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Does the Price of Carbon Affect the Verified Emissions of European Union Companies? An Analysis of Firm Behavior Within the European Union Emissions Trading Scheme

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ABSTRACT

The Emissions Trading Scheme in the European Union (EU-ETS) is a relatively under-researched field due to the complexity and immaturity of the carbon market. This paper analyzes the complex relationship between firm behavior and the price of a carbon allowance during the third trading period of the EU-ETS, which occurred from 2013-2020. Correlations are determined based on a company's quantity of carbon allowances surrendered versus the price of a carbon allowance. Data are obtained from the European Union Registry and follows the behavior of thirty-one firms that operate under permits for the combustion of fuels. All firms analyzed fall into the highest ranking of compliance for the determined trading period. The lack of findings related to firm actions due to the unavailability of information and nontransparency of the European Union contribute to the knowledge gap that exists.

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Chapter 1

Introduction

Environmental externalities are becoming an increasing factor in the financial management of companies. Societal, political, and environmental pressures have caused companies to reevaluate their carbon emissions, leading to changes in a firm's cash flows. Despite the majority of firms in the world facing pressure to change their environmental policies, the effect on company performance is a relatively new field within academia. This paper will seek to determine if a relationship exists between the behavior of firm's carbon emissions relative to a price for internalization. Few studies have aimed to analyze this behavior within the European Union, let alone in the United States and China, the largest carbon producers in the world. In this study, company data will be analyzed from thirty-one firms in the European Union that actively participate in the Emissions Trading Scheme.

This study is primarily aimed towards investors who are seeking to evaluate firm behavior in the presence of carbon regulation. As with any sort of regulation, a firm's behavior and therefore valuation can be drastically impacted. Understanding how carbon regulation affects the cash flows of a company can greatly aid investors in stock picking. Additionally, investors who are looking to add companies to ESG portfolios can use this, and similar studies, to predict which companies may adjust best to regulation. As with the prior literature within the field of environmental finance, this study will attempt to contribute to further research.

Chapter 2 includes an in-depth coverage of what the European Union Emissions Trading Scheme is and its underworking. Additionally, the chapter will highlight some of the

shortcomings of the existing regulation and how the lack of available information has led to a knowledge gap within the analysis of the data. Thereafter, Chapter 3 states the hypothesis of the study. Chapter 4 then covers the methodology of the study and reviews the usage of correlation analysis to analyze the relationship between the variables. Included in Chapter 4 are the findings from the study. The analysis of findings and its limited scope of application for future research can be found in Chapter 5. Finally, Chapter 6 summarizes the main takeaways of the paper and highlights important elements.

Chapter 2

Literature Review

Emissions Trading Scheme

The European Emissions Trading Scheme (EU-ETS) is the largest international regulated cap and trade carbon market. All EU countries, including Iceland, Lichtenstein, and Norway must participate in the trading scheme. The EU-ETS is the European Union's attempt to curb carbon emissions using market mechanisms. To date, the cap regulates approximately 11,000 energy intensive production and industrial plants and it covers nearly fifty percent of the European Union's carbon emissions (IEA, 2020). To ensure a smooth implementation of the trading scheme, the EU designed four separate trading periods that each contain varying levels of restrictions. Phase I was introduced in 2005 and is considered pre-Kyoto Protocol, which was the international agreement in 1992 to reduce carbon emissions by eight percent relative to 1990 levels (Glowacki, 2021). During Phase I, the participating sectors were awarded allowances for free and were allowed to trade amongst themselves appropriately. This phase lasted until 2007. Between 2008 and 2012, Phase II saw an expansion of sectors and emissions that were regulated. Phase II also reduced the allocation of allowances to around ninety percent of emissions requirements. Phase III ran from 2013 to 2020 and created a formalized market that companies could trade carbon allowances in. All allowances were distributed via a bidding process, except for specific electricity modernization projects. A single-EU wide cap was implemented, and the European Union Registry became the centralized registry system for allowances (Glowacki, 2021).

The EU-ETS now represents a mature market in which thousands of companies engage in. The market has a predetermined cap of emissions that is set by the European Union, and the

cap contracts over time to incentivize innovation in carbon-free energy production and overall carbon emissions reduction. The price of the EU carbon allowance is largely dictated by the average energy prices across the European Union (European Commission, 2022). Companies buy allowances for expected emissions for the year and can trade those allowances with other companies throughout the year based on fluctuations in actual emissions. At the end of each year, every company must surrender the appropriate amount of allowances to fully cover its emissions, or it will be charged a fine proportional to exceeded emissions (European Commission, 2022). The combination of the fine and the price of a carbon allowance jointly creates financial incentives for companies to reduce their emissions. Companies that are able to either reduce emissions below the allowances distributed can either keep them for future use or sell them off to other companies that are not on track to meet emissions goals. This represents an opportunity for either capital gains or losses on accounting statements. The determination of the size of the capital impacts is directly related to the price of a carbon allowance. When the price of carbon is high, it is expected that those who have abated above their allowance amount will benefit and those who have abated below their allowance will be negatively impacted. The inverse is expected when carbon prices are low.

