countries and parts of the world. For that reason, a countries tax regulation on carbon emissions can affect the financial performance of the company and jeopardize our findings, as it may be variations that are caused by country regulations and not the carbon emissions itself. This can cause big differences for companies that operate in “high carbon tax” countries, whereas companies operating in a country that does not have carbon tax will not be affected by this. Figure 4.2 illustrates percentage of countries represented in our dataset.

Figure 4.2



The y-axis presents the continents that are represented in our dataset.
The x-axis represents total number of countries from each continent. N is number of observations.

Based on the data presented in figure 4.2, Europe is the highest represented continent in our data set with the most technology companies followed by America and Asia. As mentioned, it is important to consider the fact that the tax regulations may vary across continents and countries, as this can affect our final results since our portfolios are not equally distributed across continents. In our dataset, most of the technology companies are based in Europe and for the countries the tax regulations are of significant difference, where some have no carbon tax at all and others the highest in the world. The European countries with the most technology companies in our dataset is the United Kingdom (30) followed by Germany (14), Sweden (14), France (13) and lastly Switzerland (9) as to be seen in Appendix A3. The carbon tax for Sweden and Switzerland exceeds the rest at a level of US$129.89/t$CO_2$e, and US$129.86/tCO_2e which is the highest for all European countries (Bray, 2022). Compared to the lowest carbon tax countries in our portfolio which is Germany and the United Kingdom at a carbon tax rate of zero in Germany and US$23.47/t$CO_2$e in the UK. America is the second biggest continent in our portfolio, with the majority of the companies coming from the USA. Third in our portfolio comes Asia, according to the UNFCCC (2019) Asia-Pacific is the single largest region contributing to the emissions of carbon dioxide, being responsible for approximately 40% of global emissions. Similarly, to Europe and America, the carbon tax regulations differ a lot between countries. These policies may affect our findings, as countries with higher carbon tax are punished more financially for polluting than countries without/with low carbon tax, and may therefore jeopardize the result of our study.

Methodology

In this section of the thesis, we discuss the methodology approach that was used to complete our analysis to answer our research question. In order to answer our research question, we have formed six portfolios of IT companies, two for each of the three scopes based on high and low carbon footprint. With the purpose of understanding if low carbon emission companies generate superior financial performance on the stock market, by including risk factors and looking at the Sharpe ratio. We use the CAPM and Fama French 5 factor model where monthly excess stock return for our portfolios are the dependent variable.

5.1 Value-weighted portfolio

Empirical asset pricing often deals with portfolios of stocks rather than individual shares to explain stock returns. In order to investigate our research question, we have used value-weighted portfolios where each stock is weight according to maximize the total portfolios Sharpe Ratio. Formula 5.1 illustrates how the return of each portfolio is calculated:

$$r_{pt}^{VW} = \sum_{i}^{N} r_{it} * w_{it} \tag{5.1}$$

Where w_{it} is calculated by using Solver in Excel, for maximizing the total Sharpe ratio by optimizing the weights of each stock.

5.2 Risk adjusted measures Jensen's Alpha

With the purpose of measuring risk-adjusted return of our portfolio´s in line with the expected market return from the CAPM, we use the metric Jensen´s Alpha. The alpha indicates better (or worse) performance of a portfolio, and it is one of the key metrics for risk used in the modern portfolio theory (Phuoc, 2018, p. 2). Jensen´s Alpha (1969) is calculated by deducting the estimated expected return from an asset-pricing model, from the actual return rate of the portfolio. A fairly priced portfolio will have actual returns equal to the expected return given by the asset-pricing model, and the alpha will be zero. Therefore, when the portfolio is preforming above (below) expected return the portfolio´s alpha will be positive (negative).

5.3 Sharpe Ratio

Moreover, the research was conducted by computing the Sharpe ratio for the portfolios. The Sharpe ratio presupposes risk symmetry and penalizes the average performance, as measured by the average excess return over the risk-free rate, by the up- and down-variances encoded in the global variance of stock returns (Gatfaoui, 2009, p. 8). This reward-to-volatility ratio is extensively used to evaluate investment managers' performance (Bodie et al., 2018, p. 133).

$$Sharpe\ Ratio_i = \frac{R_{it} - R_{ft}}{\sigma_{it}} \tag{5.2}$$

Where,

$R_{it} = Motnhly\ return\ on\ portfolio\ i\ in\ motnh\ t$

$R_{ft} = Monthly\ American\ risk\ free\ rate\ in\ mont\ t$

$\sigma_{it} = Standard\ Deviation\ for\ portfolio\ i\ in\ month\ t$

The Sharpe ratio is calculated for each portfolio by using formula 5.2.

5.4 Monthly returns

Our dataset consists of monthly returns for the stocks in our portfolios. The stock´s monthly rate of return can be calculated by finding the natural log of the price change from one month to the next.

$$r_{it} = LN\left(\frac{Adjusted\ price_{it}}{Adjusted\ pric_{it-1}}\right) \tag{5.3}$$

Formula 5.3 illustrates *Adjusted price* for company *i*´s market price.

5.5 Model Specification

The purpose of this section is to give a description of the quantitative research methodology we have applied to answer our research question. With the aim of understanding the portfolios risk exposure relative to its stock return, we employ the Capital Asset Pricing Model (CAPM) and the Fama-French Five-Factor Model (FF5). The CAPM is a set of predictions concerning equilibrium expected returns on risky assets, the model is one of the centrepieces of modern financial economics (Bodie et al., 2018, p. 277). Fama & French (1993) argue that CAPM lack explanations of variations in returns and propose the Fama-French five-factor model that also accounts for firm's size and book-to-market value, as well as including a profitability factor and an investment factor. By applying both the CAPM and FF5 in our research we increase the analytical complexity of our thesis, as well as the explanatory power and validity of our findings. For our six portfolios, we employed ordinary least-squares (OLS) regression. Further in this section we will present the CAPM and FF5.

5.5.1 Capital Asset Pricing Model (CAPM)

The CAPM model consists of two sets of assumptions, the first pertains to investor behaviour and allows us to assume that investors are similar in most important ways, specifically that they are all mean-variance optimizers with a common time horizon and a common set of information reflected in their use of an identical input list. Moreover, the second set of assumptions pertains to the market setting, asserting that markets are well-functioning with limited impediments to trading (Bodie et al., 2018, p. 278). The CAPM equation is given by:

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \varepsilon_{it} \tag{5.4}$$

Where,

$R_{it} = Return\ on\ portfolio\ i\ in\ month\ t$

$R_{ft} = Monthly\ risk\ American\ risk\ free\ rate\ in\ month\ t$

$R_{mt} = Return\ on\ market\ proxy\ in\ month\ t$

$\varepsilon_{it} = Error\ term\ in\ motnh\ t$

$\alpha_i = Jensen's\ alpha\ , i.e. interncept\ and\ abnormal\ return$

$\beta_i = Portfolio\ i's\ market\ risk\ exposure$

The intuition of CAPM is that to estimate the expected return of the stock, or portfolio, when the investor is exposed to systematic risk (Bøhren & Michalsen, 2012, p. 94). When there is a higher coefficient, it indicates that the portfolio is riskier and should be compensated with the market premium.

5.5.2 Fama-French Five Factor Model (FF5)

To further advance our model we will include the Fama-French risk factors to equation 5.5 presented above. By including the FF5 in our analysis, we can further evaluate our portfolios performance and explain more accurately the portfolio´s return. The aim of including the additional risk factors was to capture all variations of stock prices, to make sure we had excluded other possible factors that affect the performance of the portfolios outside of the emissions. The additional risk factors that the FF5 accounts for are firm´s size through market capitalization, book-to-market value, as well as profitability and investment grade (Fama & French, 2015, p. 3). The firm's size, small minus big (SML), is a risk factor that captures the relationship between the return on a diversified portfolio of small stocks minus the return on a diversified portfolio with big stocks. Further we have the HML, high minus low, factor which explains the difference between the returns on diversified portfolios of high and low book-to-market stocks (Bodie et al., 2018, p. 325). Stocks that have a high book-to-market value are considered *value stocks*, whereas for stocks that have a low book-to-market value are considered as *growth stocks.* RMW, robust minus weak, and CMA, conservative minus aggressive was added to the Fama-French three-factor model in 2014, making the model into the five-factor model we are applying in our thesis. The two additional factors consider differences in company assets in terms of their probability and investment rate (Fama & French, 2015, p. 3).

