Carb-on or Carb-off?

Carbon-intensive stocks' performance in an age of socially responsible investing

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Bachelor Thesis

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Abstract:

This study investigates the performance of carbon-intensive stocks in the United States and provides evidence of abnormal returns between 2000 and 2019. However, these abnormal returns are isolated to the period 2000 to 2002 which coincides with the Dot-com crash. After the financial crisis of 2008, the measured alpha is negative, but on a statistically insignificant level. This may stem from deteriorating firm value from increasing environmental and regulatory risks, and the sell-off by institutional investors. In this industry-based analysis, industries were evaluated both quantitatively and qualitatively on their emissions before being included in a carbon index. The carbon index was then analyzed using multi-factor models.

Keywords:

carbon stocks, carbon-intensive stocks, emission stocks, socially responsible investing, sin investing

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1. Introduction

Human civilization has for long been suspecting its ability to affect the climate both locally and globally as suggested by the publication "The Greenhouse Effect" in 1896. However, it was not until the mid-20th century that evidence in support of human impact on the warming of our planet truly started to stack up. Scientists' worries caught the public's eye for real in the summer of 1988 - the warmest to date at that time, causing stakeholders to start lobbying and take action (Weart, 2008). Further, on the first of May 2020, the Mauna Lewis observatory in Hawaii measured the highest daily concentration of atmospheric carbon dioxide in recent times. The last time there was such high levels of CO_2 in the atmosphere was over three million years ago (NOAA, 2020).

Carbon-intensive companies have been an important part of the globalization of the last decades, but the externalities are catching up and the environmental movement is no longer exclusively driven by NGO:s or activists, but also by ethical investors. This has moved the investment focus from Freidman's doctrine stating that the company's "... *one social responsibility of business* [is] *to use its resources and engage in activities designed to increase profits so long as it stays in the rules of the game…*" (Friedman, 1962), to socially responsible investing (SRI). By 2019, the total value of assets in the US allocated to SRI strategies amounted to more than $12 trillion, and have since 2016 grown with close to 40% annually (Kostigen, 2019; USSIF, 2018). There are differing opinions amongst scholars as to what constitutes SRI. However, in general, SRI means that investors not only screen companies based on their financial performance but aim to actively select socially responsible companies. SRI excludes companies that disregard social and ethical norms and favor companies with a profound focus on social responsibility (Sandberg et al., 2009).

The most recent effect of this shift is that institutional investors reallocate their assets toward SRI and away from companies with large carbon footprints. For example, the Norwegian oil state fund has decided to exclude Oil & Gas exploration companies from their portfolio, the Swedish National Pension Fund AP4 is benchmarking more than 20% of its equity investments against low-carbon indices, and the French Fonds de Réserve pour les Retraites has implemented new equity benchmarks to reduce their CO_2 from standard indices by 50% (Milne & Sheppard, 2019; Moss, 2018). Blackrock, one of the world's largest investment managers, has in their actively managed portfolios decided to exclude companies that derive 25% or more of revenues from thermal coal (Henderson et al, 2020). Their new attitude can be captured by the quote:

> *"Our investment conviction is that sustainability- and climate-integrated portfolios can provide better risk-adjusted returns to investors. We believe that sustainable investing is the strongest foundation for client portfolios going forward."*
>
> - Larry Fink, CEO of Blackrock (2020)

With this increase in popularity of SRI, several research studies have been conducted to examine if funds with SRI focus have experienced abnormal returns. The results show that returns on these portfolios do not statistically outperform those of conventional funds, and a recent publication by Ciciretti et al. (2017) estimates an underperformance of 4.8% annually.

Studies previously done on the opposite side of the spectrum to SRI have been primarily focused on the concept of sin stocks. The general definition of sin stocks is companies involved in weapon manufacturing, gambling, tobacco, alcohol, or pornography. The consensus amongst studies before 2015 is that sin stocks outperform the rest of the market, but, when controlling for higher profitability and conservative investment strategies, Blitz and Fabozzi (2017) show that the returns are as one would expect.

There exist few research studies on the exclusion of carbon-intensive stocks and their performance overall. One study conducted on the topic was Ramelli et al.'s (2020) research on the short-term effect of the first Global Climate Strike. They found that the strike resulted in a substantial reaction to stock prices for companies with high carbon intensity.

To contribute to this field of research, this thesis will investigate carbon-intensive stocks' returns over the last 20 years in the United States, and whether they have experienced abnormal returns as has been suggested about sin stocks in previous research. In determining abnormal returns, four asset pricing models were used: the capital asset pricing model, Fama French three-factor, Fama French five-factor model, and a fourth model also controlling for changes in the oil price. The purpose of this thesis is to provide insights into the question of whether investors lose out on performance if asset managers let ethics drive their investment decisions. It is an important contribution because if investors, such as pension funds, lose out on performance when they shun carbon stocks it will have a direct impact on millions of people's savings.

The results indicate that carbon-intensive stocks have experienced positive abnormal returns since 2000, but isolated to the Dot-com crash. Since then, the abnormal returns have decreased to be insignificantly different from zero if not negative. The abnormal returns seen in sin stocks do not exist yet. However, the previous literature suggests that future abnormal returns are plausible, *ceteris paribus*, after the reallocation of capital has stabilized.

2. Previous literature

2.1. Carbon-intensive classification

The previous literature on carbon-intensive stocks' returns is scarce, and, to the best of our knowledge, no one has previously investigated the long-term performance of these stocks from a return perspective. However, some have explored what it means to be carbon-intensive, the effects on their businesses, and how the concept of sin is priced in the market.

No common agreement on how to evaluate carbon usage in companies existed until Volker H. Hoffmann and Timo Busch (2008) published their research paper *Corporate Carbon Performance Indicators* about carbon assessment. Their research serves as a tool for policymakers and investors to estimate the implications of a company's carbon usage. The method is based on the notion of three scopes; scope 1 is the direct carbon emissions in the company's operations, scope 2 the indirect emissions from the energy utilities required in the process, and scope 3 the indirect emissions required within upstream and downstream processes.

Using the tool developed by Hoffman and Busch, Benz et al. (2019) further classify which industries are carbon-intensive and what type of investor is exposed to carbon risk. In their research, they apply an industry-based carbon risk definition based on CO_2 emissions, a carbon footprint metric and climate scoring. This to determine what industries are the biggest polluters (Appendix table 1). The authors conclude that the largest investors in carbon-intensive industries are governmental entities. Their exposure to this type of stock is around 50%, significantly higher than any other investor type who is closer to 15-30%.

2.2. Research on carbon-intensive stocks

Within the segment of carbon-intensive stocks, the research that has been conducted concerns the disclosing of climate actions, the climate's effect on their value and financing, and the short-term performance during increased environmental awareness. To date, no research has been found regarding the long-term stock performance of carbon-intensive stocks.

Ziegler et al. (2009) studied the stock performance for companies disclosing their climate actions on both the US and European markets. They conclude that there exists a positive relationship between disclosed corporate action and stock performance for energy companies. Further on this topic, Clarkson et al. (2011) found evidence of proactive environmental strategies improving financial performance indicators, such as return on equity, in the most pollutive industries in the US. Both papers provide evidence that carbon-intensive stocks improve their operations by going green and improve their market valuation, but neither look at the long-term implications of disclosing corporate actions.

Chava (2014) analyzed the impact of firms' environmental profiles on their cost of capital by deriving the implied cost of capital from analysts' earnings estimates. He found that investors demand significantly lower expected returns on stocks that passed environmental screeners. For companies with substantial emissions, hazardous chemicals, or general climate change concerns, the required returns were much higher. Further, he found that banks charged higher interest rates on loans to firms that had environmental concerns. They also had fewer banks participating in the loan syndicates. Further, Delis et al. (2020) found that, before 2015, climate policy exposure was not priced in by the banks. After 2015, however, companies sensitive to stricter climate policy had a significantly higher cost of credit.

Aggarwal and Dow (2011) researched greenhouse gas emissions (GHG) effects on firm value for over 600 firms in Europe, US and Canada. They did this using multivariate regressions with the Tobin's Q-value as the dependent variable. In their analysis, they found that firm value is affected negatively by GHG emissions and they claim that up to 10% of portfolio value could be wiped out because of overall climate issues.

Nonetheless, no research found to date examines the long-term stock performance of these carbon industries, but one study from 2020 looked at the short-term stock price reactions from the first Global Climate Strike that took place in March 2019. The results indicate that the Global Climate Strike was a success in terms of the impact on carbon-intensive stocks. They had statistically significant negative abnormal returns from three days before the strike to ten days after it. To explain these results, they focus on two possible factors. The first is the role of environmental social norms and the second is the level of stringency of climate regulation. The two factors did not provide significant results, but they found that stocks faced stronger penalization for high carbon intensity if their respective country had a higher number of google searches involving Great Thunberg – referred to in the study as the Greta Thunberg effect (Ramelli et al, 2020).

