



How does the fluctuation in oil prices impact the financial performance of alternative energy companies?

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My thesis investigates the impact of oil price volatility on the profitability of alternative energy companies. The dissertation focuses on two primary research questions: firstly, how does oil price volatility directly influence the profitability of alternative energy companies, and secondly, how does this relationship vary when controlling for firm-specific and macroeconomic variables. The empirical analysis employs a fixed effect regression approach with firm fixed effects, analyzing a global panel dataset of alternative energy companies between 2017 and 2022. The results reveal a positive and significant relationship between oil price volatility and alternative energy companies' Return on Assets ratios with a magnitude of 0,00209, 0,00218, and 0,00366, respectively, through 3 different scenarios. Overall, my models' coefficients are jointly different from zero, indicating relevant explanatory power based on F-statistics. In conclusion, the thesis contributes to the understanding of the alternative energy sector's financial performance in response to oil price movements by adding a tangible measure of financial performance to existing literature that primarily focuses on green stock performance.

Keywords: Green Finance, Oil Price Volatility, Alternative Energy Companies, Profitability, Fixed Effect Regression

Como é que a flutuação dos preços do petróleo impacta o desempenho financeiro das empresas de energia alternativa?

József Dancsó

Esta tese investiga o impacto da volatilidade do preço do petróleo na rentabilidade de empresas de energias alternativas. A dissertação foca-se em duas questões. A primeira é como a volatilidade do preço do petróleo influencia diretamente a rentabilidade das empresas de energia alternativa e, em segundo lugar, como varia esta relação quando controlamos para variáveis de empresas específicas e macroeconómicas. A análise empírica utiliza um modelo de regressão com efeitos fixos de empresa, analisando globalmente um painel de conjunto de dados de empresas de energia alternativa, entre 2017 e 2022. Os resultados revelam uma relação positiva e significativa entre a volatilidade do preço do petróleo e o rácio de rendimento de ativos de empresas de energia alternativa com uma magnitude de 0,00209; 0,00218; 0,00366, respetivamente em três cenários diferentes. Em geral, os coeficientes dos meus modelos são conjuntamente diferentes de zero, evidenciando poder explicativo baseado em estatística F. Em conclusão, esta tese contribui para a compreensão do desempenho financeiro do setor de energia alternativa em resposta às variações do preço do petróleo, ao adicionar uma avaliação tangível de desempenho financeiro a estudos existentes primeiramente focados em desempenho de títulos verdes.

Palavras-chave: Finanças verdes, Volatilidade do preço do petróleo, Empresas de energia alternativa, Rentabilidade, Regressão de Efeitos Fix

1. Introduction

As Bob Brown, a former environmentalist and politician from Australia, once said: "The future will either be green or not at all." This statement could be the main conclusion of many studies on environmental protection and climate change. Either you agree or disagree, but it is indisputable that the inhumane exploitation of the Earth's energy resources must have consequences. If, in the near future, the world's countries fail to transition their economic systems from dependence on fossil energy towards a greener, more alternative one, then it could quickly happen that we will not leave anything behind for our future generations. However, the situation is not so desperate. I am also among the optimistic ones.

If we want economic growth to be realized sustainably, fiscal and structural reforms that significantly reduce emissions will be essential (Németh-Durkó, 2020). According to a solid estimate by the OECD, to not exceed the 2 degrees Celsius average temperature increase defined in the Paris Climate Agreement, about 6.9 trillion dollars in green infrastructure investments would be necessary annually (World Energy Statistics, 2017).

Based on the data from the International Energy Outlook 2021, by 2050, the world's total energy consumption is expected to increase by nearly 50% compared to 2020. To be aligned with this estimate, both developed, and developing countries must increase the share of alternative energy sources in their economies because the energy supply from fossil energy sources alone will not be an option.