The success of the EU-ETS is widely studied within the environmental field as its impacts have lasting effects on the health of the planet. Between 2005 and 2019, the European Union experienced a 35% reduction in carbon emissions due to the cost-effective cap-and-trade system (European Commission, 2022). Additionally, in September 2020 the EU introduced the European Green Deal, which is aimed at reducing greenhouse gas emissions by 55% by the year 2030 (European Commission, 2022). Scientific literature continues to reveal the success of the

trading scheme, but there is relatively little research that has been conducted studying the financial implications of participation in the trading scheme.

Early literature in this field has mainly focused on the electricity and utility sector in the European Union, which is the largest participating sector in the EU-ETS. Oberndorfer (2009) conducted the first known econometric analysis of stock market effects from allowance price developments. The results of this study concluded that electricity EUA price increases positively affected the stock returns of electricity companies, while price decreases negatively affected returns. These counterintuitive results came about for a number of reasons. The aforementioned study covered stock returns during the Phase I period of the EU-ETS in which allowances were overdistributed and were free. Additionally, it was predicted that the electricity companies were going to be able to pass-through any additional costs to consumers during this time for emissions above the cap. Veith, Werner, and Zimmerman (2009) also drew the same conclusion regarding the relationship between the price of carbon and stock returns. A further conclusion was drawn that the convoluted nature of the relationship between carbon prices and stock returns may symbolize a temporary lack of economic significance in the carbon trading market and that once proper market mechanisms are in place, this relationship may invert.

It was also presumed that the inverse relationship between the price of carbon and stock returns would exist during the Phase II trading period (Veith, Werner, & Zimmermann, 2009). Allowances were still distributed at a large discount and the price of carbon was not entirely set by supply and demand. This allowed some companies to create an arbitrage opportunity and sell over allocated allowances at an inflated price, directly increasing profits. This hypothesis was furthered by Andreou and Kellard (2021) when studying the behavior of firms participating in the emissions trading scheme. During Phase I and II, it was found that companies who were

proactively implementing abatement technology were experiencing negative accounting profits. This relationship revealed that firms who were taking positive steps towards reducing emissions were underperforming their peers economically. Market mechanisms during the first two trading periods were penalizing those who were reducing emissions, while not rewarding those who continued to pollute at their pre-allowance levels. This was indeed a result counter to the European Union's initial market goals under the ETS.

While the EU-ETS has goals of reducing emissions across all industries, electricity generating companies contribute to the largest emission of carbon and engage in the ETS at the highest rates. Companies who are determined to have carbon intensive emission models, defined as having 50% or more of their power generation come from fossil fuels, experienced inversely related returns during periods of market stability (Tian, Akimov, Roca, & Wong, 2016). Companies that are non-carbon intensive experience positive financial returns when carbon prices are high, while those who are carbon intensive tend to suffer under similar market conditions.

It was expected that Phase II of the EU-ETS brought about more normal market mechanisms, but unfortunately, this phase coincided with the 2008 Global Financial Crisis. During this time, the price of carbon fluctuated drastically, so Tian et al. introduced a secondary model that separated returns into carbon and non-carbon intensive companies. The researchers then used an interaction term which captured returns that occurred during the period of the market shock and the returns that occurred outside of the market shock. When the impact of the market shock was controlled for, it was found that the relationship between the returns of electricity and EUA prices was determined by the carbon intensity of the specific companies (Tian, Akimov, Roca, & Wong, 2016). This was furthered by Brouwers et al. when studying the

initial financial impact of verification within the EU-ETS. Participation within the trading scheme adds a new level of volatility for company cash flows and it was determined that this volatility did affect the market value of firms when the price of carbon was high (Brouwers, Schoubbena, Van Hulleb, & Van Uytbergena, 2016). When the allocation of allowances and cap of the trading scheme are misaligned, difficulties arise in determining if there is a relationship directly between firm value and participation within the EU-ETS. The carbon intensity of a company dictated whether a firm's market value was affected by participation within the scheme during periods of market inefficiency (Brouwers, Schoubbena, Van Hulleb, & Van Uytbergena, 2016).