2.3. Sin stocks

Integral to this study is the concept of ethics and social norms' influence on investment decisions. There is evidence that carbon stocks are approaching the status of sin stocks, made evident not only from the actions of several fund managers but also from literature: *"... now ethical investors need to appreciate the importance of zero net-carbon emissions as a factor in the selection of their investments…"* (Rayer, 2017). However, sin stocks have historically been classified as the "*Sin Triumvirate*" - the three sin industries Alcohol, Tobacco, and Gambling. Also referred to as sin stocks are Weapons and Pornography, but since they are more affected by public policy, and not necessarily traded on the stock exchanges, they are often excluded from previous research.

Hong and Kacperczyk (2009) researched sin stocks' return on the US stock market and provide evidence that they outperformed comparable stocks and the market in general between 1926 and 2006. They hypothesize that social norms result in investors suffering a financial cost in abstaining from sinful investments. Their equally weighted portfolio of sinful holdings outperformed otherwise comparable stocks when controlling for the Fama French three-factor model and Carhart's momentum factor. They go on to discuss why that is, with explanations such as higher litigation risk and additional risks from social movements in society. In addition to this, they found that norm-constrained investors tend to have lower exposure to sin stocks than for example hedge-funds, and that publicly traded companies in the sin triumvirate suffer a negative valuation effect of approximately 15% (price to earnings ratio).

A similar study was conducted by Salaber (2007), but it focused on the European market instead. She looked at the alcohol, gambling, and tobacco industries in an attempt to find out if there was any significant outperformance from those sectors. Salaber concluded that even though there was a significant outperformance from the sectors mentioned, their market location was important as local regulatory circumstances was a significant explanatory variable.

A more recent study by Blitz and Fabozzi (2017) finds that there are no significant abnormal returns in the sin industries. They write: "*... the abnormally high raw returns of sin stocks can be fully explained by recently introduced asset pricing factors…*", referring to the two added factors to Fama and French's three-factor model in 2014 (see section 3.5). When controlling for these factors they find no evidence of abnormal returns, but that their performance is precisely what one would expect given their characteristics. Investors can as such achieve the same high return as sin stocks by investing in stocks that have the same exposure to the factors.

Summarized, the previous research in this area has, with statistical significance, found that sin stocks have outperformed the market when applying the three and four-factor models. However, when using the five-factor model, the abnormal returns disappear. It needs to be mentioned that the results and conclusions are varying between the different studies. Location, period, and other factors affect the results and also the significance levels of them. See Appendix table 2 for a full summary of the previous literature made on sin stocks.

2.4. Our study's contribution to previous literature

From the review of the literature, we conclude that several have studied the effects of climate action within the carbon-intensive industries, and much research have been done on the sinful phenomena in the sin triumvirate industries. However, few have researched the climate movement's effect on the carbon-intensive industries other than one study that has looked at the short-term effect. By considering the long-term perspective, we will contribute to this field of research. Researchers, investors, and policymakers must understand the implications of excluding these companies.

3. Theory

3.1. Return measurements

In this study, the concepts of *raw return*, *excess return* and *abnormal return* are used frequently, and it is important to differentiate between them. *Returns* are, first of all, the relative change in the stock price between two periods, adjusted for dividends. When comparing two assets' returns over time, one often refers to the return without making any adjustments for risk, which can be referred to as *raw return*. For example, in figure 3 the raw returns of the portfolio of assets is compared to the market index.

Excess return is the return above the risk-free rate. The risk-free rate is used as a basis for determining the expected return, with the risk-free rate being the expected return from having the money saved in risk-free bonds.

Abnormal return refers to the part of an asset's return that cannot be explained by taking on more risk, often calculated as $Return_{abnormal} = Return_{actual} - Return_{expected}$, with the expected return derived from an asset pricing model adjusting for risks in the market. Abnormal return is often measured over time rather than as a snapshot for one data point. In conventional regression analysis, the abnormal return is referred to as alpha.

3.2. Capital Asset Pricing Model

The Capital Asset Pricing Model, also referred to as CAPM, was presented by Sharpe in 1964 and describes how the expected return of assets and the systematic risk (market risk) relate to one another. It is a well-established model that is frequently used in estimating the market's expected return on assets, company valuations, as well as pricing of other derivatives. The theory is based on the notion that investors should only be compensated for the non-diversifiable risk in an investment (Sharpe, 1964). The CAPM estimates an asset's expected return as follows:

$$r_{i,t} - r_{f,t} = a_i + \beta_i MKT_t + \varepsilon_{i,t}$$

where: $r_{i,t} - r_{f,t}$ *is asset i's excess return at time t,* a_i *is alpha. MKT is the market excess return at time t.* β_i *is the asset's coefficient factor for the market variable.* $\varepsilon_{i,t}$ *is a zero-mean error term*

3.3. Fama French three-factor model

Eugene Fama and Kenneth R. French (1993) further developed the CAPM by adding two more factors known to influence a company's expected return - market capitalization and book to market ratio. The size factor is deduced from the research by Banz (1981), who provided evidence for the difference in expected return due to market capitalization. Rosenberg et al. (1985) provided evidence for the difference in expected return due to differences in companies' book to market ratios. The new asset pricing model is referred to as the Fama French three-factor model and estimates expected returns as follows:

$$r_{i,t} - r_{f,t} = a_i + \beta_i MKT_{rf,t} + y_i SMB_t + \delta_i HML_t + \varepsilon_{i,t}$$

where: *$r_{i,t} - r_{f,t}$ is asset i's excess return at time t, a_i is alpha. MKT is the market excess return at time t. SMB is the difference in returns between small and large companies. HML is the difference in returns between value and growth stocks. β_i, y_i, and δ_i are the assets' coefficient factors with their respective variable. $\varepsilon_{i,t}$ is the zero-mean error term*

3.4. Fama French five-factor model

In 2014, Fama and French developed their model further by including two more factors to the previous three-factor model. The three-factor model was inadequate as it overlooked profitability and investment when estimating the expected returns. The profitability factor is the difference in returns between firms with robust and weak profitability, and, the second factor, investment, is the difference in returns between a firm with aggressive versus conservative investment strategies. This asset pricing model is as follows:

$$r_{i,t} - r_{f,t} = a_i + \beta_i MKT_{rf,t} + y_i SMB_t + \delta_i HML_t + \mu_i CMA_t + \rho_i RMW_t + \varepsilon_{i,t}$$

where: *$r_{i,t} - r_{f,t}$ is asset i's excess return at time t, a_i is alpha. MKT is the market excess return at time t. SMB is the difference in returns between small and large companies. HML is the difference in returns between value and growth stocks. CMA is the difference in return between conservative versus aggressive investments. RMW is the difference in returns from robust versus weak profitability. β_i, y_i, δ_i, μ_i, and ρ_i are the assets' coefficient factors with their respective variable. $\varepsilon_{i,t}$ is the zero-mean error term*

3.5. Inclusion of a sixth factor - oil return

Mohanty and Nandha (2011) examined the relationship between returns on North American Oil & Gas companies and oil price movements. Their results indicate that the oil price is a significant determinant of the variation in returns for these companies and that they suffer a significant exposure from oil price shocks. We control for the oil price by adding the monthly return of oil as a factor to the regression model. This is also to control for environmental risks tied directly to the oil industry.

$$r_{i,t} - r_{f,t} = a_i + \beta_i MKT_{rf,t} + y_i SMB_t + \delta HML_t + \ \mu_i CMA_t + \rho_i RMW_t + \theta_i OilReturn_t + \varepsilon_{i,t}$$

where: $r_{i,t} - r_{f,t}$ *is asset i's excess return at time t,* a_i *is alpha. MKT is the market excess return at time t. SMB is the difference in returns between small and large companies. HML is the difference in returns between value and growth stocks. CMA is the difference in return between conservative versus aggressive investments. RMW is the difference in returns from robust versus weak profitability. OilReturn is the change in oil price.* β_i, y_i, δ_i, μ_i, ρ_i, *and* θ_i *are the assets' coefficient factors with their respective variable.* $\varepsilon_{i,t}$ *is the zero-mean error term*

4. Methodology

4.1. Creating the carbon index

As no formal definition of carbon-intensive stocks exists today, we have established a definition based on the work by Hoffmann and Busch (2008), in combination with one of the most used frameworks for sustainable investing - the Principle for Responsible Investments framework (PRI). This framework has over the last two decades been developed and can today be considered to be the norm for how companies are evaluated on their environmental impact with over 7,000 corporate signatories (UNPRI, 2020). The framework considers CO_2 emissions to be particularly important in measuring a company's environmental footprint (UNPRI, 2015).