The Fama-French Five Factor model is given by equation 5.5:

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \beta_{1i}SMB_t + \beta_{2t}HML_t + \beta_{3t}RMW_t + \beta_{4t}CMA_t + \varepsilon_{it} \tag{5.5}$$

Where,

$SMB_t = Return\ difference\ in\ a\ portfolio\ exposed\ to\ small\ cap\ stocks$

$and\ a\ portfolio\ exposed\ to\ large\ cap\ stocks, in\ month\ t$

$HML_t = Return\ difference\ in\ a\ portfolio\ exposed\ to\ value\ stocks\ \left(high\frac{BV}{MV}\right) and\ a$
$portfolio\ exposed\ to\ growth\ stocks\ \left(low\frac{BV}{MV}\right), in\ month\ t$

$RMW_t = Return\ difference\ in\ a\ portfolio\ exposed\ to\ firms\ with\ robust$
$profability, and\ a\ portfolio\ exposed\ to\ weak\ profability, in\ month\ t$

$CMA_t = Return\ difference\ in\ a\ portfolio\ exposed\ to\ companies\ with\ a$
$conservative\ invesment\ strategy, and\ a\ portfolio\ exposed\ to\ companies\ with\ an\ a$
$gressive\ investment\ strategy, in\ month\ t$

$\beta_1, \beta_2, \beta_3, \beta_4 = The\ portfolios\ exposure\ to\ the\ risk\ factors\ SMB, HML, RMW$
$and\ CMA.$

5.5.2.1 Factor calculation

Initially, 10 portfolios are compiled (one per year) including all of the different sub-categories to the IT sector. To ensure that the factors we develop are most closely aligned with our portfolios, we have selected solely IT companies. To ensure we follow the same approach as Fama and French, each portfolio is constructed on the final day of June of the relevant year. The first portfolio contains firms that were included in the IT sector in June 2012, the second portfolio contains companies that were included in June 2013, and so on. The portfolios are determined annually.

The equities within each portfolio are divided into two groups based on their market capitalization. The first category consists of the stocks that account for 90% of the portfolio's total market capitalization. The second group consists of the remaining companies, which represent the remaining 10% of total market capitalization. In this manner, the portfolio is separated into two groups of equities with significantly different sizes. The size of the portfolios vary across the years, but on average does the group that consist of 10% of total market capitalization consist of four to five times as many companies than the group with companies forming 90% of total market cap.

The market factor is determined by subtracting the risk-free rate from the monthly return on the MSCI World Information Technology Index. For the risk-free rate, we used the US one-month Treasury bill rate, the same rate utilized by Fama and French in their FF5 factor computations (French, 2022). Due to the global nature of the firms in our portfolio, we could have also selected the German one-month government bond rate. However, given the American economy is somewhat more significant, we opted for the US one-month Treasury bill rate.

To determine the HML factor, the 30% growth, 40% neutral, and 30% value breakpoints for the book-to-market equity ratio are calculated for each of the categories, and both large and small companies are identified to match. These breakpoints are in accordance with Fama and French's (1993) three-factor model.

The stocks with a book-to-market ratio 30% below the median are growth stocks, while those between the 70th and 100th percentiles are value stocks. Neutral stocks have book-to-market ratios between the 30th and 70th percentiles. These categories permit the formation of six value-weighted portfolios labeled as SH, SN, SL, BH, BN, and BL (where S and B refer to small and big, while H, N, and L correspond to high book-to-market, neutral, and low book-to-market). See table 5.1.

Then, the value minus growth (high minus low) returns for big stocks (HML_{Big}=BH-BL) and small stocks (HML_{Small}=SH-SL) are calculated. Finally, the HML factor is determined by averaging the HML_{Big} and HML_{Small} factors.

The RMW factor is calculated identically to the HML factor, with the exception that the breakpoints are not determined by book-to-market but by operating profit margin. The greater the operational profit margin, the stronger the business. The operating profit margin is created by taking revenues and subtracting cost of goods sold, sales- and administrative costs and interest expense, then divide it by book equity. This is similar to what was done by Fama and French (2015). Then six value-weighted portfolios BR, BN, BW, SR, SN, and SW are created (where B and S refer to big and small and R, N, W refer to robust, neutral and weak). For large stocks (RMW_{Big}=BR-BW) and small stocks (RMW_{Small} =SR-SW), returns for robust minus weak are determined. The final RMW factor is then calculated by averaging the RMW_{Big} and RMW_{Small} factors. The size factor, SMB, is the mean of the three small stock portfolios minus the three large stock portfolios.

The second categorization for the CMA factor is based on the previous year's investment. Conservative companies are ones with minimal investment strategies, whereas aggressive companies invest more. According to Fama and French (2015), the investment component is the yearly change in gross property, plant, and equipment plus the annual change in inventories divided by the book value of total assets. Six value-weighted portfolios are created: BC, BN, BA, SC, SN, and SA. Calculating conservative minus aggressive returns for big stocks (CMA_{Big}=BC-BA) and small stocks (CMA_{Small} =SC-SA). The CMA factor is then calculated by averaging the CMA_{Big} and CMA_{Small} factors.

Once all other risk variables have been determined, the SMB factor is computed, as each of them contributes to it. The factor is calculated by averaging the returns of the SMB portfolios based on the contributions of HML, RMW, and CMA to the size factor.

Table 5.1 (Fama & French, 2015, p. 5)

Sort	Breakpoints	Factors and their components
2 × 3 sorts on *Size* and *B/M*, or *Size* and *OP*, or *Size* and *Inv*	*Size*: NYSE median	$SMB_{B/M}=(SH+SN+SL)/3-(BH+BN+BL)/3$ $SMB_{OP}=(SR+SN+SW)/3-(BR+BN+BW)/3$ $SMB_{Inv}=(SC+SN+SA)/3-(BC+BN+BA)/3$ $SMB=(SMB_{B/M}+SMB_{OP}+SMB_{Inv})/3$
	B/M: 30th and 70th NYSE percentiles	$HML=(SH+BH)/2-(SL+BL)/2=[(SH-SL)+(BH-BL)]/2$
	OP: 30th and 70th NYSE percentiles	$RMW=(SR+BR)/2-(SW+BW)/2=[(SR-SW)+(BR-BW)]/2$
	Inv: 30th and 70th NYSE percentiles	$CMA=(SC+BC)/2-(SA+BA)/2=[(SC-SA)+(BC-BA)]/2$

5.6 Mean Variance Optimization

Henry Markowitz (1952) introduced the notion of a mean-variance efficient portfolio as one that provides minimum variance for a given expected return and provides a maximum expected return for a given variance. The mean-variance specifies that the portfolio weight for each stock are based on a function of each stock’s market value and characteristics. In order to finalize our research of the stock performance for each of our portfolios, we will adopt the analytical framework of a mean variance optimization by Henry Markowitz. The portfolios consist of companies that are either preforming among the top 20% carbon footprint score, or the bottom 20%, for all of the different carbon emission scopes, or the portfolios made up of total emissions from all scopes. We have excluded the possibility for shorting stocks, so each stock in the portfolio is not below 0 and smaller than 1 (100%) with the total value of the portfolio equal to 1 (100%).

By conducting a mean variance analysis, we can compare the financial performance of each of our six portfolios to investigate if there is a correlation between Low (High) carbon footprint and superior (inferior) financial performance. The financial performance factors we are investigating in our mean variance analysis are the Sharpe ratio, expected return, standard deviation and Minimum and Maximum return for each portfolio.

5.7 Model Testing

With the aim of validating and justifying our findings from the CAPM and FF5, our data should meet certain expectations and pass statistical tests to prove significance. In this section we will employ an Ordinary Least Squares (OLS) regression. The test outputs are to be found in Appendix A2.

In order to employ a OLS regression our data is required to meet the set of five conditions from Gauss-Markov. The five conditions from Gauss-Markov: (i) Linearity, the parameters we are estimating using the OLS method must be themselves linear. (ii) Random, our data must have been randomly sampled from the population. (iii) Non-collinearity, the regressors being calculated are not perfectly correlated with each other. (iv) Exogeneity, the regressors are not correlated with the error term. (v) Homoscedasticity, no matter what the errors of the regressors might be, the error of the variance is constant (Glen, 2018). If these five conditions of Gauss-Markov are met, it guarantees the validity of OLS for estimating regression coefficients. Since we are applying the Fama-French Five-Factor model we already know that the parameters are linear and that there is no perfect collinearity, hence, we will not test for (i) and (iii) as we have already established them.