The implementation of Phase III partially eliminated the variability in returns because participating companies needed to acquire their permits via a bidding process. This helps to establish a price of carbon set by demand, and not solely by supply. The efficiency of the EU-ETS market was first studied by Jaethn and Letmathe after the price of allowances soared to nearly thirty euros and then crashed to less than one euro during the first half of 2005. It was proposed that if companies acted rationally, then such fluctuations within the price could occur (Jaehn & Letmathe, 2010). The reason for the paradox in price trading during the beginning phases of the EU-ETS was due to information asymmetry, market power, and a profitable arbitrage opportunity between sellers and buyers (Jaehn & Letmathe, 2010). The introduction of a formal trading scheme during Phase III brought some of these much-needed market mechanisms to establish efficiency within trading. Trading within Phase I and Phase II was mainly explained by the adaptive market hypothesis (AMH) which implies that market participants act rationally, but can overreact during increased periods of volatility (Ghazani & Ali Jafari, 2021). The implementation of an EU-wide allowance cap, bidding process to acquire

allowances, decrease in the number of free allowances allocated, and the creation of a transparent registry system (The European Union Registry) all contributed to bringing market stability to European Union Allowance (EUA) prices (Tian, Akimov, Roca, & Wong, 2016). Other economic hardships did occur during this time period, which will have to be accounted for during econometric analysis. During this trading period, the European Union saw many economies falter, Great Britain declared it was exiting the EU, the pandemic hit, and eight years full of extremely volatile energy prices (Ghazani & Ali Jafari, 2021).

The stabilization of EUA prices during Phase III of the EU-ETS is paramount for a multitude of reasons. Not only does it create a mature market where the price of carbon is correctly determined by market mechanisms, but it also allows for research between the price of carbon and commodities. The price of oil is directly related to the price of a carbon allowance since oil is a major source of carbon emissions for many companies. It was found that futures prices between WTI crude oil and EUA prices are correlated with each other if both price increases and price decreases (Ma, Yan, Wu, & Li, 2021).

The European Union is unique since it has the most well-known and established market for trading carbon allowances. It is noteworthy that China also has a carbon trading market that was launched in 2013 within seven provinces. This trading scheme is named the CET and it began to specifically target the power industry in 2017 (Chen, et al., 2022). Chen et al. confirmed that while the CET statistically impacted the size of carbon emissions, the overall structure of the market failed to produce any financial results for companies that were engaging in the CET (Chen, et al., 2022). The focus of this study was solely narrowed down to the companies within the seven provinces, leaving room for a multitude of statistical inputs to the research process. To refine this research, Tang, et al. conducted a statistical analysis on how the Emissions Trading

Scheme (ETS) in China affected the market cap of Chinese Stock "A" markets. They evaluated the influence of carbon emission trading (CET) on overall market cap. The analysis concluded that carbon emission trading promotes companies' market value significantly (Tang, Cheng, Guo, Ma, & Hu, 2022).

The significance of participation in carbon trading schemes on firm behavior is relatively unknown. Within the EU, it was found that participation in the emissions trading scheme for the company Lufthansa did result in statistically significant changes to the company's approach of environmental monitoring and financial risk management (Vespermann & Wittmer, 2011). The scale of impact varies based on the growth of the permits issued for a certain activity and the price of allowances (Vespermann & Wittmer, 2011). Within the U.S., the behavior of companies participating in California's cap-and-trade system was also altered. It was found that companies that are financially strained move their production to states outside of the regulation of California (Bartram, Hou, & Kim, 2022). For firms that are unconstrained in their resources, it was found that no significant changes occurred in carbon emissions (Bartram, Hou, & Kim, 2022).

Due to the limited scope of research within this field, there are a host of hypotheses about the future success of the EU-ETS relative to financial performance. Research that has been conducted in China is applicable for methodological reasoning but is hard to apply to Europe due to the varying market structures of emissions trading. The research conducted within the scope of Europe has largely focused on Phase I and Phase II of the EU-ETS, which limits the scope of applicability. This is due to the fact that in the first two phases, market participants were able to participate with relatively little to no costs; that is, they either received allowances for free or mostly free. Veith and Oberndorfer both acknowledge that as the market matures, it is expected that the price of carbon has the anticipated effect by policy makers on stock prices. Another

limitation of these studies is that they focus singularly on the electricity sector and not on the entire European market participating in the trading scheme. Due to the infantile nature of the market, it is almost impossible to take a holistic approach to econometric analysis. Cap-and-trade markets are unique in the fact that all participants need to be buying and selling across market sectors based on their marginal costs. Segmenting the market and analyzing just one sector eliminates the possibility of understanding how price changes in carbon affect the financial performance of all companies.