While Hoffmann and Busch look at the three scopes of CO_2 emissions separately, we only consider total CO_2 emissions reported by the company. This is to increase the number of reporting companies for the analysis. Further, similarly to the study by Benz et al. (2019), we included the measure of the carbon emissions in relation to size (in our analysis revenue instead of market capitalization due to availability of information) to standardize the measurement, and thus facilitate comparison between industries. This improved the classification as large industries, with relatively high emissions, are not necessarily considered polluters if their emissions are small compared to revenue. The resulting definition of carbon-intensive stocks is: *those stocks that report above-average total CO_2 emissions and above-average carbon footprint (CO_2 to Revenue ratio).*

However, since only a small share of companies report their emissions, and to avoid reporting bias, the assembling of the carbon portfolio index has been based on a sub-sector analysis rather than on an individual asset level. This is assuming that the CO_2 emissions are closely tied to the sub-sector rather than an individual firm's operation. The sub-sector analysis was based on the North American Industry Classification System (NAICS), and the more than 20,000 companies listed on an American, Western or Northern European stock exchange were grouped into the 95 different sub-sectors available on Thomson Reuters EIKON terminal. The European companies were not included in the portfolio of stocks used later in the return analysis, but only used to elevate the number of reporting companies in the industry analysis. Despite the clear discrepancies between how many companies that report their CO_2 numbers in the different industries, there were sufficiently many in each sub-sector to rank them within the scope of our research (see table 1). The reason for evaluating the industries on the NAICS sub-sector level rather than an even more precise industry classification, such as Industry Groups with 324 different groups, is because there was not enough data for a more specific analysis in the database. To avoid this type of classification or reporting bias the sub-sector level was deemed granular enough for this study.

As a final step in the classification, the data was cross-referenced with the Environmental Protection Agency (EPA, 2020), the European Environmental Agency (EEA, 2019), and the paper by Benz et al. (2019) researching which industries had been classified as the biggest polluters. This to make sure a sub-sector's reporting standards would not interfere with the selection and to reduce the risk of potential flaws in the quantitative data. By adding this qualitative layer, the sub-sectors Forestry, Gasoline Stations, Truck Transportation, and Support Activities for Mining were included. Couriers & Messengers, and Merchant Wholesalers of Durable Goods were excluded despite high reported CO_2. This analysis classified 15 sub-sectors as carbon-intensive, found in table 1.

Table 1: Shows the sub-sectors which are included in the CARBDEX and the quantitative indicators of each sub-sector.

NAICS Sub Sectors - Included in Carbon Index	**Total Companies**	**Reporting Companies**	**Share Reporting**	**Average CO_2 Emission**	**Average CO_2/Revenue MUSD**
Plastics and Rubber Products Manufacturing	145	19	13.1%	33,484,420	4,180
Petroleum and Coal Products Manufacturing	72	21	29.2%	29,611,291	335
Utilities	522	89	17.0%	22,269,834	1,640
Nonmetallic Mineral Product Manufacturing	177	18	10.2%	18,485,439	2,264
Air Transportation	47	17	36.2%	17,028,182	905
Primary Metal Manufacturing	201	26	12.9%	14,525,343	1,322
Pipeline Transportation	56	7	12.5%	9,551,161	1,449
Water Transportation	147	14	9.5%	6,382,429	700
Mining (except Oil & Gas)	590	36	6.1%	5,077,121	408
Oil & Gas Extraction	480	43	9.0%	4,959,339	436
Waste Management and Remediation Services	129	12	9.3%	4,523,041	826
Support Activities for Mining	184	20	10.9%	879,850	187
Forestry and Logging	23	0	0.0%	-	-
Gasoline Stations	26	0	0.0%	-	-
Truck Transportation	84	0	0.0%	-	-
Total Carbon Industries	**2,883**	**322**	**11.2%**	**13,898,121**	1,221
Total Non-Carbon Industries	18,873	1,333	7.1%	719,907	83
Total	**21,756**	**1655**	**7.6%**	**2,800,678**	262

From these sub-sectors, an equally weighted portfolio with all available US stocks in Thomson Reuters DataStream was created using monthly data points for the years 2000 to 2019. This portfolio of stocks will henceforth be referred to as the carbon index or CARBDEX. Previous related research on sin stocks have used an equally weighted portfolio (see Appendix table 2) and to facilitate comparison, this study will be conducted in the same manner. For the same reason, we are using monthly data points rather than weekly or daily. Also, all stocks with an average market capitalization of less than $100 million during the period have been excluded as the scope of this research is to evaluate assets that large investors, such as pension funds, would invest in. Companies with an average market capitalization of less than $100 million are deemed too small to be considered by this type of asset manager. The results' sensitivity to this assumption can be found in Appendix table 3.

The resulting carbon index can then be described as an equally weighted portfolio of 487 listed companies on an American stock exchange, with a total market capitalization of $3.5 trillion 2019 year-end. There is some overlap between the carbon index, S&P 500 and Russell 2000, but the majority are stocks separate from the two market indices, illustrated in figure 1.

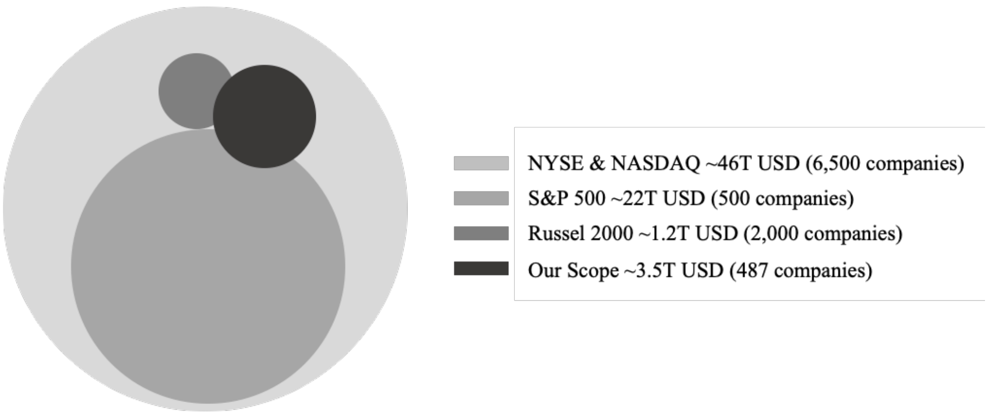

Figure 1: Illustration of the overlap between all the companies listed on NYSE and Nasdaq, stocks included in Russell 2000 or S&P 500, and the created carbon index. Size of circles is the market capitalization. The overlap is ~25% of companies. Source: Thomson Reuters DataStream

4.2. Linear regression analysis

To assess the existence of abnormal returns over the period, we conducted a regression analysis with the carbon index using the CAPM and Fama French factor models. The asset pricing models were used to estimate the expected return of the carbon index and control for special characteristics. These factors have been researched and confirmed in previous literature to be factors increasing (decreasing) the expected return as the factors increase (decrease) risk in the asset. Specific to this portfolio of stocks is also their exposure to the oil price, and, as such, it was added as a sixth factor to the analysis to control for an associated risk premium demanded by the market.

Factors used in the analysis

For the regression analysis, the most appropriate market return index to measure the systematic risk in the market is considered to be a weighted total return index of S&P 500 and Russell 2000. The weights are based on the average market capitalization of the stocks included in the carbon index - which is approximately $7 billion. By creating an index with 80% Russell 2000 and 20% S&P 500 the index has a similar market capitalization as the carbon index as of year-end 2019. This will limit the effect of different returns between small and large companies (Banz, 1981). The index data points are extracted from Thomson Reuters DataStream with monthly data points.

A second reason behind the chosen market index can be deduced from the underlying purpose of this study. The S&P 500 and Russell 2000 are two key indices in the US stock market with the goal of reflecting the overall US economy. Since the purpose of this research is to examine if investors lose out on alpha by shunning carbon-intensive stocks, we want to compare it to the systematic risk in indices that institutional investors would normally invest in.

Fama and French's four factors SMB, HML, CMA, and RMW were collected from Kenneth R. French data library (French, 2020), and the monthly oil price was acquired from the US Energy Information Administration website (EIA, 2020). Studying the correlation, see table 2, between the six factors reveal a high correlation between the CARBDEX and the market index suggesting that the overlap in stocks, brought up in section 4.1, is significant. This is discussed in the limitations section but is not considered a major flaw in the research as the overlap only concerns 25% of companies.