In order to test for autocorrelation in our data set we need to perform a Breusch-Godfrey test. Autocorrelation happens when the residuals of a model are correlated with one another, which may suggest that the model is misspecified or that important predictor variables are missing. The test suggests that there does not exist autocorrelation within our data. Further we need to test if the residuals in the regression exhibit heteroscedasticity by employing a Breusch-Pagan test. Heteroscedasticity occurs when the variance of the residuals varies over the predictor variable range. The result from our test indicates that there is no indication of heteroscedasticity. Finally, we will employ the Augmented Dickey-Fuller (ADF) test to determine if our data has a unit root. We apply the optimal lag length and our results suggest that the stationary assumption is satisfied.

Findings

In this section of the thesis, the outcome of our analysis is presented. We discuss the results of the regressions and illustrate the various risk exposures resulting from applying the CAPM-model and the FF5-model to the created portfolios. Additionally, we will provide the risk-adjusted return for each portfolio based on the results of applying the mean-variance portfolio optimization.

Before we present the findings of our research, we repeat our research question: *How does carbon emissions from each scopes affect financial performance of IT companies in the stock market?*

6.1 Mean Variance Analysis

In this sub-section, we provide a Mean-Variance analysis of our six value-weighted portfolios. Mean-variance analysis is a widely used method of portfolio analysis and is considered to be a cornerstone of modern finance theory. It was first developed by economist Harry Markowitz in the 1950s and has since become an important tool for investors and financial analysts (Board et al., 2008). By calculating the mean and variance of a portfolio, investors can determine the expected return and risk of the portfolio and use this information to make decisions about how to allocate their assets.

The tables illustrate financial performance for the six portfolios we are investigating, compared to a market portfolio that has been created by using MSCI data for global technology stocks.

Table 6.1

Statistics	*Sharpe Ratio*	*Excepted Return*	*St. Deviation*	*Min*	*Max*
Panel A: Scope 1					
High S1 Portfolio	0.4699	0.0218	0.0442	-0.0169	0.0393
Low S1 Portfolio	2.0726	0.0217	0.0001	-0.0232	0.0478
Market Portfolio	0.3350	0.0162	0.0453	-0.1269	0.1273
Panel B: Scope 2					
High S2 portfolio	0.4277	0.0236	0.0528	-0.0269	0.0402
Low S2 Portfolio	1.7494	0.0204	0.0001	-0.0225	0.0646
Market Portfolio	0.3350	0.0162	0.0453	-0.1269	0.1273
Panel C: Scope 3					
High S3 Portfolio	0.4719	0.0192	0.0387	-0.0177	0.0346
Low S3 Portfolio	0.6179	0.0307	0.0023	-0.0269	0.0506
Market Portfolio	0.3350	0.0162	0.0453	-0.1269	0.1273

Table 6.1 illustrates the performance of portfolio High and Low for each of the three scopes. The market proxy is calculated by the MSCI technology stock portfolios over a ten-year period. The Sharpe ratio is calculated by conducting risk free rate from the expected return, divided by standard deviation and is a measure to compare the return of a portfolio with its risk. Expected return illustrates monthly returns that are expected to generate for the future. The standard deviation illustrates volatility for the portfolios.

Table 6.1 presents descriptive statistics on financial performance for the six portfolios we have created to answer our research question. Panel A consists of the technology companies with the 20% highest, and lowest, carbon emissions in our dataset for Scope 1 emissions. Equivalent for Panel B and Panel C, with Scope 2 and 3 emissions. As mentioned in chapter 5, the mean-variance optimization specifies that the portfolio weight for each stock is based on a function of each stocks market value and characteristics. Hence, in order to find the combination of each stock in our portfolios we used Excel's Solver to maximize the portfolios Sharpe ratio by changing the weights. The market portfolio is created by monthly returns from the MSCI World Info Tech found data from January 2012 to December 2021, to include the same ten-year period we have used to create the carbon footprint portfolios for each scope.

We will start by considering Panel A, the aim is to maximize each portfolios Sharpe ratio by any possible combination of stocks. The Low portfolio has a superior Sharpe ratio to the High portfolio, with a Sharpe ratio of 2.0726 compared to 0.4699. By looking at the Sharpe ratio we get a clear view of the relationship between risk and return, it tells us how much excess return we get for the additional risk. A Sharpe ratio between 2 and 3 is considered to be very good (Baldridge & Curry, 2022). From the market portfolio and portfolio High we can assume that the investor is maybe taking on too much risk for the excess return, as they have a Sharpe ratio under 1. It is essential to point out that the Sharpe ratio measures risk adjusted return that considers systematic, and unsystematic risk.

Further in Table 6.1 we can see that the expected return is slightly higher for the "High" portfolio than the "Low", at 0.0218 compared to 0.0217. The market has the lowest expected return at 0.0162, and the highest standard deviation of the portfolios in panel A. The standard deviation is a statistical measure of market volatility, it measures how much prices are dispersed from the average stock price. When stock prices are experiencing a lot of ups and downs the standard deviation will be high to indicate high volatility. The risk for the "Low" portfolio is the lowest measured in standard deviation at 0.0001 whereas "High" and the market portfolio measures 0.0442 and 0.0453, hence, it is the Low portfolio that is holding the least risk. The High portfolio generates the greatest returns, but at a higher risk than portfolio Low, whereas the market portfolio contains the lowest expected return with the highest risk which is not consistent with financial theory that considers the market to be the optimal choice.

The "Low" portfolio has a higher risk-adjusted return than the "High" portfolio, but the "Low" portfolio has a lower projected return. In contrast, when examining Panel C, the Low portfolio had greater risk-adjusted return, standard deviation, and projected return.

Based on the findings in table 6.1, the two portfolios created from scope 1 and 2 generates similar results with a higher risk-adjusted return for the Low portfolio, but a higher expected return for the High portfolio. However, we see different results for scope 3 where the Low carbon footprint portfolio has a greater expected return than any other portfolio. Altogether, it is the Low scope 1 portfolio that is the optimal portfolio with the greatest risk adjusted return.

6.1.1 Mean-Variance Total Portfolio

Based on the results in table 6.1, we developed two more portfolios to explore the influence of carbon emissions on stock performance. These two portfolios were created by combining emissions from all three scopes and dividing by the actual year's revenue of the respective enterprises. The two portfolios comprise of the top 20% and lowest 20% of all firms in terms of carbon emissions.

Table 6.2

Statistics	*Sharpe Ratio*	*Expected Return*	*St. Deviation*	*Min*	*Max*
Low Total	0.5155	0.0218	0.0404	-0.0091	0.0462
High Total	0.5170	0.0210	0.0387	-0.0181	0.0355
Market	0.3350	0.0162	0.0453	-0.1269	0.1273

In table 6.1, the Low portfolio has a higher Sharpe ratio and reduced volatility across all three scopes, however in table 6.2, the High emissions portfolio has the greatest Sharpe ratio. In addition, the portfolios in table 6.1 perform substantially better, with the Low S1 portfolio producing the greatest Sharpe ratio (2.0726). This may be explained by the fact that the majority of firms in the High portfolio will be the same companies that were in the High S3 portfolio, as scope 3 emissions are considerably higher than emissions from the other two scopes. Therefore, the Sharpe ratio will resemble the Sharpe ratio for scope 3 portfolios more closely.

6.2 Cumulative Return

This section will provide findings of cumulative return for High and Low carbon footprint portfolios for scope 1, 2 and 3, as well as a market portfolio created by the MSCI World Information Technology Index. The cumulative return gives us the total change in the portfolios price over, from January 2012 to December 2021.

Figure 6.1

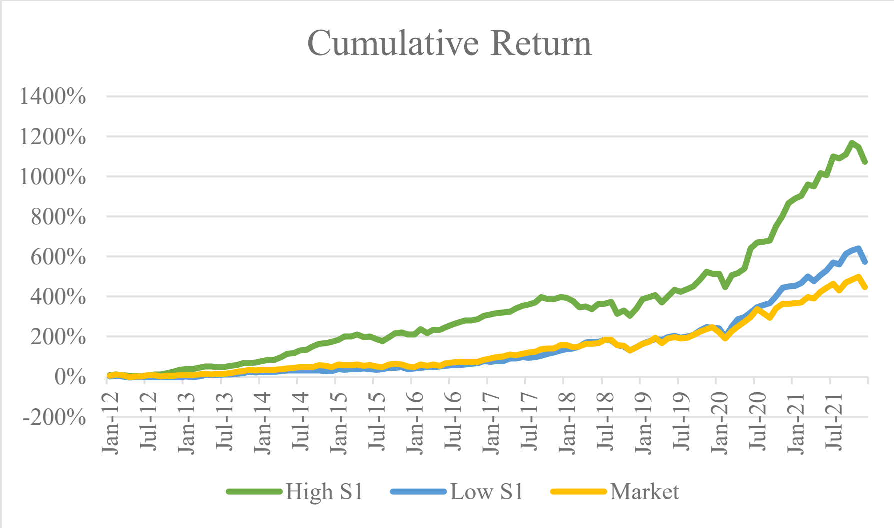


Figure 6.1 illustrates the cumulative return for scope 1.