Knowledge Gaps

Knowledge Gaps are areas of research where there is either a lack of available data or the field is relatively under-studied. While gaps present opportunities for new research, the scope of research that can be conducted is often limited due to either the lack of available information or the timing with which an event occurred. These knowledge gaps are difficult to navigate as it either produces a lack of literature to reference, or literature is not published as it may contain no significant findings. In time, knowledge gaps are often closed as academia begin to understand why such gaps exist and can obtain data relevant to the field (National University, 2023).

In the case of the European Union's Emissions Trading Scheme, a significant knowledge gap exists due to both available information and the novelty of the carbon allowance market. The lack of available information is largely due to the European Commission's lack of transparency regarding the distribution of allowances and how firms participate in the auction process. Another hurdle that makes data collection difficult is the lack of disclosure for which firms must participate in the EU-ETS and which can be privately regulated. As with other financial analysis, the timing of research is very important as it allows market mechanisms and trading periods to

conclude to the point where the market returns to equilibrium. In the case of the EU-ETS, the fourth trading period will not conclude until 2040, so the market has not established equilibrium, which makes statistical analysis difficult. The overall lack of information and the timing of the market has led to a gap in literature to reference for data collection and methodology construction. The study conducted attempts to close the knowledge gap that exists by analyzing the verified emissions of firms during the third trading period. This study is important as it contributes to introductory research that analyzes how firms change their carbon emissions when they are forced to internalize the negative effects of carbon.

Chapter 3

Hypothesis

Following the assessment of previous studies mentioned in the last chapter, it is expected that there is a negative relationship between the price of a European Union carbon allowance and the quantity of carbon allowances surrendered by firms throughout the third trading period. This relationship is presumed to exist because as the price of a carbon allowance increases, companies will have to either increase abatement technology or change the source of energy generation to either decrease or hold costs steady.

Additionally, it is expected that there is a negative relationship between the price of oil and the price of a carbon allowance. Following this intellection, it is expected that there is a negative relationship between the price of natural gas and the price of a carbon allowance. The intuition behind this is that when the price of energy inputs is low, companies will be incentivized to increase their emissions to decrease overall costs. To offset this increase in carbon emissions, the price of a carbon allowance will increase. The inverse is also expected to hold true.

Chapter 4

Methodology of the Study and Findings

Methodology Overview

This study relies upon data that was obtained from the European Union Registry and financial software in order to analyze the relationship between the price of a carbon allowance and the units of allowances surrendered. Brent Oil and Dutch TTF Natural Gas Futures are referenced with data derived from FactSet. The price of the European Union carbon allowance (FEUA-FDS) has been additionally derived from FactSet. The correlations for each company and commodity were determined on a security-specific basis. Ultimately, the relationship found between the companies and commodities relative to the price of the EU carbon allowance attempts to signify the importance of the carbon allowance in capital budgeting decision making.

Sourcing Constituents

The following companies that were included in the analysis were chosen based on the following factors: operating permits for the combustion of fuel and a compliance code of level "A". The combustion of fuel represents the largest permit type for emitters of carbon within the EU, accounting for 6,007 of the 13,178 approved permits. This was the largest pool of data to draw from and also represented a sector of permits which had a sufficiently large number of companies to draw from for an analysis. Other industries featured paltry amounts of data, with the permits covering the steel and aircraft industries each possessing less than thirty constituents.

For the compliance code, the ranking of "A" was chosen so that sufficient data is available to analyze the correlation between price of the EU carbon allowances and the quantity of allowances surrendered. For companies with a compliance code below "A", the quantity of units surrendered does not correctly match with the level of verified emissions. Inclusion of these companies in the dataset would draw incorrect correlations. The list of companies included in this study are found in Appendix A.

Initial Data Collection

To compile the list of companies, the list of current operators in the EU-ETS provided by the European Union Registry is used. Within the downloadable Microsoft Excel document, data was sorted by "Activity Type". Only companies operating under the permits of the combustion of fuels were selected. The thirty-one companies chosen represent a diverse set of countries operating within the EU-ETS.

To obtain the data for each company, each company's permit ID was entered into the European Union's Transaction Log. Once finding the Operator Holding Account Information, the Compliance Information for each company was transferred into a Microsoft Excel worksheet. Data from the years 2005-2012 and 2021 were omitted as the focal point of the study was the third trading period of the EU-ETS, which occurred from 2013-2020. Additionally, the data for Allowances in Allocation, Cumulative Surrendered Units, and Cumulative Verified Emissions were omitted as they were not pertinent to the content of the study.