Table 2: Correlation matrix for the six variables and the carbon index used in the research. The values are for the whole period from 2000 to 2019.

Variable Correlation	CARBDEX	Market	SMB	HML	RMW	CMA	OilReturn
CARBDEX	1.0000						
Market	0.7567	1.0000					
SMB	0.3813	0.5225	1.0000				
HML	0.2463	0.0069	-0.0309	1.0000			
RMW	-0.2628	-0.5197	-0.4957	0.4003	1.0000		
CMA	0.0185	-0.1644	0.0168	0.6206	0.3034	1.0000	
OilReturn	0.2907	0.1382	0.0503	0.0368	-0.0538	-0.0910	1.0000

5. Hypotheses

Based on the previous literature, two hypotheses were created. The first founded in the belief that carbon-intensive stocks would share the sinful nature of the sin triumvirate, and, therefore, investors would have to pay a financial cost to abstain from these assets. Hence, carbon-intensive stocks would experience abnormal returns. The second hypothesis is based on the idea that the sinful nature of carbon-intensive stocks has been increasing over the period studied. Because of this, the abnormal return should have increased over time. Specifically, the two hypotheses and their respective null hypotheses are:

$H_{1,0}$: *The carbon index has not generated significant abnormal returns over the period 2000 to 2019.*

$H_{1,1}$: *The carbon index has generated significant abnormal returns over the period 2000 to 2019.*

$H_{2,0}$: *The alpha analyzed is not larger for the period after the financial crisis than for the period before.*

$H_{2,1}$: *The alpha analyzed has increased over time and will thus be higher for the period after the financial crisis than the period before.*

6. Empirical results

The 487 companies, included in the CARBDEX, individually display higher volatility than the weighted market index, but the carbon index has a lower spread than the weighted index illustrated in the graph below, figure 2. Worth noticing is the slightly higher median monthly raw return of CARBDEX, and the several outliers. To control for extraordinary events, and reduce noise in the data, the most extreme outliers in the 0.1 and 99.9 percentile have been excluded on an individual stock level.

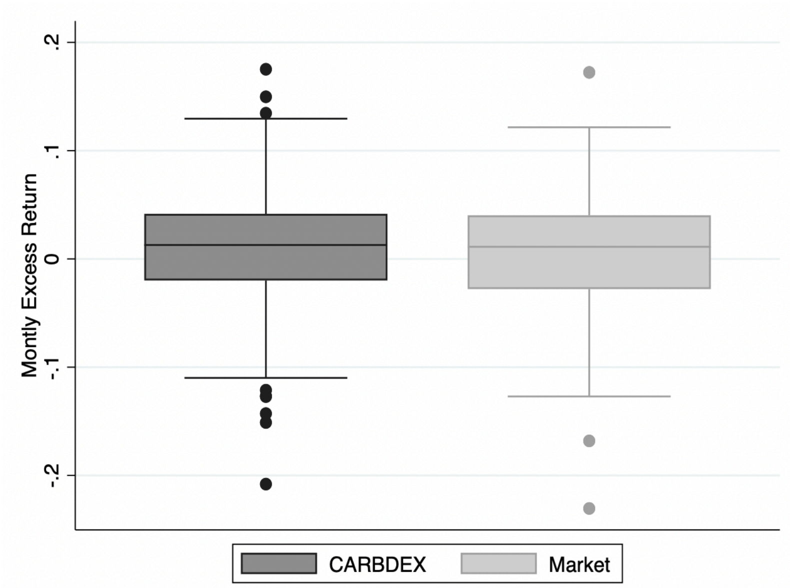

Figure 2: Shows the minimum, lower quartile, median, higher quartile, and maximum return of CARBDEX and the market portfolio which is represented by a weighted index with 80% Russell 2000 and 20% S&P 500.

6.1. Absolute performance

Comparing the cumulative monthly raw returns for the carbon index versus the market index results in a significant difference. Since the beginning of 2000, the CARBDEX has increased with 490% (9.3% annually), while the market index has only increased with 120% (4.1% annually). However, figure 3 is misleading as the difference is due to the higher raw returns in the early period, specifically before 2005. Looking at figure 4 instead, starting in 2005, the cumulative return is more or less the same between the two indices. It is evident from the graph that, after the financial crisis, the market has closed the gap and experienced higher raw returns than the CARBDEX. Worth noticing in the two graphs are the Dot-com crash in 2000 to 2002, the financial crash in 2008, and the oil crisis in 2016 to 2017 affecting the two indices differently.

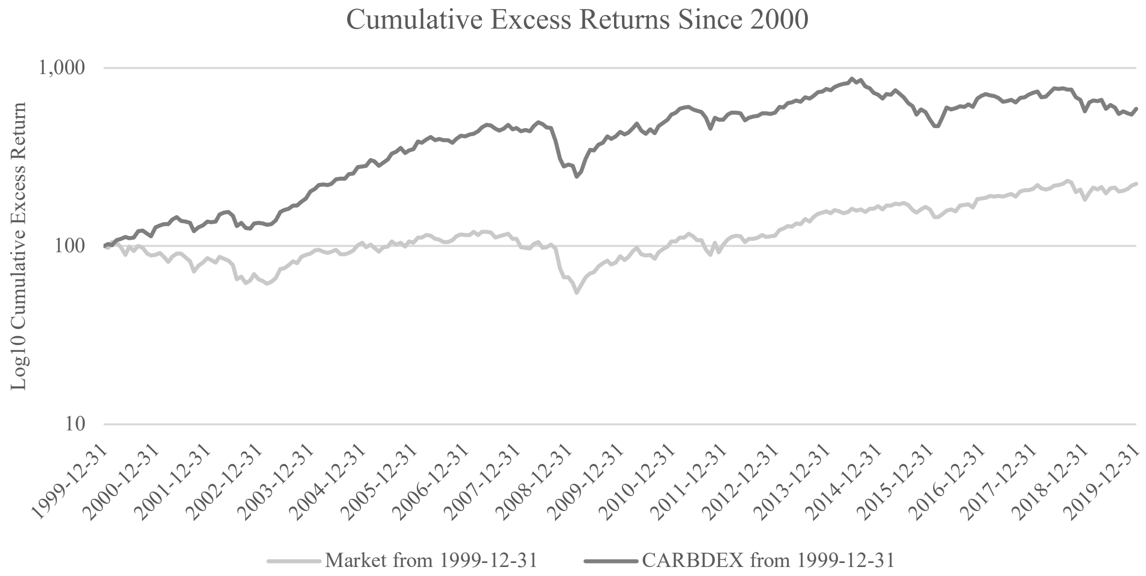

Figure 3: Log10 return performance of CARBDEX and the market portfolio which is represented by a weighted index of 80% Russell 2000 and 20% S&P 500. The table refers to the period 1999-12-31 to 2019-12-31

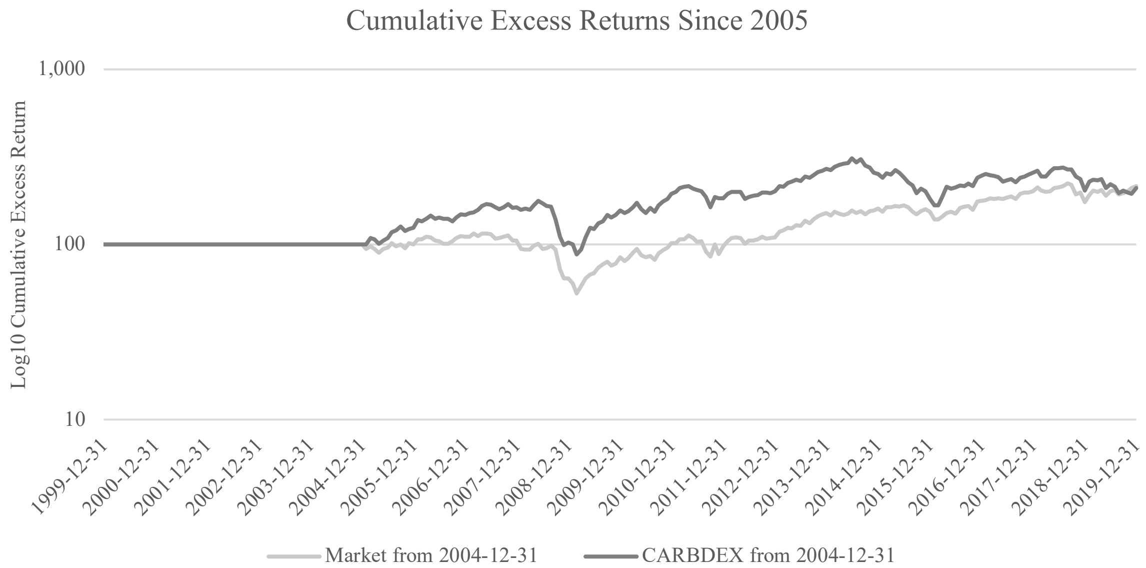

Figure 4: Log10 return performance of CARBDEX and the market portfolio which is represented by a weighted index of 80% Russell 2000 and 20% S&P 500. The table refers to the period 2004-12-31 to 2019-12-31

6.2. Capital Asset Pricing Model

When using the Capital Asset Pricing Model, the carbon index has experienced abnormal returns when considering the whole period between 2000 and 2019. The regression yielded a monthly alpha of 52 basis points, significant at the 5% level, and a market coefficient of 0.77 (see table 3). The CAPM only controls for the systematic risk in the market, and 57% of the variations in the carbon index can be explained by fluctuations in the market index. This is unusually high but natural given that the carbon index correlates strongly with the market index due to the overlap of stocks in the two indices. The regressions fit is illustrated in figure 5.