Oil production and consumption increased from 86.65 million barrels per day in 2008 to 98.11 million in 2017. In the same year (2017), global oil consumption exceeded its production rate (International Energy Outlook, 2021). According to Appenzeller (2004), production will peak between 2016 and 2040. Therefore, considering the limited supply of energy resources and the increasing demand, it becomes clear that the pessimistic predictions about fossil resources, especially crude oil, which holds a significant portion of the energy mix, are well-grounded.

It is reinforced by the fact that the alternative energy sector is expected to be the fastest-growing economic sector shortly, whose compound annual growth rate is estimated to be 17.2% between 2024 and 2030 (GVR, no date). This can undoubtedly outline a more optimistic scenario for the future since this growth rate would surpass the annual estimate for the growth rate of the world's total energy consumption, which is approximately 0.7% YoY (IEA, 2023)

(this is a slowed-down number due to global events like Covid-19, but it is high likely that it will rise again once this uncertain period passes).

It is evident, then, that the idea of "being green" also has great significance on financial markets. Simply because the financing side ultimately determines whether a sustainable future will be feasible. there is a growing trend among investors to incorporate social, environmental, and governance (ESG) factors into their investment strategies, ensuring that their portfolios reflect responsible and sustainable practices. (Reboredo and Ugolini, 2018). For instance, over \$2.6 trillion has already been invested in green initiatives between 2010 and 2019 (BloombergNEF, 2019).

Nowadays, responsible investors can think of their invested capital in a way that, besides achieving a relevant return, they also want to reduce the risk of climate change and environmental pollution. To achieve this, alternative energy companies can provide new ways to create a well-diversified portfolio that considers ecological aspects.

However, to properly manage the risks, such an investor needs to take into account the effects of oil price volatility, both in the short and long term. The reason is that oil price mechanisms can be integrated into the economic processes across sectors and influence the returns directly and indirectly. Therefore, asking how the oil and the alternative energy sector can be connected is essential.

Renewable energy sources are widely recognized as eco-friendly alternatives to oil and other fossil fuel resources. When there are considerable adverse fluctuations in crude oil, green investment incentives decrease (Dutta, Jana, and Das, 2020). Otherwise, incentives will likely increase when oil prices rise, potentially leading to higher stock prices and increased profitability for companies in the renewable sector (Bondia, Ghosh, and Kanjilal, 2016). Therefore, it is reasonable to anticipate that the oil price dynamics will be observed somehow in the performance of alternative energy companies. However, the exact nature and intensity of this relationship will be unclear.

Based on my previous statements, in this thesis, I will look for the answers to what extent oil prices can influence the alternative energy sector's profitability, examining a 5-year time horizon. I will look at this relationship more in-depth through 3 different scenarios, including variables from the broader market landscape. In general, I expect that this relationship will be positive. Although I do not know how robust, but positive, as both the oil market and the renewable sector are proven to respond similarly to the underlying shifts in global demand (Vrînceanu et al., 2020)

My thesis is structured as follows. In the second chapter, I will present oil prices as widely used indicators in macroeconomics. To demonstrate the unpredictable nature of the oil market, I will detail a range of economic and non-economic factors that can lead to price fluctuations and shocks.

Moving to the following section, I will examine oil price changes' direct and indirect effects on the country level. It is important to note that I will not distinguish between oil-exporting and importing countries. However, in the future, with the aim of a potential expansion, it is recommended to observe them in a broader context since the effects may differ depending on whether a country is an oil exporter or an oil importer.

In the next chapter, I will tighten the horizon by presenting the relationship between oil prices and financial markets. I will monitor the relationship between oil prices and stock market trends, complementing my thesis with insights from existing literature on the subject. In the second part, I will focus on the interrelations between the environment and financial systems, and by examining this in greater depth, I will explore the potential links between oil prices and the profitability of alternative energy companies.

Proceeding with the methodological overview, I will present the dataset and the variables in the first part of the chapter, along with an explanation behind their selection. In the rest, I will describe those empirical models, statistical tests, and robustness tests that need to be implemented to analyze the research questions coherently.