Figure 6.1 captures the movement of each portfolio´s returns from January 2012 to December 2021. It is clear to see that portfolio High scope 1 historically has generated the highest returns and over the ten-year period we are investigating, it has a total return of 1073.37% compared to portfolio Low scope 1 with a return of 574.59%. Up until the end of 2019, the Market portfolio generated higher returns than the Low portfolio. The Low reached the Market portfolio, giving the Market portfolio the lowest cumulative return out of the three after the ten-year period ending at 446.49%.

Figure 6.2

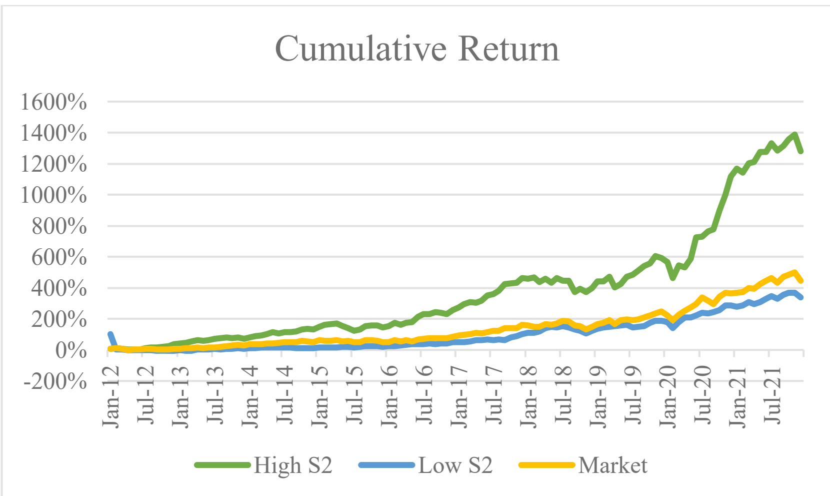


Figure 6.2 illustrates the cumulative return for scope 2.

Correspondingly with the findings in Figure 6.1, we see that it is the High scope 2 portfolio that has the superior historical performance on total return, compared to portfolio Low scope 2 and the market in Table 6.2. The portfolio High achieves a total return of 1280.52% after the ten-year period, whereas the Low portfolio has a total return of 337.85%, and the market 446.49%.

Figure 6.3

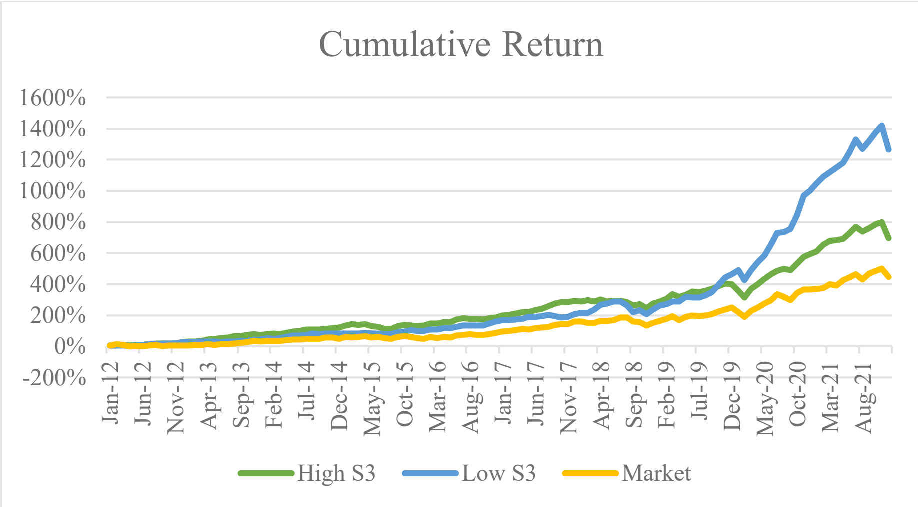


Figure 6.3 illustrates the cumulative return for scope 3.

Based on figure 6.3, the portfolios are moving correspondingly with each other from the beginning of 2012 to the end of 2021. There is a positive trend for all portfolios and the Scope 3 portfolios are experiencing similar ups and downs as the market portfolio. As we can see from the figure, the portfolio consisting of Low carbon emission stocks has been superior to the High carbon emission scope since around October 2019. Up until this point, it was mainly the High emission portfolio that had a superior performance, even greater than the market portfolio until the start of 2018 before the Low portfolio became superior. These findings differ from the portfolios consisting of Scope 1 and 2 emissions, as now it is the Low portfolio that has the superior performance after the ten-year period with a total return of 1267.31% compared to 693.88% and 446.49% for the High and market portfolio.

6.2.1 Cumulative Returns Total

In this part, we will examine the cumulative return of the two additional portfolios shown in table 6.2. We do this to evaluate whether the firms with the highest emissions or the companies with the lowest emissions have created the highest return over the last decade. Also, to see if they have historically outperformed portfolios that solely include emissions from a single scope.

Figure 6.4

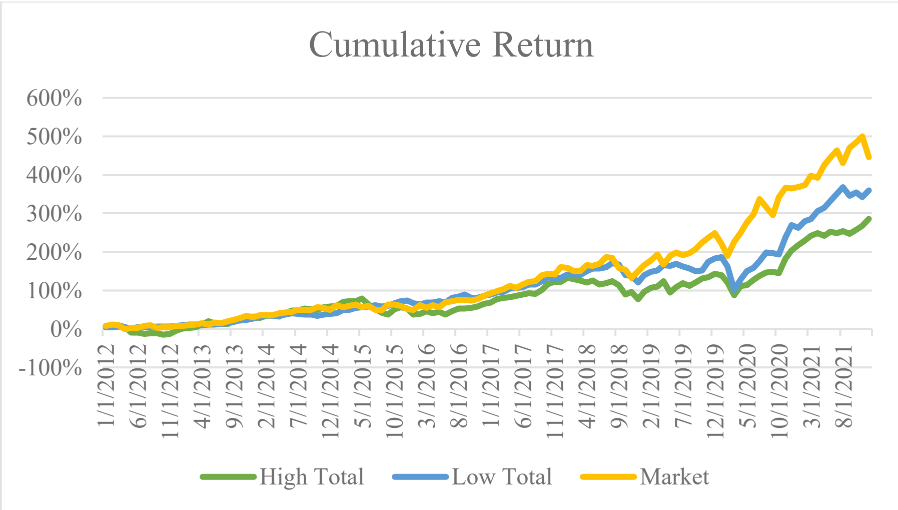


Figure 6.4 illustrates the cumulative return from 2012 to 2021.

The y-axis presents the total return. The x-axis illustrates the time frame.

Compared to the other two portfolios, the market portfolio has had the best financial success, with a return of 446%. Contrary to what we saw in Figure 6.1-3, where the market portfolio had the lowest total return for scopes 1 and 3, these results are not supported by the data. After ten years, the portfolio with the highest total emissions has the poorest performance, with a return of 286%, compared to the portfolio with the lowest total emissions, which has a return of 360%. The portfolio developed by scope emissions with the highest performance was High S2 with a total return of 1,286%. Compared to the Market's ending return of 446%, it is evident that it was most profitable to invest in the portfolio of firms with high scope 2 emissions. Among the eight portfolios examined, the Low S1 portfolio with a Sharpe ratio of 2.0726 is the best option.

6.3 Regression results

This chapter highlights the portfolio-specific regression results. This part will aim to highlight significant estimates and outputs, while the subsequent section will analyze the results. We have run both the high and low emission portfolios against the CAMP and the Fama- French model. The dependent variable for each portfolio is the monthly excess return. All of our portfolios are value-weighted. " MSCI_IT" represents the value-weighted monthly return of the MSCI IT index minus the risk-free rate. The constant represents the monthly abnormal return produced by the portfolio. The SMB factor, "Small Minus Big" (market capitalization), illustrates the portfolios' exposure to small caps company's relative to large caps companies. Whilst the HML factor, "High Minus Low" (book-to-market ratio), captures the portfolios' return gap between value firms and growth firms. The RMW factor represents the portfolio's exposure to firms with robust (high) and weak (low) profitability, while the CMA factor is the exposure to stocks of conservative and aggressive investment firms.