Further, the other two regressions conducted on the period before and after the financial crisis of 2008 yielded two different outcomes. Before the financial crisis, the regression yielded a larger alpha of 156 bps per month significant at the 1% level, while the regression for the second period resulted in a negative alpha not significantly different from zero. The regression intercept has decreased significantly since the financial crisis. This result will be explored further in the sensitivity section 6.5.

*Table 3: Shows the regression output for the different periods. The return of the market portfolio is represented by a weighted index of 80% Russell 2000 and 20% S&P 500. The three-month treasury bill is used as the risk-free rate. Data for CARBDEX, market portfolio, and the risk-free rate is gathered from Thomson Reuters DataStream. *, **, ***, and **** symbolize a statistical significance of 1%, 5%, 10%, and 15% respectively.*

Timeframe	**1999-12-31 - 2019-12-31**	**1999-12-31 - 2007-12-31**	**2009-12-31 - 2019-12-31**
Obs (months)	240	96	120
Model R^2	57.26%	46.79%	61.44%
Adj. R^2	57.08%	46.23%	61.11%
Alpha	0.005215**	0.0155713*	-0.0038196
Std. Error	0.0023197	0.0032446	0.0031278
Market coef.	0.7666621*	0.5801308*	0.8601546*
Std. Error	0.042937	0.0638035	0.0627306

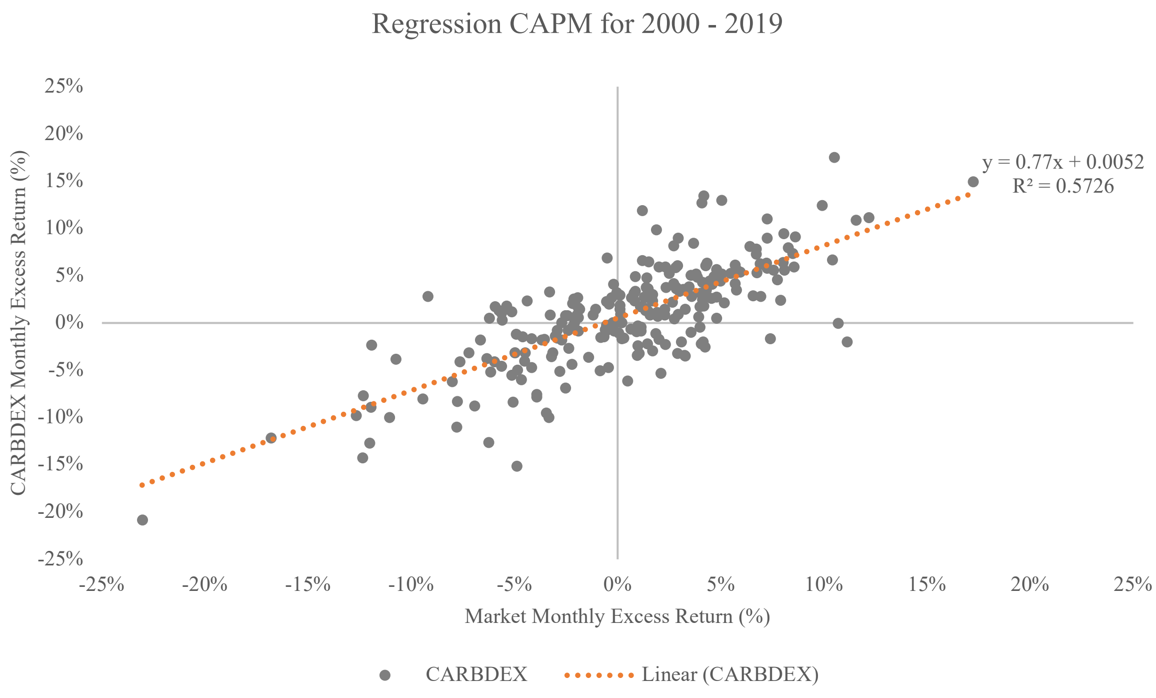

Figure 5: Illustrates the regression and the overall fit of the model for the whole period.

6.3. Fama French three and five-factor models

Augmenting the CAPM by also controlling for the size and value factors (SMB and HML respectively), the regression yielded an alpha of 42 bps, significant at the 10% level, for the whole period 2000 to 2019 (see table 4). The added two factors increased the model's R^2-value by 6 percentage points (from 57% to 63%) and suggests that 63% of the variations in the carbon index can be explained by the new model. However, only the HML variable provides a significant coefficient consistently over the three regressions (0.41, significant at the 1% level for the whole period) and the added 6 percentage points are thus attributable to the HML variable primarily.

Similar to the results from the first asset pricing model, the regression for the period before the financial crisis yielded a larger alpha (120 bps, 1% level) than the period after (-17 bps, insignificant), and the model's explanatory value is higher for the second period.

*Table 4: Shows the regression output for the different periods. The return of the market portfolio is represented by a weighted index of 80% Russell 2000 and 20% S&P 500. The three-month treasury bill is used as the risk-free rate. Data for CARBDEX, market portfolio, and the risk-free rate is gathered from Thomson Reuters DataStream. The SMB and HML were collected from the Kenneth R. French data library (French, 2020). The SMB factor is the difference in returns between small and large companies, HML the difference between value and growth stocks. *, **, ***, and **** symbolize a statistical significance of 1%, 5%, 10%, and 15% respectively.*

Timeframe	1999-12-31 - 2019-12-31	1999-12-31 - 2007-12-31	2009-12-31 - 2019-12-31
Obs (months)	240	96	120
Model R^2	63.07%	61.53%	66.91%
Adj R^2	62.60%	60.27%	66.05%
Alpha	0.0042324***	0.0119589*	-0.0016949
Std. Error	0.0021739	0.0029329	0.0029715
Market coef.	0.7691681*	0.7476972*	0.750837*
Std. Error	0.0470246	0.0662964	0.072321
SMB coef.	-0.0144118	-0.1180606	0.2435392****
Std. Error	0.0843989	0.0891351	0.1570238
HML coef.	0.4142413*	0.4759764*	0.5041352*
Std. Error	0.0681239	0.0863644	0.1305912

Controlling for the last two Fama French factors profitability and investment, the alpha decreases further to 37 bps. This should, however, be viewed with caution as it is only significant on a 15% level (see table 5). The regression coefficients for the Market and HML factors are consistently significant on a 1% level, but none of the other three variables help explain the excess returns of the CARBDEX. The RMW variable coefficient is significant on a

15% level for the second period, but not in any other regression. The size variable SMB does not carry a significant coefficient, and this is expected since the market portfolio is weighted so that the average size is the same as the carbon index. The factors profitability and investment provide close to no explanatory value as the model's R^2-value only increases by 0.2 percentage points and neither factor carry a significant coefficient. This suggests that the majority of the variance is already captured in the three-factor model through the Market and HML variables. Also, consistent with the previous models, the alpha is larger for the first period (131 bps, 1% significance level) than for the second period (-21 bps, insignificant).