In the last section, I will summarize the empirical results, beginning with the descriptive statistical part and finishing with the regression results. In the end, I will outline the limitations of my analysis and briefly summarize my plans for expanding my dissertation.

2. Theoretical Discussion

2.1. Oil and the economy

Oil became the driving force of economies during the 20th century. To oversee this fact, Hamilton (2011) mentions several historical periods when the importance of oil globally reached different levels. Researchers have contributed distinct significance to oil for the last 30-40 years, but its substantial impact on world economic processes has remained indisputable.

Hamilton places the initial period of oil ("the awakenings of oil"), between 1859 and 1899. During this time, oil prices were very volatile and reacted sensitively to fluctuations in supply and demand. This was followed by the second historical period, lasting from 1900 to 1945. In this era, crude oil captured more and more share in the world's economies and began

to be integrated into various economic sectors. Nothing proves this better than the early regulations of oil extraction in the USA (the Texas Railroad Commission was established to carry out oil extractions more efficiently and maintain stable crude oil prices).

The following historical period was the post-World War II era from 1946 to 1972, characterized by solid automatization efforts. The demand for all petroleum-based products sharply increased, primarily because of the rising demand for weapons, and in general, the war required an enormous amount of energy.

The author places the last period of oil between 1973 and 1996. The "OPEC era", as explained by Hamilton, was characterized by turbulent historical events, such as the Yom Kippur War (1973), the Iranian Revolution (1979), and the Iraq-Iran War (1980). In managing or escalating the conflicts (decide as you wish), OPEC's role was unquestionable regarding external intervention (e.g., in 1980, OPEC doubled the price of oil on the world market, triggering severe financial crises in the case of industrialized countries).

Today, scientists argue whether crude oil can still be considered that significant influential factor, like in the previous decades. On the one hand, Basher and Sadorsky (2006) directly characterize oil as the heart of the modern economy whenever they mention the importance of oil prices. On the other hand, there are many arguments in favor of its decreasing influence. Due to the strengthening of climate and green economic initiatives, alternative energy is preferred in more and more economic sectors. Here, we can think of the rapidly growing demand for electric cars or the increasing decarbonization efforts, especially in the transportation sector.

However, the fact is that economies are still highly dependent on fossil energy resources, as the shift to renewable energy and the establishment of their infrastructural environment is increasingly costly (Inspire Energy, 2019). Thus, it is understandable that oil continues to exert its direct and indirect influence despite past tendencies. The uncertainty in its price affects households, corporate sectors, and the economic decision-making process. Consequently, investigating the key factors that cause oil price fluctuations is crucial.

2.2. What factors influence the oil prices?

The literature offers many studies that provide explanations for oil price movements. However, in this chapter, I would like to mention only the most relevant ones based on the literature consensus. Generally, two key effects can comprehensively explain a significant part of the price changes. The first can be traced to market mechanisms, i.e., the supply-demand relationship. The second one is caused by exogenous shocks that are not present due to the

nature of oil itself but arise from changes in the economic environment. I will categorize these into two parts and analyze them separately in the short and long term. (Kilian, 2008).