We start by investigating regression table 6.3, with portfolio Low S1 and High S1 constructed by IT companies with low and high emissions in scope 1. The two portfolios exhibit significant alpha for CAPM, but not for the Fame-French model. The two portfolios from scope 1 emissions show significant exposure to companies with weak profitability and aggressive investment strategy. We also find adjusted R2 to be close to 50%, which means that our model explains about 50% of the returns of the portfolio.

Table 6.3

Portfolios Emissions from Scope 1

	Dependent variable:			
	High S1		Low S1	
	CAPM	FF5	CAPM	FF5
MSCI_IT	0.694***	0.704***	0.694***	0.704***
	t = 10.189	t = 10.212	t = 10.189	t = 10.212
SMB		-0.236		-0.236
		t = -0.960		t = -0.960
HML		0.096		0.096
		t = 0.647		t = 0.647
RMW		-0.266**		-0.266**
		t = -2.054		t = -2.054
CMA		-0.215**		-0.215**
		t = -2.527		t = -2.527
Constant	0.011*	0.009	0.011*	0.009
	t = 1.883	t = 1.477	t = 1.883	t = 1.477
Observations	120	120	120	120
R^2	0.468	0.507	0.468	0.507
Adjusted R^2	0.464	0.486	0.464	0.486
Note:				*p**p***p<0.01

The regression in table 6.4 is for the portfolio of companies with the highest and lowest emissions in scope 2. Both portfolios exhibit a significant alpha, and although it is small, it tells us that the portfolio performs better than the index. We also see that both portfolios has significant betas for the index at the 1% level. As it is still below 1, it tells us that companies with high or low emissions in scope 2 still has lower volatility than the index. For FF5 we observe that the index beta is bigger for the portfolio with high emissions. This portfolio also exhibit exposure to companies with larger market cap and lower book-to-market value. For both portfolios we see that they are exposed to companies with weak profitability, as well as companies with aggressive investment strategies.

Table 6.4

Portfolios Emissions from Scope 2

	Dependent variable:			
	High S2		Low S2	
	CAPM	FF5	CAPM	FF5
MSCI_IT	0.673***	0.705***	0.687***	0.692***
	t = 10.827	t = 11.578	t = 9.441	t = 9.340
SMB		-0.407*		-0.270
		t = -1.874		t = -1.021
HML		-0.228*		0.134
		t = -1.750		t = 0.848
RMW		-0.333***		-0.306**
		t = -2.914		t = -2.201
CMA		-0.257***		-0.181**
		t = -3.432		t = -1.982
Constant	0.013**	0.014**	0.015**	0.013*
	t = 2.377	t = 2.566	t = 2.389	t = 1.919
Observations	120	120	120	120
R^2	0.498	0.565	0.430	0.466
Adjusted R^2	0.494	0.546	0.425	0.443
Note:				*p**p***p<0.01

In table 6.5 we find the portfolio of companies with the largest and smallest emissions in scope 3. Both portfolios exhibit a significant alpha and it is bigger for the portfolio with low emission companies. The two portfolios have significant betas for the index at the 1% level, and as it is somewhat larger for the high portfolio, this could suggest that this portfolio has more volatility than the other portfolio, relative to the market. Both portfolios of emissions in scope 3 is exposed to companies with weak profitability and aggressive investment strategies, as we saw for the portfolios for scope 2.

Table 6.5

Excess Return Portfolios Emissions from Scope 3

	Dependent variable:			
	High S3		Low S3	
	CAPM	FF5	CAPM	FF5
MSCI_IT	0.689^{***}	0.710^{***}	0.685^{***}	0.697^{***}
	t = 11.448	t = 11.855	t = 9.817	t = 9.939
SMB		-0.264		-0.234
		t = -1.233		t = -0.935
HML		-0.184		0.162
		t = -1.431		t = 1.077
RMW		-0.281^{**}		-0.227^{*}
		t = -2.493		t = -1.718
CMA		-0.215^{***}		-0.244^{***}
		t = -2.908		t = -2.824
Constant	0.015^{***}	0.017^{***}	0.016^{**}	0.012^{**}
	t = 3.042	t = 3.171	t = 2.507	t = 1.986
Observations	120	120	120	120
R^2	0.526	0.575	0.450	0.497
Adjusted R^2	0.522	0.556	0.445	0.475
Note:				*p**p***p<0.01

Finally, we investigate the differences between the two extreme portfolios consisting of the companies with the 20% highest and 20% lowest emissions relative to the companies' revenue. From table 6.6 we observe that both the portfolio of high emission companies and low emissions companies has significant alphas at the 1% level. The portfolio with the high emissions have a significant beta to the IT index at the 10% level for CAPM and 5% level for the Fama-French model. As these are below 1, we know that the portfolio generates lower returns compared to the index. As we use an IT index as the market factor, we are not surprised to find a significant beta here, however such a low beta tells us that the portfolio has a lower risk than the index and also a lower expected return. Both portfolios has a significant exposure to companies with large market capitalization, companies with a weak profitability, as well as companies with an aggressive investment strategy.

Table 6.6

Excess Return Total Portfolios Emissions

	Dependent variable:			
	High Total		Low Total	
	CAPM	FF5	CAPM	FF5
MSCI_IT	0.073^{*}	0.089^{**}	0.034	0.056
	t = 1.709	t = 2.063	t = 0.805	t = 1.324
SMB		-0.351^{**}		-0.503^{***}
		t = -2.257		t = -3.339
HML		-0.022		0.103
		t = -0.227		t = 1.094
RMW		-0.183^{**}		-0.199^{**}
		t = -2.211		t = -2.459
CMA		-0.122^{**}		-0.148^{***}
		t = -2.262		t = -2.819
Constant	0.025^{***}	0.025^{***}	0.022^{***}	0.024^{***}
	t = 6.653	t = 6.596	t = 5.834	t = 6.481
Observations	120	120	120	120
R^2	0.657	0.693	0.621	0.654
Adjusted R^2	0.652	0.689	0.617	0.651
Note:				*p**p***p<0.01

6.4 The Fama-French Five-Factors

Table 6.7 displays the findings of the FF5 model for all portfolios within the three scopes, making it easy to distinguish between them. Here, we can observe that their betas for the IT index are almost the same size. Only the portfolio with high emissions in scope 2 has a considerable exposure to large market capitalization businesses, and the same is true for companies with a low book-to-market ratio. All portfolios have a substantial and negative coefficient for the RMW and CMA components, indicating that all of our IT portfolios are exposed to firms with low profitability and aggressive investment strategies.

Table 6.7

Excess Return Portfolios Emissions

	Dependent variable:					
	High scp 1 FF5	Low scp 1 FF5	High scp 2 FF5	Low scp 2 FF5	High scp 3 FF5	Low scp 3 FF5
MSCI_IT	0.704***	0.704***	0.705***	0.692***	0.710***	0.697***
	t = 10.212	t = 10.212	t = 11.578	t = 9.340	t = 11.855	t = 9.939
SMB	-0.236	-0.236	-0.407*	-0.270	-0.264	-0.234
	t = -0.960	t = -0.960	t = -1.874	t = -1.021	t = -1.233	t = -0.935
HML	0.096	0.096	-0.228*	0.134	-0.184	0.162
	t = 0.647	t = 0.647	t = -1.750	t = 0.848	t = -1.431	t = 1.077
RMW	-0.266**	-0.266**	-0.333***	-0.306**	-0.281**	-0.227*
	t = -2.054	t = -2.054	t = -2.914	t = -2.201	t = -2.493	t = -1.718
CMA	-0.215**	-0.215**	-0.257***	-0.181**	-0.215***	-0.244***
	t = -2.527	t = -2.527	t = -3.432	t = -1.982	t = -2.908	t = -2.824
Constant	0.009	0.009	0.014**	0.013*	0.017***	0.012**
	t = 1.477	t = 1.477	t = 2.566	t = 1.919	t = 3.171	t = 1.986
Observations	120	120	120	120	120	120
R^2	0.507	0.507	0.565	0.466	0.575	0.497
Adjusted R^2	0.486	0.486	0.546	0.443	0.556	0.475
Note:						*p**p***p<0.01

6.5 The null hypothesis

Before we discuss our hypothesis, we will summarize our main findings, we have some divided results from the three portfolios.