*Table 5: Shows the regression output for the different periods. The return of the market portfolio is represented by a weighted index of 80% Russell 2000 and 20% S&P 500. The three-month treasury bill is used as the risk-free rate. Data for CARBDEX, market portfolio, and the risk-free rate is gathered from Thomson Reuters DataStream. The SMB, HML, RMW, and CMA were collected from the Kenneth R. French data library (French, 2020). The SMB factor is the difference in returns between small and large companies, HML the difference between value and growth stocks, RMW difference in robust profitability, and CMA the difference in expected returns based on how aggressively the companies are investing. *, **, ***, and **** symbolize a statistical significance of 1%, 5%, 10%, and 15% respectively.*

Timeframe	**1999-12-31 - 2019-12-31**	**1999-12-31 - 2007-12-31**	**2009-12-31 - 2019-12-31**
Obs (months)	240	96	120
Model R^2	63.27%	64.05%	67.30%
Adj R^2	62.49%	62.06%	65.87%
Alpha	0.003676****	0.0130705*	-0.002126
Std. Error	0.0022617	0.0029206	0.0030327
Market coef.	0.7897048*	0.6799835*	0.7665059*
Std. Error	0.0533251	0.0739554	0.0754335
SMB coef.	0.0217393	-0.1053744	0.2237654
Std. Error	0.0909836	0.0947883	0.163438
HML coef.	0.3838573*	0.7735327*	0.3736052**
Std. Error	0.0964303	0.1475718	0.1719445
RMW coef.	0.1182152	-0.188072****	-0.036725
Std. Error	0.1058237	0.1260131	0.2278851
CMA coef.	-0.0286674	-0.3309584	0.314397
Std. Error	0.1383654	0.1460139	0.2683515

6.4. Regression model including oil price

After controlling for several known factors, the oil price returns were included to isolate the returns associated with oil. This resulted in an insignificant alpha of 22 bps from the regression for the entire period (see table 6). The alpha measured using the CAPM of 52 bps could be explained in the variations of the other four Fama French factors and the oil price. The oil return factor improves the model's R^2-value with 3 percentage points suggesting that there are risks in the carbon index attributable to oil, which were not captured by the other factors.

*Table 6: Shows the regression output for the different periods. The return of the market portfolio is represented by a weighted index of 80% Russell 2000 and 20% S&P 500. The three-month treasury bill is used as the risk-free rate. Data for CARBDEX, market portfolio, and the risk-free rate is gathered from Thomson Reuters DataStream. The SMB, HML, RMW, and CMA were collected from the Kenneth R. French data library (French, 2020). The oil return was collected from the EIA (EIA, 2020) The SMB factor is the difference in returns between small and large companies, HML the difference between value and growth stocks, RMW difference in robust profitability, and CMA the difference in expected returns based on how aggressively the companies are investing. *, **, ***, and **** symbolize a statistical significance of 1%, 5%, 10%, and 15% respectively.*

Timeframe	1999-12-31 - 2019-12-31	1999-12-31 - 2007-12-31	2009-12-31 - 2019-12-31
Obs (months)	240	96	120
Model R2	66.50%	64.42%	73.77%
Adj. R2	65.64%	62.02%	72.38%
Alpha	0.0028995	0.0125738*	-0.0020982
Std. Error	0.0021708	0.0029679	0.0027284
Market coef.	0.7690262*	0.6925692*	0.6905939*
Std. Error	0.0512221	0.075156	0.0693695
SMB coef.	0.0228489	-0.1161724	0.3119807**
Std. Error	0.0870781	0.0955063	0.1479804
HML coef.	0.3419963*	0.7696478*	0.2440399****
Std. Error	0.0927124	0.1477	0.1566219
RMW coef.	0.1196149	-0.1872167****	0.0143911
Std. Error	0.1012813	0.1260779	0.2052405
CMA coef.	0.045221	-0.3143336**	0.46702***
Std. Error	0.1333401	0.1471188	0.2431422
Oil coef.	0.1139235*	0.0304891	0.1869665*
Std. Error	0.0240372	0.031925	0.0354239

After evaluating the four models, only the three variables Market, HML, and OilReturn provided significant coefficients. By assuming the other factors' coefficient values are indeed zero, we can increase the model's adjusted R^2-value slightly with the following regression model:

$$r_{i,t} - r_{f,t} = a_i + \beta_i MKT_{rf,t} + \delta_i HML_t + \theta_i OilReturn_t + \varepsilon_{i,t}$$

Alpha is measured to 36 bps, significant on a 10% level (see table 7). All coefficient values are significant at the 1% level consistently (except for oil price during the first period), and the model's explanatory R^2-value is 66% (Adj. R^2 is 65.9%).

*Table 7: Shows the regression output for the different periods for the last model. The model assumes the non-significant factors to be zero. The return of the market portfolio is represented by a weighted index of 80% Russell 2000 and 20% S&P 500. The three-month treasury bill is used as the risk-free rate. Data for CARBDEX, market portfolio, and the risk-free rate is gathered from Thomson Reuters DataStream. The HML factor was collected from the Kenneth R. French data library (French, 2020). The oil return was collected from the EIA (EIA, 2020). The HML is the difference between value and growth. *, **, ***, and **** symbolize a statistical significance of 1%, 5%, 10%, and 15% respectively.*

Timeframe	1999-12-31 - 2019-12-31	1999-12-31 - 2007-12-31	2009-12-31 - 2019-12-31
Obs (months)	240	96	120
Model R^2	66.28%	61.25%	71.69%
Adj. R^2	65.86%	59.98%	70.96%
Alpha	0.0036089***	0.0106933*	-0.0021615
Std. Error	0.0020788	0.0029495	0.0027247
Market coef.	0.7396403*	0.7176499*	0.7544365*
Std. Error	0.0386668	0.0600685	0.0566162
HML coef.	0.4035393*	0.5014662*	0.4785323*
Std. Error	0.0650818	0.085966	0.1202694
Oil coef.	0.1129081*	0.0336269	0.1694478*
Std. Error	0.0237899	0.0323892	0.0357744

6.5. Sensitivities

The results from the linear regressions presented in the earlier part of section 6 have been based on the period 2000 to 2019, and to test the robustness of those findings we test their sensitivity to the start date, end date and period split. For the sake of simplicity, the sensitivity analysis was conducted using the three-factor model.

Sensitivity to start date

By conducting a series of regressions moving the start date one year forward at a time, alpha disappears after 2002, as can be seen in table 8. The measured alpha from December 2002 and onwards is about one standard error different from zero and not enough to provide significant results. This fact points to a crucial aspect of this research, namely the fact that earlier results in section 6.1 to 6.4 rely on the inclusions of the earliest years in the period.

Table 8: Illustrates the regression output's sensitivity to the start date by moving the start date one year ahead in time and keeping the end date fixed at 2019-12-31.

Start Date	**1999-12-31**	**2000-12-31**	**2001-12-31**	**2002-12-31**	**2003-12-31**
Obs (months)	240	228	216	204	192
Model R^2	63.07%	66.41%	66.00%	64.88%	64.64%
Adj. R^2	62.60%	65.96%	65.52%	64.36%	64.08%
Alpha	0.0042324***	0.0034374****	0.0035303****	0.002884	0.0025022
Std. Error	0.0021739	0.0021384	0.0022341	0.002351	0.0024471
Market coef.	0.7691681*	0.7580051*	0.7551438*	0.7692231*	0.7618624*
Std. Error	0.0470246	0.047484	0.0510266	0.0570636	0.0588448
SMB coef.	-0.0144118	0.1548238****	0.1933796***	0.1991414****	0.2452745***
Std. Error	0.0843989	0.1009188	0.1119359	0.1255029	0.1302912
HML coef.	0.4142413*	0.3045708*	0.2795362*	0.2529589*	0.2318678**
Std. Error	0.0681239	0.0774303	0.090988	0.0953595	0.097613

Sensitivity to end date

Using a similar method, but moving the end date earlier in time, shows that the analysis is not as sensitive to the end date as with the start date. Alpha is significant on at least a 10% level for all regressions, and the Market and HML coefficients are significant on at least a 5% level as well. Hence, the alpha and variable coefficients are not dependent on the end date decision (see table 9).

Table 9: Illustrates the regression output's sensitivity to the end date by moving the end date one year back in time and keeping the start date fixed at 1999-12-31.

End Date	**2015-12-31**	**2016-12-31**	**2017-12-31**	**2018-12-31**	**2019-12-31**
Obs (months)	192	204	216	228	240
Model R^2	62.57%	62.04%	62.03%	62.58%	63.07%
Adj. R^2	61.97%	61.47%	61.49%	62.08%	62.60%
Alpha	0.0058241**	0.0061192**	0.0056863**	0.0048835**	0.0042324***
Std. Error	0.0024274	0.0024139	0.0022915	0.0022287	0.0021739
Market coef.	0.7583862*	0.7638197*	0.7609444*	0.7641144*	0.7691681*
Std. Error	0.0502277	0.0505432	0.0492666	0.0478743	0.0470246
SMB coef.	-0.0684424	-0.0604946	-0.0523468	-0.026751	-0.0144118
Std. Error	0.0888192	0.0898523	0.086668	0.0849952	0.0843989
HML coef.	0.3750289*	0.3771831*	0.3866557*	0.3977868*	0.4142413*
Std. Error	0.0736031	0.073117	0.0705644	0.0698198	0.0681239

Sensitivity to period split

In the regressions, the split in periods has proven to provide disparate results and different R^2-values. For example, using the CAPM, the regression for the first period has an R^2 of 47% while the consecutive period has a better fit of 61%. This can in part be explained by the significantly higher correlation between the CARBDEX and market for the second period than for the first period. The correlation coefficient for the entire period is 0.76, with the first period at 0.68 and the second period at 0.78. This means that the co-movement in the second period is stronger than in the first period and helps to explain the increase in R^2-value between the two periods. It also helps explain the decrease in alpha as more of the variance is captured by the market variable. Nonetheless, moving the period split in either direction does not affect the result in any way. The cut-off points of 2007 and 2009 are considered reasonable.