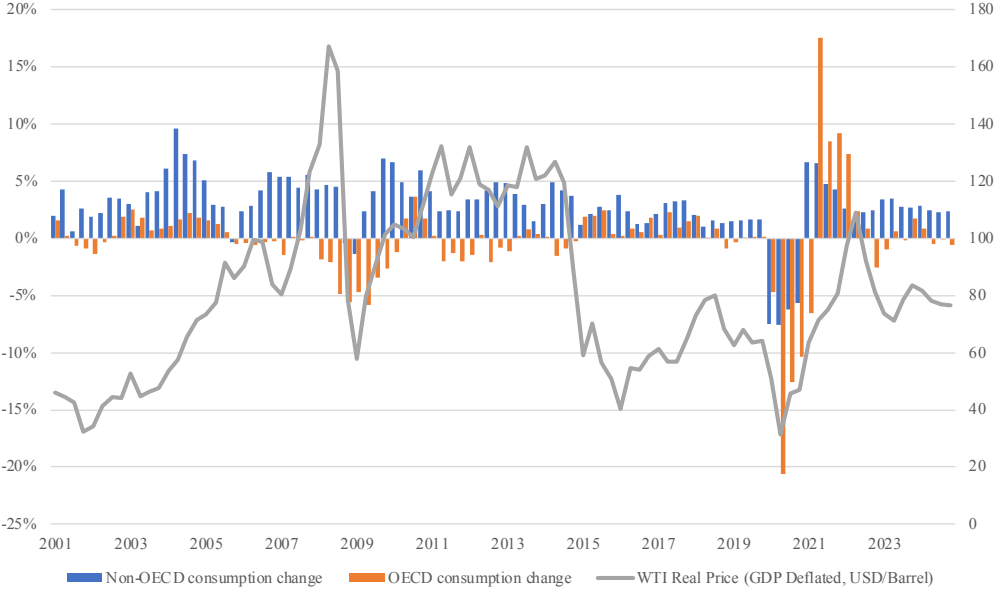


Figure 1: Crude oil consumption YoY% change in OECD and Non-OECD countries, Energy Information Administration, 2023, created by the author

The demand for oil prices is divided between the Organization for Economic Cooperation and Development (OECD) and non-OECD countries. From the '70s until the beginning of the 2000s, industrialized countries (e.g., the USA) gave the primary market of oil demand. However, this trend has reversed, especially in the last decades, and emerging economies have become the primary markets of oil (e.g., China and India). The trend can also be observed in Figure 1, highlighting the development and distribution of consumption among OECD and non-OECD countries.

In addition, it is worth investigating how fast demand can adapt to price shifts. Roubini and Setser (2004) demonstrated that the price elasticity of oil demand and its derivatives is relatively low, indicating that demand does not change due to price shifts. They also found that many reactions to supply-side shocks, often characterized by significant price surges, did not lead to a decrease in consumption on the demand side, at least not in the short term. Typically, the consumption of substitute products remained unaffected. For instance, despite notable price hikes, it was common to see dozens of people queuing with cans at gas stations in the early 70s in the USA.

The example illustrates that we can distinguish between primary and secondary demand when discussing oil demand. Primary demand is directly provided by oil industrial companies (e.g., BP, Royal Dutch Shell, Sinopec) operating as intermediaries within a country. Regarding

secondary demand, the plastic or pharmaceutical industries are excellent examples as they do not acquire oil for direct commercial purposes but utilize it as a by-product.

In contrast, oil demand is significantly more price elastic in the long run. Just think about how many internal or external events can entirely change the market of energy resources by observing a 10 - 15-year horizon (consumers have more time to react to price changes). Alternative substitutes can (and will) appear that would offer "green" solutions to meet the increasing long-term energy demand. Thereby making the consumption patterns of fossil energy resources go in a negative direction. In contrast, new markets can likely appear as well. For instance, the emergence of new economic regions focusing on cost-effectiveness can result in a shift back towards fossil energy production.

When examining the supply side of oil, it is primarily sourced from OPEC countries (15 members) and non-OPEC countries (13 members). Established in 1960 with the cooperation of 5 nations (Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela), the organization is responsible for nearly 30% of the current crude oil production (Barkindo, 2021). Among its members, Saudi Arabia has the largest share (12%) of world production, and overall, it is the second largest after the USA (20%). In the long run, OPEC's role in shaping the oil supply is enormous, we can even call it monopolistic. Their interest is to sustain high oil prices and control them as they please.

In the short term, oil supply can be characterized as the aggregate quantity of crude oil produced and stored in tanks at a given point in time. This can be considered permanent since there is no cap on the amount that can be stored (Uliha, 2017) (oil wells, silos, and tanks can be established as desired).