From the mean-variance analysis we found that High S1 and High S2 generates the highest returns at a higher risk, which results in them achieving a lower risk-adjusted return. This makes the Low scopes portfolio´s the optimal portfolio according to Markowitz (1952). When looking at cumulative returns it is often the carbon intense portfolios that has the superior performance. However, scope 3 show different result with the Low S3 portfolio generating higher returns and risk-adjusted-return than both the market and High S3, as well preforming historically greater from 2012 to 2021. Hence, it differs between the scopes weather a low carbon investment strategy will generate the highest expected return. When creating portfolios by scopes not total emissions, low carbon footprint portfolios generate the highest risk-adjusted return making them the optimal portfolio choice.

In the results from the regression table Low S2 displays an significant alpha of 0.013 for the Fama-French model and Low S3 displays an significant alpha of 0.012. The alpha for portfolio High S2 is significant at 0.014, and 0.017 for High S3. A positive (negative) alpha indicates that the expected return will generate a higher (lower) abnormal return in addition to the expected return for this level of risk. The High S3 portfolio will therefore generate the highest additional abnormal return, out of all scope portfolios.

We will repeat the hypothesis that has been presented previously in the thesis.

H0: IT companies in the Low S1, S2 and S3 portfolio`s **will not** generate higher risk-adjusted return than the IT companies in the High carbon footprint portfolio, when
H1: IT companies in the Low S1, S2 and S3 portfolio **will** generate higher risk-adjusted return, than the IT companies in the High carbon footprint portfolio

H0: Reducing emissions in Scope 3 **will not** have the most impact on stock returns.
HA: Reducing emissions in Scope 3 **will** have the most impact on stock returns.

The first null hypothesis assumes that the Low carbon footprint will generate lower risk-adjusted returns than the High portfolios. Based on the findings seen in the mean variance analysis in table 6.1, the Low portfolio´s generates a higher risk-adjusted return for all three scopes. However, when creating portfolios of total emissions for each scope it is the carbon intense portfolio that has the superior performance compared to the total low carbon portfolio. We can reject our first null hypothesis as the mean variance analysis indicates that the Low carbon scope portfolios generates the highest risk-adjusted return.

The second null hypothesis predicts that scope 3 is the most impactful scope, we assumes this as the IT sector has the most carbon emissions in scope 3. The findings from scope 3 differs to the other scopes, with a higher expected return for the Low portfolio than the High, as well as higher historical returns for the Low portfolio in the mean variance analysis, however, it is the Low S1 portfolio that generates the highest Sharpe ratio making it the most desirable to investors. According to the regression it is the Total High portfolio that has the highest abnormal return, not Scope 3 alone. Based on this we keep the null hypothesis since we cannot conclude if reducing scope 3 emissions is more beneficial than reducing emissions in the other scopes.

Discussion and limitations

In this part, we will analyze the significance of the findings in relation to our research question: *How does carbon emissions from each scopes affect financial performance of IT companies in the stock market?* We will also compare our findings to those presented in previous research.

7. 1 Previous literature

In this section of the thesis we will discuss our findings against previous research and theory that we discussed under chapter two.

7.1.1 The work towards the UN Sustainable Development Goals

From the literature review in chapter two, we discussed the UN´s Sustainable Development Goals adopted by the United Nations in 2015. The technology sector is in need of massive amounts of energy to generate data centers and other operations. The 7th UN Sustainable Development Goal is “Affordable and Clean energy” and within this it states to ensure access to affordable, reliable, sustainable and modern energy for all (United Nations Development Programme, 2022). Scope 2 measures the energy use of the companies and we can see from the mean variance analysis that companies that have a lower carbon footprint in scope 2, also have a higher risk adjusted return. This can be an incentive for other firms to reduce their scope 2 emissions and contributing to the 7th UN Sustainable Development Goal.

The 13th UN Sustainable Development Goal is Climate Action and is urging companies to take action to combat climate change and its implication. This goal is affected by emissions in all three scopes, and to work towards this IT companies will have to work towards reducing both direct and indirect emissions. As we observe that companies with lower emissions also generate higher adjusted-return this will give investors an incentive to invest in technology companies with a low Scope 1 to maximize adjusted-returns.

7.1.2 Previous Research

ESG investing aims to generate both financial return and positive societal impact, by investing in companies that perform well on ESG ratings (Environmental, Social and Governance). In the literature review we found that ESG investment has provided favorable returns for investors and that companies with a high level of sustainability had much reduced risk. Previous study has also examined the relationship between increasing carbon costs and declining stock returns, concluding that firms with a higher carbon cost will see a decrease in their share price. We see a lower anticipated return in our mean variance analysis and historically poorer cumulative returns for the Low carbon footprint portfolios. At the same time, our data coincides with studies that demonstrate a smaller standard deviation for equities with a reduced carbon impact.

We found a statistically significant difference between the standard deviations of the High and Low portfolios based on the findings of our mean variance analysis shown in table 6.1. Volatility is measured by standard deviation, and our findings indicate that investing in carbon-intensive enterprises has a higher risk than investing in organizations with low carbon emissions. In contrast, the High S1 and High S2 portfolios have a higher predicted return and have generated better cumulative returns from 2012 to 2021 compared to the low carbon footprint portfolios. As compensation for their exposure to carbon emission risk, these statistics may suggest that investors expect higher rates of return. These findings are comparable to those of Bolton and Kacperczky (2021), who demonstrated that after correcting for common characteristics, stocks of companies with higher carbon emissions generate higher returns.

7.2 Discussion of our results

From calculating the Sharpe ratios of our portfolios from the different scopes, we find that it is the portfolios of low emissions that offer the best risk-adjusted returns compared to the high. However, looking at the total emission portfolios, the high emission portfolio offer a slightly higher Sharpe. In total, it is the portfolio of companies with low emissions in scope 2 that offer the highest Sharpe ratio.

It is essential to explore the significance of our findings in relation to the evaluation of our portfolios. By using the FF5-framework to our study, we want to obtain a deeper knowledge of each portfolio's fundamental drivers for returns. The portfolios are constructed based on the different scopes and carbon emissions within those scopes. By doing so, we are able to clearly define and highlight what distinguishes the risk exposure and return components in our dataset. When attempting to adjust for the quantity of carbon emissions released by the portfolio's stocks, it is necessary to examine the extreme percentiles in order to identify disparities in terms of return. This helps us address the impact of carbon emissions on financial performance.

According to section 6.3, all portfolio alphas were statistically significant, except for the portfolios from scope 1, and had similar size in both the high and low emission portfolios. This demonstrates that regardless of emissions level, all portfolios are capable of generating abnormal returns and are thus comparable in this regard. We observe that all betas for the IT index are almost the same size. This indicates that all portfolios have roughly the same market-adjusted volatility and return, however the beta for low emissions scope 2 is just a bit smaller than the others which means the volatility towards the market premium is somewhat lower.

Observing the SMB factor, we find that it is only significant at the 10 percentile for the portfolio with the highest Scope 2 emissions. The coefficient is negative, indicating that small cap stocks have underperformed relative to large cap stocks. In general, small cap stocks are more volatile and have higher levels of risk compared to large cap stocks, so it is not uncommon for them to underperform in certain market environments. Even if the SMB component is not significant for the other portfolios, we note that the beta is negative and about the same size for both high carbon emitting stocks and for the low carbon emitting stocks. All though we can not conclude on this, it implies that when investing in IT companies, regardless of the emission level, large cap stocks tend to perform better than small cap stocks.

It is only the portfolio with high carbon emissions in scope 2 that has a statistically significant beta for the HML factor at the 10% significance level. We observe that it is negative, which indicates that value stocks have underperformed relative to growth stocks. Value stocks tend to be less expensive relative to fundamental measures such as earnings or book value compared to growth stocks. However, value stocks may underperform in certain market environments, particularly when investors are willing to pay a premium for growth. Despite this, over the long term, value stocks have on average been shown to outperform growth stocks (Cheh & Kim, 2017). This highlights an important implication of our findings, namely that growth stocks have contributed most to the return of our portfolio of high carbon emissions in scope 2.

Regarding the RMW component, all portfolios exhibit a significant and negative coefficient at the 5% or 1% level, telling us that all portfolios are exposed to companies with weak profitability. Firms with higher profitability tend to be more stable and less risky compared to firms with weak profitability in general. When companies with weaker profitability outperform, it could be due to various factors such as changes in investor sentiment or changes in the economic environment. As we know, the IT sector has had a large increase the last decade and this could be such a factor. We observe that beta of the CMA factor is also significant and negative for all portfolios. This suggest that our portfolios consists of companies with aggressive investing strategies that have outperformed companies with conservative ones.