For the data pertaining to Brent Oil, Dutch TTF Natural Gas Futures, and the EU Carbon Allowance, FactSet was used to pull the data into an Excel Worksheet. All data pulled from FactSet is reported on a calendarized, annualized basis and is presented in Euros.

After the collection of data for the relevant securities and years, correlation analysis was conducted. Specifically, for each company, the correlation was found between verified emissions and the price of the EU carbon allowance across the eight years within the third trading period. For the two commodities, the median yearly price was used to find the correlation against the EU carbon allowance. Excel's correlation function was used to find each security's correlation.

Methodology Limitations

There are several limitations to note in regard to the chosen methodology. The European Union is very vague in its disclosure of which companies have to participate in the ETS and which do not, which leads to self-selection bias. The selection of companies solely operating under a permit for the combustion of fuels also limits the study since there are external pressures, such as environmental and political influences, that influence the decision making of companies in regards to its level of verified emissions. Additionally, the examination of only firms that have a compliance rating of "A" limits the applicability of the results.

Separately, even though the third trading period was analyzed, companies within the selected data set possess allowances that were either allocated to them during the trading period or have allowances they have banked from previous years. Allocated and banked allowances may affect a company's decision making for curbing emissions since a firm may hold extra allowances to cover future emissions.

Results Overview

The summarized results include the correlation analysis for each individual security. The correlations for Brent Oil and Dutch TTF Natural Gas Futures are noted separately from the thirty-one securities that were analyzed. In the Constituent Analysis, the companies that were most and least correlated with the price of the EU-ETS are noted. Additionally, figures for the count of companies with negative relationships to the price of the EU-ETS are presented.

Brent Oil Returns Analysis

The returns of Brent Oil over the third trading period show a negative relationship relative to the price of the EU-ETS Carbon Allowance. The correlation coefficient as shown below is -.37. This correlation shows that as the price of a carbon allowance increased throughout the trading period, the price of Brent Oil decreased. The returns of the two securities traded in opposite directions.

Figure 1: Correlation Coefficient of Brent Oil Returns and the EU-ETS Carbon Allowance

Brent Oil Correlation Coefficient	-0.3724

Dutch TTF Natural Gas Futures Analysis

The returns of the Dutch TTF Natural Gas Futures during the third trading period show a positive relationship relative to the price of the EU-ETS Carbon Allowance. The Correlation Coefficient as shown below is .74. This correlation shows that as the price of a carbon allowance

increased throughout the trading period, the price of Dutch TTF Natural Gas Futures also increased. The returns of the two securities traded in the same direction.

Figure 2: Correlation Coefficient of Dutch TTF Natural Gas Futures and the EU-ETS Carbon Allowance

Dutch TTF Natural Gas Futures Correlation Coefficient	0.7392

Constituent Analysis

The quantity of carbon allowances surrendered by the set of thirty-one companies during the third trading period shows a negative relationship relative to the price of the EU-ETS Carbon Allowance. The median correlation coefficient across the thirty-one companies as shown below is -.54. The highest correlation found amongst the data set is attributed to EniPower S.p.A., an Italian producer of electricity and steam. Its correlation coefficient is .74. The lowest correlation coefficient found amongst the data set is attributed to GlaxoSmithKline. Its correlation coefficient is -.99. Of the thirty-one companies analyzed, twenty-two of them have a negative relationship of carbon allowances surrendered relative to the price of the EU-ETS Carbon Allowance. The full data for each company and its related correlation coefficient can be found in Appendix B.

Chapter 5

Analysis and Application of the Study

Hypothesis Evaluation

We cannot reject the initial hypothesis that the set of company data had a negative correlation with the price of the EU-ETS. It was found that the company quantity of carbon allowances surrendered has a negative relationship relative to the price of the EU-ETS. Within the data set, nine companies were found to have positive relationships with the price of the EU-ETS Carbon Allowance, while twenty-two companies were found to have a negative relationship relative to the price of the EU-ETS Carbon Allowance. The findings of the test indicate that on an aggregate level, a negative relationship exists between the price of a carbon allowance and the quantity of carbon allowances surrendered.

For Brent Oil Returns, we cannot reject the initial hypothesis. It was found that Brent Oil Returns and the price of the EU-ETS Carbon Allowance has a negative relationship. The hypothesis in regards to the returns of the Dutch TTF Natural Gas Futures is rejected. It was found that natural gas futures have a positive relationship relative to the price of the EU-ETS Carbon Allowance. The returns of these commodities are highly impacted by outside influences, which may describe why the natural gas futures have a correlation that is substantially different from what was hypothesized. Specifically, the onset of the Covid Pandemic in 2020 significantly altered the price of these commodities.