To sum up, the oil market also seeks equilibrium. Like most markets, it changes cyclically (Roubini and Setser, 2004). It means that when there is an economic upturn, demand grows faster than supply, so prices will likely rise. Whereas, in the case of a recession, prices usually fall sharply due to the decrease in demand, while the supply *ceteris paribus* (in most cases) does not change.

2.3. Other factors: exogen shocks

The literature also emphasizes several exogen shocks that can significantly impact oil prices. Any event that causes an unpredictable significant price drop in the spot price of oil can be defined as an exogenous shock. These are typically the results of persisting geopolitical conflicts, wars, terrorist attacks, or pandemics (such as Covid-19).

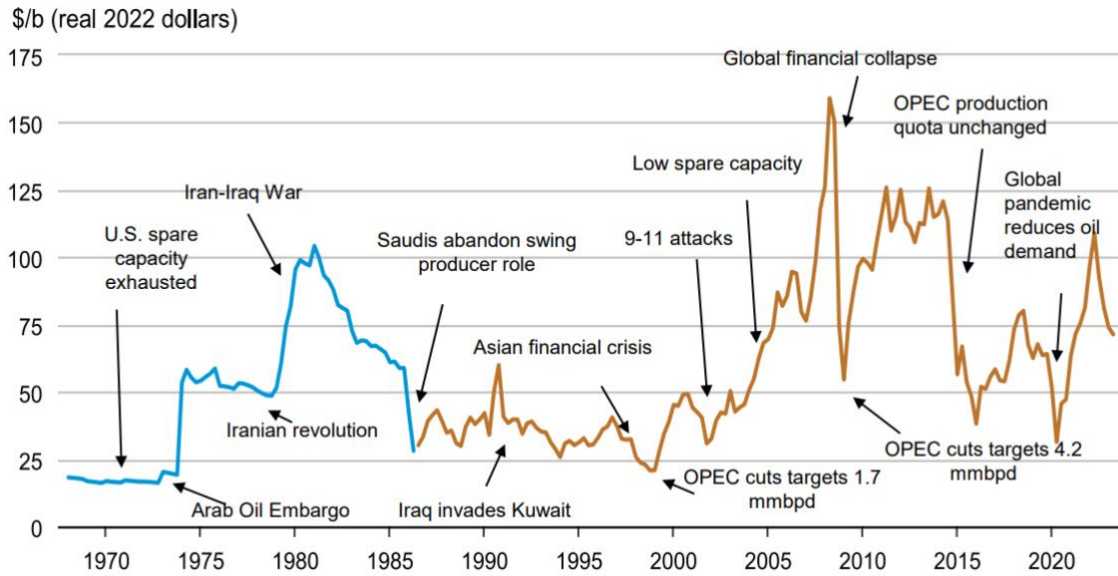


Figure 2: Oil price changes due to exogen shocks, EIA Energy Outlook, 2023

Figure 2 depicts a timeline of exogen oil price shocks over the past 50 years. As you can see, the first significant price shock is associated with the Arab Oil Embargo (the first oil crisis). Similarly, when the Iranian Revolution started, the trend was the same. Additionally, if we go further, it is remarkable how prices remained persistently low despite these two shocks and the Iraq-Iran war. This downward trend was cut by the first Gulf War (Iraq invaded Kuwait).

Looking at the early 2000s, we can conclude that it was a hectic period for oil prices. The severe price increases before 2008 and after the global financial crisis show extremely high-amplitude changes without critical geopolitical events. In contrast, the early 2010s demonstrate these events, such as crises in oil-producing countries (such as Libya) and the Syrian civil war (which appeared to have little impact on oil prices).