6.6. Robustness tests

To critically evaluate the data sample used we test for heteroskedasticity, autocorrelation, and multicollinearity using Breusch-Pagan, Durbin-Watson, and Variance Inflation Tests respectively. The results are summarized in table 10. The tests are conducted on each of the four models used in section 6.1 to 6.4 separately. All three tests were passed for the four models, with VIF scores below 2.02, Breusch-Pagan chi2 values below 1.00, and the Durbin-Watson d-statistics support no autocorrelation in the regressions by being in between the du and 4-du values. The regression model does not contain flaws due to multicollinearity, autocorrelation or heteroskedasticity.

Table 10: Shows the results from the Variance Inflation Test, Durbin-Watson Test, and Breusch-Pagan / Cook Weisberg Test. They indicate that the regression models do not suffer from tendencies of multicollinearity, autocorrelation or heteroscedasticity.

Variance Inflation Test for multicollinearity

Model	Market	SMB	HML	RMW	CMA	OilReturn	Mean
CAPM	1.00	-	-	-	-	-	1.00
Three-Factor	1.38	1.38	1.00	-	-	-	1.25
Five-Factor	1.76	1.60	2.00	1.98	1.77	-	1.82
Five-Factor + OilReturn	1.78	1.60	2.02	1.98	1.79	1.04	1.70

Durbin-Watson Test for autocorrelation

Model	(k , obs)	d-statistic	dl	du	4-du	4-dl
CAPM	(2 , 240)	1.86	1.65	1.69	2.31	2.35
Three-Factor	(4 , 240)	1.88	1.63	1.72	2.29	2.37
Five-Factor	(6 , 240)	1.87	1.61	1.74	2.27	2.39
Five-Factor + OilReturn	(7 , 240)	2.19	1.60	1.75	2.25	2.40

Breusch-Pagan / Cook Weisberg Test for heteroskedasticity

Model	chi2(1)	Prob > chi2
CAPM	0.01	0.94
Three-Factor	0.22	0.64
Five-Factor	0.32	0.57
Five-Factor + OilReturn	0.97	0.33

7. Discussion

7.1. Interpretation of results

When estimating expected returns using established asset pricing models, the carbon index has experienced abnormal returns over the period 2000 to 2019, and we can as such reject the null hypothesis $H_{1,0}$ at the 10% significance level (three-factor model). This is also true for the regression in section 6.4 in which all non-significant coefficients are assumed to be zero. Most of the excess return is captured by the market index variable and is understandable given the strong correlation (see table 2).

The two factors HML and OilReturn provide significant explanatory value, suggesting that the portfolio of carbon stocks exhibit characteristics similar to value stocks and that they vary with the oil price. On a group level, the carbon portfolio of stocks has a high book to market ratio, which is common among companies with extensive balance sheets and modest growth projections. They also inhabit risks associated with the oil price movements, and this is natural given several sub-sector's dependency on oil and oil commodities. This will be further discussed in the limitations, section 7.2. The other three factors from Fama French five-factor model do not provide consistent significant coefficient values and indicate that, on a group level, the portfolio is not overly robust or weak in its profitability, nor aggressive or conservative in its investments.

However, the abnormal returns observed are isolated to the period 2000 to 2002 as can be seen in the sensitivity analysis section 6.5. The start date of this study coincides with the Dot-com crash and its extreme influence on the market index. The industries included in the CARBDEX were to a large extent not involved in the hype surrounding technology companies, see figure 3, and helps to explain the positive alpha during the first couple of years. We contemplated that the alpha from the Dot-com crash was going to be captured by the HML-factor as the crash primarily affected growth stocks. This was not the case as significant alpha was still measured in the results, indicating additional risks in the market's pricing of the assets.

Another possible explanation for the positive alpha is deduced from Chava's study in 2014 described in the literary review. Companies that possessed environmental concerns had a higher cost of capital between the period 1992 to 2007, meaning that investors demanded a higher expected return from those types of firms. We do not specifically control for environmental concerns in our regressions, but it is believed that such risk could be captured by the OilReturn variable. Nonetheless, if the oil price underestimates this risk the model would miscalculate the expected return and falsely indicate alpha. The positive alpha measured in the first period is likely due to a combination of the two variables, OilReturn and HML, not capturing the full extent of the environmental risks and risks common for value stocks.

Further, the results presented in section 6 do not provide evidence allowing us to reject the $H_{2,0}$ hypothesis. Alpha has instead decreased between the two periods to become insignificantly different from zero for all models. This decrease could be explained by the fact that environmental and regulatory risks have been increasing over the period. As more environmental risk is priced into the required return the firm value is depreciating, causing negative returns in the stock price (Aggarwal & Dow, 2011). The decreasing firm value would cloud the possible abnormal returns until the required return and firm value stabilizes.

A decreasing firm value could also be the result of decreasing demand. Vayanos and Woolley (2010) explain how large institutional selloffs drive stock prices down and cause the subsequent returns to be abnormally high. This paper hypothesized that carbon-intensive stocks have been shunned by large mutual and pension funds, and increasingly so over the period researched. We were assuming that abnormal returns would have started to show, but if the asset prices are not fully adjusted because of a selloff, we would not experience abnormal returns yet. Rather, we would see continuous price decreases in the stocks and negative alpha - similarly to our data sample. As presented in the introduction, the neglect of carbon stocks from institutional investors is a recent event. Norwegian pension fund started to exclude oil companies in 2019 and Blackrock's CEO made his statement of Blackrock's new greener strategy in 2020. Therefore, this seems to be a likely contributing factor to our results.

Assuming we are at such a stage described by Vayanos and Woolley (2010), our results would imply that we will see abnormal returns in the future once the asset prices stabilizes. The previous literature suggests that the carbon industries will experience abnormal returns in the future because of the selloff, but also, potentially, because of the sinful attribute. Ethical constraints have historically required additional returns to justify holding this type of asset, and as carbon-intensive stocks are becoming more unethical the required return would increase. This is, however, speculation based on previous literature, and our data does not specifically provide support for this forecast.

Our results show that alpha, while being positive when considering the whole period, has decreased over time. Since the sinful attribute can only be considered as having increased over the period, we cannot conclude that the carbon index experiences alpha due to social norm constraints. Rather, the positive alpha is ascribable to the relatively well performance during the Dot-com crash in the early 2000s.

7.2. Limitations

Survivorship bias

One source of error in our data concerns the phenomena of survivorship bias. We have not been able to obtain data of companies that, during our selected period, have been delisted. This means that the carbon index excludes bankruptcy companies that would have performed worse than the rest of the index and pulled the average return down. For the same reason, the number of companies included in the carbon index is drastically increasing from 216 in 2000 to 487 in 2019. We would argue that this effect on our results is small because of the large sample size. Also, by conducting an analysis with an equally weighted portfolio the effect from a few companies pulling it down would be neglectable.

Difference in emissions within the same sub-sector and the concept of sin

In the creation of the CARBDEX, all stocks within a carbon-intensive sub-sector were classified as carbon-intensive. There may be companies within the industry that are not carbon intensive as, for example, companies that operate in these industries with an alternative business model. This method was deemed necessary to conduct this research, but, as more and more companies start to declare their emissions, it would be interesting to replicate this study in the future on an individual stock level.

Furthermore, even though an industry may be considered carbon-intensive it must not be considered a sinful industry. Airlines and Forestry are arguably less sinful than Oil & Coal exploration industries, and do not face the same risk of being excluded by ethical investors. Our methodology is based on the reported carbon numbers, but to further isolate the sinful concept is outside the scope of this study. This will, however, cloud our results as it includes non-sinful sub-sectors.

Overlap and correlation with the market index

As touched upon, there is a significant overlap between the market index and the carbon index, causing the two to correlate strongly and limit the insights from this research. One could, therefore, question if the selection of stocks was too broad and included too many sub-sectors as carbon-intensive – that the cut-off point was too generous. While there is an overlap, only 25% of the companies in the carbon index are included in either S&P 500 or Russell 2000 (see Appendix table 4). Since this research uses an equally weighted index, the number of companies overlapping is more important than the value of the overlapping companies. Furthermore, given that more than 30% of the variations in the regressions remain unexplained, we don't consider this a problem for the scope of this study.