Application of the Results

Analyzing the conclusions of the study, firms may experience changes in verified emissions as a result of participation within the EU-ETS. There is no definitive evidence suggesting that the price of carbon allowances dictate firm behavior, but it may be a key point in future decisions regarding power generation. Outside of influencing firm emissions, this behavior is applicable for analyzing the stock returns of the companies that participate. Investors should understand that participation in the EU-ETS does affect capital budgeting, and therefore firm performance.

Extension of the Study

The results of this study are relatively limited in scope. However, expanding upon the trading periods, permit for type of activity, and compliance code may enhance the applicability of the results. Additionally, the inclusion of more firms in the study will allow for a more holistic analysis of firm behavior relative to the price of the EU-ETS.

Due to the relatively immature nature of the carbon market, the extension of statistical analysis is ambitious. The workings of the trading scheme are still relatively under researched and this makes the application of statistical analysis limited. With the available information, a possible extension of this study would analyze how firms manage carbon allowances accounting for distributed allowances in the beginning of the year, input costs such as oil and gas, and other dummy variables such as societal or political pressures to reduce carbon emissions.

The fourth trading period of the EU-ETS will likely be the most researched trading period due to the elimination of allocated allowances in the beginning of years to participating companies. This trading period, however, will be difficult to analyze due to its ending date in 2040. After the end date, the EU-ETS is expected to be a fully functioning market with no controls in which companies freely trade allowances. Only when this occurs can firm behavior truly be studied and understood.

Another possible extension of this study is based on the EU-ETS's impact on the reduction of overall carbon emissions in Europe. From this study, it is seen that firm behavior is impacted based on the price of carbon allowances, but carbon allowances may not be the only thing impacting firm behavior. Other inputs such as regulation and the availability of renewable resources can change the demand for carbon intensive energy sources.

Alternative Data Collection

There are several alternative methods of data collection that could be examined. However, due to the limited availability and transparency of data, these methods may not be analyzed until the fourth trading period of the EU-ETS is complete. Below are several methods of data collection that could extend the results of this study.

The first limitation to this study is the inclusion of only thirty-one companies that operate with permits for the combustion of fuel. A data set that includes a larger set of companies or more industries could analyze firm behavior across a wider range of participating companies. This could lead to results that analyze how firms in different industries change their emissions based on participation. Additionally, the firms in this study fall into the highest compliance code

and therefore have never had to pay fines associated with not surrendering enough units. Including companies that do not fall into the highest compliance code could reveal correlations between the price of the EU-ETS and verified emissions.

Another possible route for data collection could be analyzing companies in the United Kingdom that only operated in the EU-ETS during the first trading period from 2005-2007. In this period, allowances were freely allocated so firms had almost no incentive to change behavior. After the first trading period was completed, the United Kingdom announced that it would initiate its own emissions trading scheme with a cap-and-trade system that pulled some companies, including multinational oil and gas company Shell, out of participation in the European Union's cap-and-trade system. This dynamic shift altered the distribution of market power and emissions regulated under the EU-ETS. Analyzing the emissions of companies that left the EU-ETS and shifted to the United Kingdom's cap-and-trade system could reveal correlations about how much the market mechanisms influenced firm behavior.

Alternative Quantitative Analysis

In addition to selecting different data to be included in the study, there are several other methods of quantitative analysis that could be conducted. Similar to the collection of data, the quantitative analysis of the data may be difficult due to the knowledge gaps that exist in the data and literature. As stated above, proper quantitative analysis might not be able to be conducted until a later point in the future when the fourth trading period of the EU-ETS has finished and the market operates without direct regulatory oversight.

One of the main limitations of this study is that it purely looks at the correlations that exist between company verified emissions and the price of European Union carbon allowances. This datum alone does not reveal anything about how the price of carbon allowances influences firm behavior. In order to understand the way that the price of the carbon allowance affects firm behavior, regression analysis can be used.

The allocation and auction process used in the four trading periods should be included as an independent variable in the study. In each of the four trading periods, the allocation process varied and henceforth affected firm behavior in different ways. During the first trading period, allocations were freely given to companies, meaning that there was no additional cost to emit carbon for the units they were given. During the second and third trading periods, some allowances were freely allocated and the rest were sold in an auction process. During the fourth trading period, all allowances were obtained via an auction process (European Commission, 2022). This data can be seen in the figure below, which shows the holding account information for EniPower, an Italian electricity company.