2.4. Oil price effects on the economic environment

In this chapter, I will briefly discuss the economic impacts of oil price changes. These effects can be classified into two main categories: direct and indirect effects (Kilian, 2014). Figure 3 shows an overview:

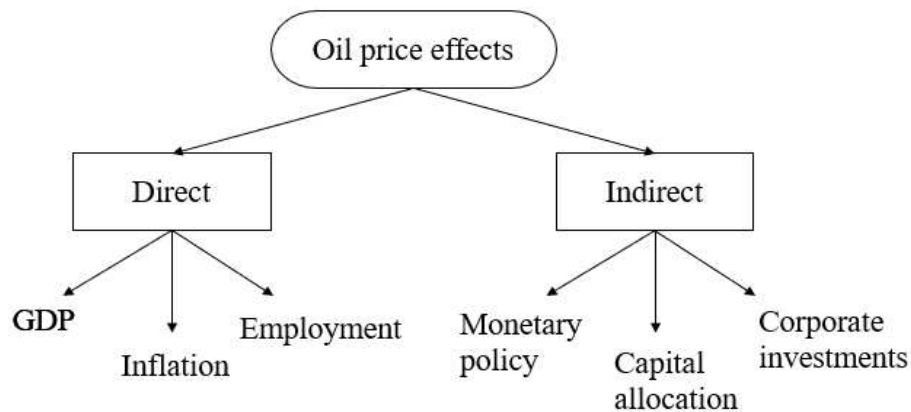


Figure 3: The effects of oil prices, created by the author

The continuous increase of energy prices has historically been proven to cause recession in economies (Finn, 2000). This statement is further confirmed by the study of Rotemberg and Woodford (1996), in which robust results were found when investigating the relationship between the energy sector and gross domestic product. They estimated that in the case of a 1% increase in oil prices in the USA, the American GDP fell by 0.25%, accompanied by a 0.09% decrease in real wages. The same effect can occur on the corporate side through increased input costs (Finn, 2000).

Additionally, Birol (2004) notes that high oil prices act as inflation-stimulating indicators, primarily due to increased production costs and the inflexibility of economic structures. We can divide this into primary and secondary inflationary effects.

The primary effect of inflation can be observed on the consumer side in the price changes of products. This effect is further enhanced indirectly (secondary impact) by companies passing on their financial deficit (increased production input costs) to their customers (Kotán, László, Sali, 2007). As a result, employees demand a higher salary level due to the elevated prices. However, if a company cannot fulfill these obligations, then the pressure on wages and the decrease in demand will lead to an increase in layoffs, at least in the short term.

However, considering the price level of the financial markets, the picture could be more explicit. Kilian and Park (2009) indicate that sectors with a high dependence on their final consumer base, such as retail and tourism, respond more sensitively to external changes in oil prices compared to sectors that rely heavily on fossil energy for production, like the chemical industry. This phenomenon can primarily be attributed to the low-price elasticity of energy demand.

Due to the limited explanatory power of direct effects, researchers have also found indirect effects. The reason is that, in most cases, rising oil prices did not cause the expected

magnitude of recession and inflation in the models. Additionally, they could not explain why an intense negative stagflation period was not followed by an economic upturn (Uliha, 2016).

Overall, the literature identifies three types of indirect effects: reallocation, uncertainty, and monetary policy effects. The reallocation effect can be understood by observing the movement of capital and labor, particularly in how these resources are reorganized in reaction to unforeseen fluctuations in the oil market (Lang and Auer, 2020). Such changes in the economic structure tend to shift the production patterns towards goods and services that can be produced with less energy, as the increased prices reduce the demand for goods that depend on oil. Therefore, if the expenditures for energy-intensive durable goods increase due to oil price shocks, producers are forced to reallocate capital and labor.

However, in many cases, human and physical capital cannot be used in other sectors, sometimes not even within the same sector, which leads to sunk costs (Uliha, 2017). Eventually, these market frictions significantly impact economic production and employment levels.

In contrast, reallocation effects occur even when oil prices are falling. This inverse phenomenon also leads to a structural transformation, entailing the economy with constantly rising extra costs. The redistribution mechanism amplifies the adverse direct effects of oil shocks while partially offsetting the positive direct movement in the event of a price drop.