Explanatory value in the oil Price

In our scope of industries, we have both companies that benefit and those who are penalized from changes in the oil price. Oil & Gas companies benefit from a higher oil price improving their stock price and bottom line, while Airlines and Shipping companies consume oil products in their services and are negatively affected by a high oil price. Both types of industries are included in the carbon index. Some companies correlate positively while others negatively with the changes in oil price, and, therefore, the OilReturn factor coefficient could be considered misleading.

7.3. Future expansion of the study

Considering the increase in attention devoted to the environment during recent years, a remake of this study five years from now would provide further insight into how carbon stocks have performed in times of increased scrutiny. To redo this study with a market index excluding technology companies would also help pinpoint the risk and perhaps better control for the early years of this study's chosen period.

To combat the increased scrutiny, several Oil & Gas companies supposedly try to rebrand themselves, such as Lundin Petroleum. They recently changed their name to Lundin Energy and announced that they aim to be climate neutral in their production by 2030. Their CEO Alex Schneiter said that he hoped this would lead to that *"more ESG-funds would invest in them"* (Phillips, 2020). This statement shows how managements of carbon stocks understand the importance of having institutional capital invested in their companies. One's branding strategy is likely to affect investors' behavior and following this development could provide further insights into what industries will be most affected by the changing business environment.

It would also be interesting to conduct a thorough analysis of each sub-sector to further isolate the effect and compare industries. Some sub-sectors in the portfolio are under more scrutiny than others which suggests that the effect would be unevenly distributed among the portfolio companies. For example, Oil & Gas companies are likely to be excluded to a higher degree than Forestry. To isolate the effect further would help one's understanding of which specific industries that are to be considered sinful.

To expand this study to other regions would also be beneficial for the understanding of carbon-intensive stocks and their performance. Salaber's study (2007) showed that sin stocks' market location was an important variable when it comes to abnormal returns. Europe is arguably further ahead of the United States when it comes to dealing with environmental concerns with a carbon emission trading system as well as all EU members being part of the Paris Agreement. Therefore, to further replicate our study on the European market would nuance the results of our research.

8. Conclusion

This research has investigated the performance of carbon-intensive stocks listed on the exchanges in the United States between 2000 and 2019. Carbon-intensive companies have been an important part of the globalization, but, as the externalities of their operations are becoming more evident, large institutional investors are joining the environmental movement making their future uncertain.

Our research provides evidence that the carbon index has experienced abnormal returns over the period 2000 to 2019. However, the abnormal returns are isolated to the period 2000 to 2002, which coincides with the Dot-com crash, and no alpha exists beyond this point. We were expecting that the abnormal returns would increase with the boost in environmental awareness and scrutiny, but, quite oppositely, our results show that the alpha has since decreased to be insignificantly different from zero. Hence, no alpha measured in the regressions can be attributable to social norms.

However, we emphasize that no statistical significance was found for the fact that investors would be missing out on alpha when avoiding carbon-intensive stocks. The alpha has been decreasing after 2005, and the reason behind it is difficult to pinpoint. Two plausible explanations discussed are the deteriorating value with increasing environmental risk and that carbon stocks are being sold off by large investors. Tendencies of this could be seen in the paper investigating the Greta Thunberg Effect and the mechanics are explained by Vayanos and Woolley (2010).

The question that arises is what this research can tell us about the future. Will the actions of large investors force high polluting industries to go green? If that is the case our results may not help to understand what the future holds for carbon stocks, but such a transition takes time and the era of carbon stocks is not over yet. If carbon stocks will continue to be shunned by institutional investors and sold off, the negative returns could prevail for the near future, but, as Vayanos and Woolley (2010) concluded in their study, the subsequent returns after a sell-off are abnormally high. Nonetheless, for the current time being, it is Carb-off.

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Appendix

Benz et al. (2019) – Carbon-intensive industries

Appendix Table 1: CO2-intensive industries
Source: Benz et al. (2019)

Energy industry	Energy-intensive industry	Energy-consuming products
Coal	Chemicals	Aerospace and Defense
Electric Utilities and IPPs	Construction Materials	Automobile and Parts
Natural Gas Utilities	Metals and Mining	Freight and Logistics Services
Multiline Utilities		Passenger Transportation Services
Oil and Gas		Transport Infrastructure
Oil and Gas - Equipment and Services		
	Paper and Forest Products	

Previous literature on sin stocks

*Appendix Table 2: Summarizes the previous literature made on sin stocks. Sin Triumvirate includes the industries Alcohol, Gaming and Tobacco. The results column shows the alpha received under the CAPM as well as the multi-factor models used. *, **, *** symbolize a statistical significance of 1%, 5%, and 10% significance level.*

Authors	Year	Region	Period	Sin industries	Weight	Results	
						CAPM	**Multi-factor**
Salaber	2007	Europe	1975-2006	Sin Triumvirate	Equal	N.A	0.33*
Fabozzi et al	2008	Global	1970-2007	Sin Triumvirate, Adult Entertainment, Biotech, Defense	Equal	0.96	N.A
Statman & Glushkov	2008	US	1992-2007	Sin Triumvirate, Defense, Nuclear Power	Equal	0.27**	0.19
Hong & Kacperczyk	2009	US	1960-2006	Sin Triumvirate	Equal	0.25*	0.26**
Salaber	2009	US	1926-2006	Sin Triumvirate	N.A	N.A	0.30***
Liston & Soydemir	2010	US	2001-2007	Sin Triumvirate	Equal	0.082	N.A
Visaltanachoti et al.	2011	China	1995-2007	Sin Triumvirate	Equal	0.50*** 2.43***	N.A
Lobe & Walkshäusl	2011	Global	1995-2007	Sin Triumvirate, Adult Entertainment, Defense, Nuclear Power	Equal	0.18	0.02
Richey	2014	US	2007-2013	Sin Triumvirate, Defense	Equal	0.002	0.002
Richey	2017	US	1996-2016	Sin Triumvirate, Adult Entertainment, Defense	Price	0.029*	0.010
Blitz & Fabozzi	2017	Global	1963-2016	Sin Triumvirate, Defense	Value	0.47***	0.10

Sensitivity to $100 million

Appendix Table 3: Sensitivity analysis for the assumption of $100m in the research

Cut off point	$50m	$100m	$150m
Obs (months)	240	240	240
Model R2	60.24%	63.07%	63.07%
Adj. R2	59.73%	62.60%	62.61%
Alpha	0.0066752*	0.0042324***	0.0033135****
Std. Error	0.0022696	0.0021739	0.0022108
Market coef.	0.7472677*	0.7691681*	0.7821832*
Std. Error	0.0490945	0.0470246	0.0478216
SMB coef.	0.0288671	-0.0144118	-0.012556
Std. Error	0.0881139	0.0843989	0.0858292
HML coef.	0.3893855*	0.4142413*	0.4186848*
Std. Error	0.0711225	0.0681239	0.0692784

Overlap

Appendix Table 4: Table of the overlap between the indices

Index	Overlap (# of companies)	Overlap (% of companies)
S&P 500	76	15.6%
Russell 2000	47	9.7%
Both	0	0.0%
Total	123	25.3%

Sub-sector split

Appendix Table 5: Carbon Index industry weights

NAICS Sub-sector	2000	2019
Air Transportation	2.3%	3.1%
Forestry and Logging	0.9%	0.4%
Gasoline Stations	0.0%	0.6%
Mining (except Oil and Gas)	9.3%	10.3%
Nonmetallic Mineral Product Manufacturing	3.7%	2.9%
Oil and Gas Extraction	16.7%	19.9%
Petroleum and Coal Products Manufacturing	3.2%	3.1%
Pipeline Transportation	1.9%	7.0%
Plastics and Rubber Products Manufacturing	5.1%	4.3%
Primary Metal Manufacturing	7.4%	5.3%
Support Activities for Mining	9.3%	9.9%
Truck Transportation	6.0%	4.3%
Utilities	26.9%	17.2%
Waste Management and Remediation Services	3.7%	2.3%
Water Transportation	3.7%	9.4%
CARBDEX	**100.0%**	**100.0%**

Companies per year

Appendix Table 6: Carbon index number of companies

YE-Dec	# of companies
2019	487
2018	479
2017	464
2016	436
2015	409
2014	397
2013	365
2012	347
2011	331
2010	314
2009	304
2008	299
2007	292
2006	272
2005	257
2004	245
2003	236
2002	233
2001	222
2000	218
1999	216