Figure 3: Holding Account Information for EniPower

EU Compliance Information							
EU ETS Phase	Year	Allowances in Allocation	Verified Emissions	Units Surrendered	Cumulative Surrendered Units**	Cumulative Verified Emissions***	Compliance Code
2005-2007	2005	953414	1442113		0	1442113	B*
2005-2007	2006	953414	2258693	3700806	3700806	3700806	A
2005-2007	2007	953414	2663202	2663202	6364008	6364008	A
2008-2012	2008	2623369	2301706	2301706	2301706	2301706	A
2008-2012	2009	2623369	2258955	2258955	4560661	4560661	A
2008-2012	2010	2623369	2696434	2696434	7257095	7257095	A
2008-2012	2011	2623369	2344830	2344830	9601925	9601925	A
2008-2012	2012	2623369	2313090	2313090	11915015	11915015	A
2013-2020	2013	36969	2135679	2135679	2135679	2135679	A
2013-2020	2014	33086	1982785	1982785	4118464	4118464	A
2013-2020	2015	29313	2091170	2091170	6209634	6209634	A
2013-2020	2016	25659	2371378	2371378	8581012	8581012	A
2013-2020	2017	22119	2426577	2426577	11007589	11007589	A
2013-2020	2018	18695	2432711	2432711	13440300	13440300	A
2013-2020	2019	15382	2552877	2552877	15993177	15993177	A
2013-2020	2020	19	2587649	2587649	18580826	18580826	A
2021-2030	2021		2622785	2622785	2622785	2622785	A

This data point will have a strong statistical impact on the verified emissions that a company has. Unfortunately, the European Union does not openly publish data on how allowances were freely allocated to companies, so a knowledge gap may continue to persist with this data point.

Other variables that should be included in future regression analysis are the prices of input variables such as the prices of energy. Oil, natural gas, and coal prices largely influence the power generation mix that companies use, and as these prices fluctuate, so will the emissions related to each power source. The volatility of energy prices makes this data point hard to analyze, as seen in periods such as the Great Recession and the Covid-19 Pandemic where prices fluctuated to extreme values. Along with the impact from nonrenewable energy sources, the European Union has made pledges related to carbon emissions under the Kyoto Protocol as mentioned in above literature. This pledge has led to both regulatory and societal pressures to transition to renewable energy sources such as wind, solar, and geothermal. This outside pressure also significantly impacts the power generation mix of companies and should be included in future regression analysis.

One other factor to consider for additional quantitative analysis is the time lag that occurs with capital intensive projects such changing power generation mix. Reducing emissions by switching energy sources requires years of investment and often will result in dramatic changes in emissions in the first years that a renewable source of energy is used. For this reason, there may be companies that experience significant shifts in emissions that are not related to the price changes of carbon allowances. This additional data may have to be studied on a company specific level.

Chapter 6

Conclusion

Emissions trading schemes are complex regulatory mandates that affect firms both environmentally and financially. Research in this field is relatively new and the depth of impact is not yet well understood. In this study, the behavior of firms participating in the European Union's Emissions Trading Scheme was analyzed by observing how firm emissions changed based on the price of a carbon allowance. This study followed thirty-one firms during the third trading period that operate with permits for the combustion of fuel.

Ultimately, the results of this study found that firm emissions have a negative relationship to the price of the EU's carbon allowance. It is noted, however, that of the thirty-one companies studied, nine companies had positive correlations to the price of the carbon allowance. Moreover, Brent Oil returns were found to have a negative relationship to the EU-ETS, while Dutch TTF Natural Gas Futures were found to have a positive relationship. These correlations are strictly observations about firm behavior and do not conclude that the changing price of the EU's carbon allowance is the single variable influencing emissions. Further analysis on emissions trading schemes should attempt to incorporate data regarding the allocation of allowances, costs of energy inputs, and outside regulation to shift to renewable energy. The dynamic and complex markets created for carbon regulation will continue to increase in popularity and transparency, and this will merit future research to close the knowledge gap related to the financial impact of firms.

Appendix A

List of Companies Analyzed in the Study

Sucros Oy
Valero
Phillips 66
Repsol Energy
GSK
T-Power
Liberty Ostrava
United Energy
August Storck KG
Uniper Kraftwerke GmbH
Iberdrola Generacion
Essar Oil UK Ltd
Exxon Mobil
INEOS FPS Limited
Equinor
Neste
BP
CNOOC Petroleum Europe Limited
Naturgy
Heineken Espana
Covestro, S.L.
ENGIE ENERGIE
NSO ENERGIE
ORANO RECYCLAGE
DIJON ENERGIES
FICOBEL
Elm Operations
Elengy
Kecskemeti Termostar
Synergen Power Limited
EniPower S.p.A.