A similar asymmetric phenomenon can be observed when the uncertainty effect occurs. Based on the real option theory (Bernanke B.S. 1983), high oil prices encourage companies to postpone their investments. For the public, unexpected oil prices manifest not only in an actual decrease in employment levels but also in creating constant fear of unemployment. As a result, households try to accumulate as much wealth as possible, which ultimately leads to a decrease in consumption. In this scenario, the demand for products related to the energy sector is one of many aspects that slow down. A similar market anomaly can also emerge in the case of durable, everyday consumer goods (Edelstein and Kilian, 2009).

Finally, how effectively and promptly monetary policy reacts to the oil price shock generates considerable indirect economic impacts (Kilian, 2014). The success of this largely depends on the behavior and expectations of market participants. In a country where financial participants are aware of the expansionary monetary objectives of the central bank, which tries to filter out the effects of oil shocks on demand and the level of employment, inevitably creates inflationary pressures. Thus, this behavior eventually encourages the central bank to raise interest rates (restrictive economic policy) to offset rising inflation. Therefore, inflation remains stable, but the economy slows down. If, on the other hand, consumers perceive the effects of

rising oil prices as a tax burden, then without any particular monetary political intervention, the core inflation, without the net increase of energy prices, will remain stable (Leduc and Sill, 2004).

2.5. Oil and the stock market

As we understood in the previous chapters, oil price fluctuations actively shape economic cycles. Now, to narrow the horizon of my thesis, let us look at the theoretical considerations of oil and the stock market. This connection can also be approached from the macroeconomic perspective.

As mentioned earlier, changes in oil prices affect a company's profit generation capacity. For instance, higher oil prices increase production costs on the supply side, negatively impacting companies' profitability, which in turn can have a secondary impact on stock performance. On the demand side, increased inflation due to the rise in oil volatility may hold back stock market investments (Bondia, Ghosh and Kanjilal, 2016). Therefore, it is understandable that oil price fluctuations have been considered influential factors in the capital markets even from the early 50s and 60s.

Numerous studies have examined the relationship between oil price fluctuations and stock returns. Still, more consensus has yet to be reached on how strongly oil's short-term and long-term effects appear on the capital markets (if we can talk about it at all). The different results were caused mainly by the examined time horizon. As we saw earlier in the paper of Hamilton (2011), oil has had different magnitude and significance over history.

Most of the early literature reports asymmetric and periodic effects. Chen, Roll, and Ross (1986) discovered an insignificant effect of oil betas on NYSE stock portfolios from 1953-1983. Kilian and Park (2009) found that the impact of shocks is reflected in fundamental economic processes and capital markets as well. By examining the relationship between US stock prices and oil market shocks between 1975 and 2006, they demonstrated that oil fluctuations explain 22% of the variance in the long-term returns of stock market securities. They also found that it does matter what kind of oil shock hits the economy. A supply shock did not significantly affect the returns, but yields could increase or decrease on the demand side.

Refining the work of Kilian and Park, Bastianin and Manera (2018) implemented a structural VAR model to examine the effects of monthly Brent oil prices on the US stock market from 1973 to 2003. They concluded that Kilian's research contains valid results, but the effects of oil volatility are delayed.

2.6. Oil and green trends

Understanding that oil prices affect almost every aspect of the global economy, it is time to focus on an increasingly important area: the alternative energy sector. In this part, I will summarize the actual trends and relationships between the oil price changes and the alternative energy sector.

During the 21st century, global energy demand significantly increased compared to the previous decade (IEA, 2023). Although, during the Covid-19 pandemic, the partial shutdown of the economies, according to the World Meteorological Organization, made the CO₂ global output decrease by 4–7% in the first half of the year (in other words, the Earth gained itself some time), but it did not solve the problem of global warming. The solution is not to reduce the world's energy demand but to prioritize other alternative energy sources over fossil ones. To this end, many countries have decided to become carbon neutral by 2050 (IEA, 2020).