7.3 Limitations

In this section of the thesis we will address the limitations we have identified in our research. The main limitations are related to our dataset, more specifically the restrictions for the time period and inclusion of unequally distributed country data.

The portfolios are created with stock performance for a ten-year time period whereas in the creation of High and Low carbon footprint performance portfolios, we used emission data for the last six years, as a time frame longer than had several deviations as not many companies had reported emissions until recent years.

Figure 7.1 illustrates the countries that are included in our portfolio`s.

Figure 7.1

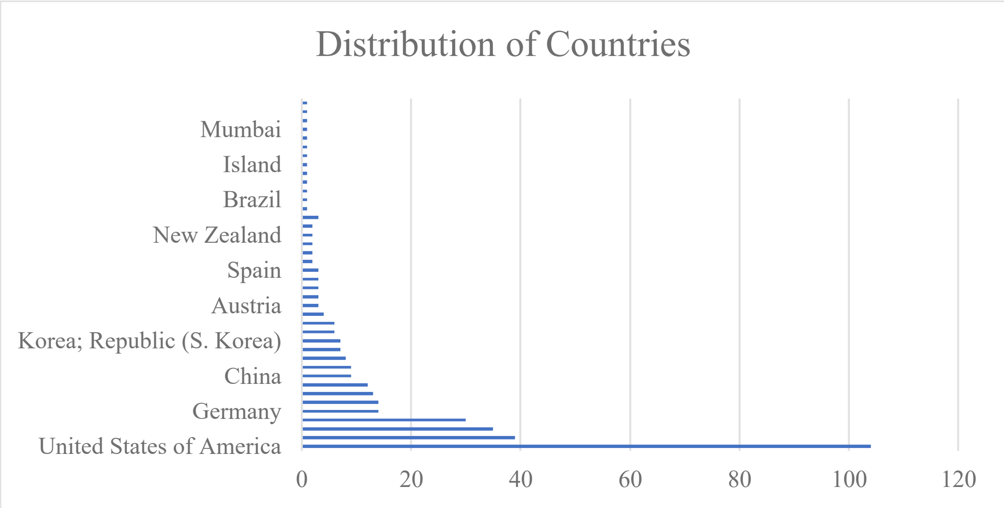


Figure 7.1 Illustrates the distribution of countries included in our dataset.

The countries tax regulations on carbon emissions can affect the financial performance of the company and jeopardize our findings. It is therefore an important to identify and comment on this limitation, as it may be variations that are caused by country regulations and not the carbon emissions itself. This can cause big differences for companies that operate in "high carbon tax" countries, whereas companies operating in a country that does not have carbon tax will not be affected by this. As we see, the top three countries have little to nothing in carbon tax, whereas the Sweden and Switzerland is the two countries with the highest carbon tax and constitutes 6.3% of the technology companies in our portfolio. For further research, it would be interesting to dive into the countries and see if it is also the companies with the high carbon tax that are included in our bottom 20% portfolio.

Another possible challenge in our dataset is the sample size. From Refinitiv Eikon they deliver data for 6347 companies in the information technology sector, but after our restrictions for factors like carbon emissions for scope 1, 2 and 3 as well as revenue for this companies over a 6-year period we were only left with 358 companies. This can impair our findings as we have excluded almost 6000 technology companies from our research as they did not have available data on carbon emissions.

7.4.1 Data selection

The selection of companies from the IT industry may be a challenge for our research. In order to meet the requirements of multiple factors and historical data in our dataset, it was necessary to eliminate a number of companies. The deleted firms may have been removed due to insolvency during the corresponding time, failure to submit specific variables, or lack of recorded history data. As we acquired the stock data using Yahoo Finance, there may have been firms whose stock information was not registered on the site and were thus omitted. If the omitted firms were at the extremes of our scales, exhibiting abnormally high carbon emissions, this may influence the findings of our thesis. In addition, we were restricted to companies that reported their emissions. If there are firms that do not disclose or under-report, this would also impact our findings. It appears that ESG investment is more prevalent in Europe than in the United States and Asia (Ralston 2017). This apparent regional disparity in ESG investing suggests that if we simply analyzed European data, the findings might differ.

7.4.2 Limitations of the model

It is difficult to determine if abnormal returns are the result of market inefficiency or poor asset pricing models. Even though our study revealed a significant abnormal return, there are challenges associated with the use of CAPM and the FF5 model since they are based on assumptions such as rational investors and efficient markets. Missing variables can result in omitted variable bias, which is a frequent worry in regression analysis (Wooldridge, 2012). Fama and French (2014) assert that the five-factor model beats the three-factor model. With the addition of the profitability variable and the investment variable, the HML risk-factor is deemed unnecessary in many cases. This restriction is mostly since the average stock return is captured by the other components present. Fama and French also claimed that the model's most significant flaw is its inability to capture the poor average return of small stocks that invest heavily while having low profitability (Fama, 2014). We employ both models to enhance the robustness of our analysis by mitigating the restrictions resulting from the use of each model alone.

7.5 Suggestions for future research

Future research should consider the potential effects of carbon tax regulation as discussed in our limitations, as it would be interesting to find out how the carbon tax is affecting stock performance. In addition, investigating multiple industries might prove an important area for future research. The findings from our research can only tell us about how carbon emissions effect stock performance for information technology companies and these findings may differ if other sectors are researched. Finally, future studies could investigate whether having and ESG investment strategy is more or less valuable than a real impact (e.g. carbon footprint) investing strategy.

Conclusion

This study's primary objective was to determine how the carbon emissions of IT companies impact their financial performance and if investors differentiate between direct and indirect emissions. Throughout this thesis, we have investigated whether investing in portfolios with low carbon emissions may provide comparable returns to investing in portfolios with high carbon emissions. Investing in portfolios of IT companies with low carbon intensity yields a higher risk-adjusted return than investing in portfolios with high carbon intensity, when looking at scopes individually. We note that emissions from scope 1, which involve the firms' emissions from production, will have the greatest impact on the Sharpe ratio of the portfolio. These findings give the investors an incentive to research carbon emissions for IT companies before investing, as the optimal portfolio choice would be to invest in IT companies with low scope emissions.

Our results agrees with the conventional belief that ethical investment entails low risk and a lower rate of return. However, our findings disagree with the concept that ecologically friendly stock portfolios have a negative influence on the Sharpe ratio, as the low carbon portfolios in our research generates a higher Sharpe ratio for all scopes. This further shows, according to our argument, that investors may not be as compelled to accept less, to care about the environment. Our results suggests that investors want to be compensated for taking on additional risk by achieving higher returns, making the carbon intense portfolios less desirable. Investors are hedging against uncertainty in climate policy and are therefore achieving lower expected return for lower carbon risk. By investing in firms with lower Scope emissions, you achieve the optimal portfolio choice with the highest risk-adjusted return while also contributing to a cleaner future.

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Appendix

A1 Sub-Sector Carbon Footprint

Technology Hardware, Storage & Peripherals

The blue column illustrate the average carbon footprint for each sector in each scope.

Scope 1	Scope 2	Scope 3
1 841,012554	7 799,539115	203 368,868850
65,75	278,55	7 263,17

Software

Scope 1	Scope 2	Scope 3
709,00	15 198,17	77 432,90
12,66	271,40	1 382,73

Semiconductors & Semiconductor Equipment

Scope 1	Scope 2	Scope 3
27 673,88	64 018,40	661 889,02
522,15	1 207,89	12 488,47

IT Services

Scope 1	Scope 2	Scope 3
2 974,49	93 184,54	312 216,25
38,13	1 194,67	4 002,77

Electronic Equipment, Instruments & Components

Scope 1	Scope 2	Scope 3
5 882,84	61 152,18	302 229,46
96,44	1 002,49	4 954,58

Communications Equipment

Scope 1	Scope 2	Scope 3
3 506,56	24 417,29	1 158 084,81
184,56	1 285,12	60 951,83

A2 Model Testing

A2.1 Breush- Godfrey

Breusch-Godfrey Test for Autocorrelation Scope 1

Table A3.1a

	LM-stat	P-value
CAPM		
Low S1	3.8566	0.0506
High S1	3.8566	0.0506
FF5		
Low S1	2.7458	0.0975
High S1	2.7458	0.0975

Table A3.1a shows the Breusch-Godfrey serial correlation LM test for autocorrelation in the errors. At a 5% significance level we cannot reject the null hypothesis, meaning that we do not consider our regression to have issues regarding autocorrelation.