List of thirty-one companies analyzed in the study which contain permits for the combustion of fuels in the European Union Emissions Trading Scheme

Appendix B

Correlation Coefficients of Individual Securities

Sucros Oy	-0.2959
Valero	-0.8734
Phillips 66	-0.8734
Repsol Energy	-0.6392
GSK	-0.986
T-Power	0.48764
Liberty Ostrava	-0.6587
United Energy	-0.7307
August Storck KG	0.66265
Uniper Kraftwerke GmbH	-0.8497
Iberdrola Generacion	0.19348
Essar Oil UK Ltd	-0.8657
Exxon Mobil	0.01514
INEOS FPS Limited	-0.1693
Equinor	0.11201
Neste	-0.6494
BP	-0.8449
CNOOC Petroleum Europe Limited	-0.7451
Naturgy	-0.5422
Heineken Espana	-0.7651
Covestro, S.L.	0.54727
ENGIE ENERGIE	-0.6219
NSO ENERGIE	-0.434
ORANO RECYCLAGE	-0.8764
DIJON ENERGIES	-0.4848
FICOBEL	-0.2979
Elm Operations	0.28312
Elengy	0.34219
Kecskemeti Termostar	-0.4109
Synergen Power Limited	-0.7928
EniPower S.p.A.	0.74459

List of thirty-one companies and their corresponding correlation value between the quantity of carbon allowances surrendered and the price of the European Union EUA

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EDUCATION

The Pennsylvania State University | Schreyer Honors College — **University Park, Pennsylvania**
Smeal College of Business — *Graduation: May 2023*
B.S. in Finance, Minor in Economics

Relevant Experience

Modera Wealth Management, LLC — **Wayne, Pennsylvania**
Intern — *June 2022-Present*

- Produce Wealth Plan Update presentations for high net worth and ultra-high net worth clients
- Record client data and develop retirement plan projections in eMoney Advisor software

Nittany Lion Fund, LLC — **University Park, Pennsylvania**
Fund Manager, Utilities Sector — *April 2021-June 2022*

- Manage a student-run fund of ~$14.00 MM striving to outperform the S&P 500 through fundamental analysis
- Oversee private investor capital in the Utilities Sector through superior stock selection using discounted cash flow models, research reports, comparable analysis, and macroeconomic trends within the industry

Penn State Investment Association — **University Park, Pennsylvania**
Analyst, Consumer Staples Sector — *Fall 2020-Spring 2021*

- Engage in informational presentations conducted by Nittany Lion Fund members to learn about market and stock analysis, interviewing techniques, accounting methods, ratio comparison, and valuation techniques
- Compete in stock pitch competition in which a discounted cash flow analysis with investment drivers for a one-year outlook was created for FedEx Corporation as a potential buy for the Nittany Lion Fund

Penn State Club Triathlon — **University Park, Pennsylvania**
Club member — *Spring 2020-Present*

- Compete in Olympic distance triathlons during school year against other northeastern university clubs
- Follow a weekly training plan composed of swimming, cycling, and running workouts to prepare for races

DiscipleMakers Christian Fellowship — **University Park, Pennsylvania**
Small Group Co-Leader, Marketing Team — *Spring 2020-Present*

- Engage in fellowship with Christ followers to create community and outreach opportunities to campus
- Organize, prepare, and plan for West housing women's small group in weekly meetings with staff members
- Design and publicize social media posts created to inform students of club engagement opportunities

OTHER WORK EXPERIENCE

The Pennsylvania State University — **University Park, Pennsylvania**
Economics Undergraduate Grader's Assistant — *Fall 2020-Fall 2021*

- Assist Professor Dr. Brown in grading approximately 120 students' weekly assignments in Econ 102

The Pennsylvania State University — **University Park, Pennsylvania**
Auxiliary and Business Services-Commons Desk Clerk — *Fall 2020-Spring 2022*

- Provide excellent customer service to students and guests who visit commons desks in housing areas
- Perform normal operations such as sorting mail and packages, distributing mailbox flyers, processing financial transactions, facilitating check-in and check-outs of residents, maintaining key security, and loaning equipment

Bear Creek Mountain Resort — **Macungie, Pennsylvania**
Outdoor Mountain Camp Summer Counselor — *Summer 2019, 2020*

- Supervise and lead outdoor activities for elementary aged children to explore their outdoor surroundings
- Conduct private lessons for Bear Creek guests in archery, axe-throwing, and ATV tours during camp hours
- Operationally create weekly plans during the pandemic for campers based on age, weather, and interests

SKILLS & INTERESTS

Honors: Sharbuagh Honors Scholarships, President's Freshman Award, Dean's List 5/5
Interests: Triathlon, hiking, travelling, football, gardening, history, foreign affairs, fly fishing
Skills: Level I Certification in Microsoft Excel, Word, and PowerPoint, BLS/CPR and First Aid Provider