Breusch-Godfrey Test for Autocorrelation Scope 2

Table A2.1b

	LM-stat	P-value
CAPM		
Low S2	2.5377	0.1112
High S2	3.0612	0.0812
FF5		
Low S2	2.1150	0.1459
High S2	1.0844	0.2977

Table A2.1b shows the Breusch-Godfrey serial correlation LM test for autocorrelation in the errors. At a 5% significance level we cannot reject the null hypothesis, meaning that we do not consider our regression to have issues regarding autocorrelation.

Breusch-Godfrey Test for Autocorrelation Scope 3

Table A2.1c

	LM-stat	**P-value**
CAPM		
Low S3	2.4586	0.1169
High S3	1.5806	0.2087
FF5		
Low S3	3.2348	0.0721
High S3	0.3651	0.5457

Table A2.1c shows the Breusch-Godfrey serial correlation LM test for autocorrelation in the errors. At a 5% significance level we cannot reject the null hypothesis, meaning that we do not consider our regression to have issues regarding autocorrelation.

From table A2.1a-c we cannot reject the null hypothesis, hence we do not have issues regarding autocorrelation.

Appendix A2.2 Breusch-Pagan

Breusch-Pagan Test for Homoscedasticity Scope 1

	BP	**P-value**
CAPM		
Low S1	9.4880	0.0986
High S1	9.4880	0.0986
FF5		
Low S1	9.3498	0.0959
High S1	9.3489	0.0959

Breusch-Pagan Test for Homoscedasticity Scope 2

	BP	P-value
CAPM		
Low S2	10.2640	0.0601
High S2	9.3700	0.1126
FF5		
Low S2	8.7236	0.1206
High S2	8.9370	0.1088

Breusch-Pagan Test for Homoscedasticity Scope 3

	BP	P-value
CAPM		
Low S3	9.2490	0.1187
High S3	10.1280	0.0699
FF5		
Low S3	10.8020	0.0555
High S3	10.2580	0.0641

The result from our test indicates that there is no indication of heteroscedasticity.

Appendix A2.3 Augmented Dickey-Fuller

Augmented Dickey-Fuller Test for Unit Root

Scope 1

Dependent Variables	*DF*	*P-value*
Low S1 Portfolio	-1.7167	0.6942
High S1 Portfolio	-1.7167	0.6942

Scope 2

Dependent Variables	*DF*	*P-value*
Low S2 Portfolio	-1.7874	0.6649
High S2 Portfolio	-1.7925	0.6628

Scope 3

Dependent Variables	*DF*	*P-value*
Low S3 Portfolio	-1.6865	0.7068
High S3 Portfolio	-1.7939	0.6622

The Augmented Dickey-Fuller (ADF) test is a statistical test used to test the null hypothesis that a time series is non-stationary. A time series is a series of data points measured at regular intervals over a period of time. Non-stationarity means that the statistical properties of a time series, such as the mean and variance, are not constant over time.

A3 Countries included in our portfolio

Country	n	Country	n
United States of America	104	Spain	3
Taiwan	39	Denmark	2
Japan	35	Italy	2
United Kingdom	30	Luxembourg	2
Germany	14	New Zealand	2
Sweden	14	Singapore	2
France	13	South Africa	3
India	12	Bermuda	1
China	9	Brazil	1
Switzerland	9	Cayman Islands	1
Finland	8	Dubai	1
Canada	7	france	1
Korea; Republic (S. Korea)	7	Island	1
Australia	6	Isle of Man	1
Norway	6	Israel	1
Netherlands	4	Malaysia	1
Austria	3	Mumbai	1
Belgium	3	Poland	1
Hong Kong	3	Thailand	1
Ireland; Republic of	3	Turkey	1

A4: Companies included in the different scopes

High scp 1	Low scp 1	High scp 2	Low scp 2	High scp 3	Low scp 3
GDDY	A1OS	GDDY	GGS	WOLF	X2379
WOLF	TNE	VNET	RMBS	GDDY	CNIC
ON	LTG	NTGR	DMRC	ECK	X2454
X5347	HUBS	X5347	CNIC	X2385	CLA
NTGR	CNIC	X2449	MIDW	X000063	X011070
X2303	TOBII	X3436	CIEL3	AVT	X5162
X034220	NETW	X601012	SHOP	WAF	SINCH
MU	TYR	X8046	KXS	X601012	KCT
X3105	PRGS	X2303	SOF	X8035	MIDW
MCHP	X360	X3481	ORIGO	X6645	IOM
X000660	MIDW	ATS	SINCH	NOKIA	TYR
TXN	AKAM	X3037	ALSN	X2301	X2352
STM	X5269	X2409	TPX	ERIC	ECLERX
X2330	SOF	X8150	SCT	X6762	TXN
NXPI	NOD	WOLF	VAIAS	X601231	X0285
X4062	X2379	X5483	PRT	BESI	SCT
X3481	SPLK	MAXN	AUB	GGS	ELCO
X2408	BLKB	X4062	DORO	X7735	CNDT
X4901	RMBS	X4958	ERD	STX	ENPH
IFX	X6669	X034220	X360	ANET	X3227
X6967	X0354	WAF	ECONB	KLAC	ASOZY
STX	TANLA	X2408	QBY	X7701	X5269
X005930	IOM	X6976	ATEA	HPQ	BYIT
INTC	ADYEN	X009150	ADYEN	X6967	X2382
ADI	LNK	X6239	SQ	X3711	RCN
X006400	XRO	X6963	SOP	X6146	CBTT
X6723	ZENSARTECH	X3105	XRO	X2409	LOGO
X4902	TWLO	X000660	ELCO	X6448	PRGS
X2409	GWRE	X3711	X5162	FSLR	NICE

LFUS	TIETO	MU	PD	ASML	AVV
AUS	X9719	ON	BYIT	X2303	MAXN
X6981	TPX	X2330	PAYX	BAR	X2324
X2383	TEAM	FSLR	INTU	X6703	X2382.1
X6239	SWIR	X006400	HMS	ADV	BOUV
X6976	KXS	X6723	VOLUE	LEHN	NTNX
COMM	BOUV	X6762	WLN	X7762	NCC
X6724	DARK	X0285	ALFA	BR	X6669
LOGO	KNOW	X3008	NCAB	X6845	ESI
X6963	SINCH	X7204	BOUV	X2408	PERSISTENT
XRX	COFORGE	IOM	IDOX	FLEX	TANLA
X3037	ECONB	STX	GOFORE	X6971	ON
X009150	ZM	X6981	X6669	HPE	VOLUE
AMS	SCT	X6967	NETC	AMD	X0RFW
X8046	PANW	NXPI	KNOS	JNPR	TEL
VNET	X0992	TXN	TEAM	X6965	SOW
X6971	SQ	STM	ATE	X0992	X0354
X4958	MPHASIS	LFUS	MNTV	CSCO	NEXI
X3436	PRT	AMS	KNOW	X6701	PYPL
EOH	COUP	X005930	X2353	AVYA	ADI
X6762	X3626	MCHP	ADSK	X6981	LAND
BB	X6121	X6176	SWIR	X8046	WLN
ATI	AAPL	IFX	DARK	INTC	X2395
WAF	X7204	X6971	PANW	X6857	NETW
QDT	IT	WDC	X5269	X6724	GOFORE
X7762	MNTV	X7762	SPLK	SOH1	ZENSARTECH
X7752	GOFORE	JBL	TMV	AMS	ATEA
X6965	SOW	X2382	NEWR	X6723	CRAYN
SOI	X4307	X011070	KTCG	X5347	DBX
X6448	NVDA	AKAM	FDM	ERD	PAYX
X5483	FDM	X2308	GWRE	MYCR	ACSO
X601012	BYIT	X2498	NEXI	X7751	WDC
X6645	X2454	RBBN	ASOZY	X6702	AMADY

X3711	LOGI	KETL	CRAYN	X4739	IT
TEL	SPT	X6724	SOW	LFUS	XAR
MBTN	NEWR	X2301	TYR	X6963	GIB
M5Z	X4739	X2317	TWLO	X601138	KWS
FSLR	CRM	X0303	KCT	MU	ADYEN
QBY	KCT	RCN	DIGIA	X018260	UIS
MTLS	NOW	APH	TOBII	DELL	IDOX
SXS	KNOS	X4915	SIM	X9719	TER