This decision strengthened the transition initiatives towards a new, alternative energy production system in order to reduce emissions more effectively. However, to accomplish that, a critical factor is to secure the right amount of capital (Arrow et al., 2004). Lending or capital financing to the renewable energy sector is crucial in building an economy with such an advanced financial system (Németh-Durkó, 2020). In this way, green energy projects and technological innovations that reduce energy consumption (meeting efficiency criteria) and simultaneously increase the degree of transition from fossil energy resources to clean energy can receive a more comprehensive space (Berlinger and Lovas, 2015).

Environmental, social, and governance factors, collectively called ESG principles, are now inevitable in modern finance and financial decision-making (Dudás and Naffa, 2020). Today, every major bank has globally incorporated green loan and bond portfolios or engaged in socially responsible (ESG-based) asset management (Gyura, 2019). Therefore, it is no wonder that most listed companies are crucially trying to operate and align with these standards to maintain and improve their reputation.

Based on these considerations, it becomes evident why renewable energy stocks are gaining popularity in the stock market. These shares hold immense future potential, as evidenced by the increasing interest from investors. It is reflected in the exceptionally high price-to-earnings (P/E) ratios observed in companies like Tesla, sometimes reaching extreme values of 800-1000.

However, the relationship between oil price fluctuations and green stocks still needs to be clarified. There are several reasons why the impact of oil on the alternative energy sector will change over time and depend on market conditions.

For instance, Henriques and Sadorsky (2008) found a positive significant relationship (VAR approach) and even Granger causality between the two. However, they emphasized that a lot depends on the examined period, as structural regime changes can affect the relationship between oil prices and alternative energy prices from time to time. They also explain that this exists because, through technological development, alternative energy becomes relatively cheap, and oil prices become rather expensive, so substitution takes place in some areas. Consequently, it is not surprising that these dynamics have been extensively studied by various scholars, each arriving at slightly different conclusions (Kyritsis and Serletis, (2019); Broadstock et al. (2012); Managi and Okimoto (2013)).

Nevertheless, a noticeable gap would be interesting to look at. Namely, how does the relationship change if we observe these companies' profitability rather than directly focusing on their stock returns?

According to the Efficient Market Hypothesis (EMH) of Fama (1970), stock prices reflect all information available to investors. So, in this context, stock returns can be considered the primary driver of a company's profitability. Investors can perceive the change in the volatility of oil prices as a signal of potential higher returns from alternative energy investments. However, in a more realistic scenario, stock returns may not accurately reflect the underlying profitability, especially in sectors like alternative energy, where global economic trends (like oil price fluctuations), policy changes, or regime shifts can heavily influence investor sentiment. Therefore, their stock price may show something other than their actual economic health. That is why it is crucial to dig deeper in terms of direct profitability metrics and try to enlarge the picture of the interconnectedness between oil and green energy.

When further examining the relationship between the profitability of alternative energy companies and oil price volatility, it is worth realizing that the results will be nuanced and incomplete. An increase in oil prices does not automatically lead to a rise in demand for renewable energy resources, as their production often entails significant costs. (Kumar, Managi, and Matsuda, 2012). However, I still hypothesize that the relationship between oil price volatility and alternative energy profitability will be positive in the observed period, as rising oil prices encourage replacing conventional energy sources with alternative ones (Henriques and Sadorsky, 2008).

3. Methodology

In this section, I will provide an overview of the empirical framework that I used to answer my two research questions: *How does oil price volatility influence the profitability of alternative energy companies in a direct relation, and how does it vary through different scenarios when we are controlling for Macro and firm-specific variables.*

Firstly, I will outline my approach to data collection. Following this, I will provide overviews of each variable and justify their relevance to my research. I will then delve into the background of the data structure and engage in a discussion about the correlation coefficients. To address my research questions, I will describe the theoretical framework of fixed effect models and highlight the robustness tests that need to be conducted to ensure the reliability of the findings.

3.1. Data collection

When I determined the time horizon of my research, my main objective was to collect and incorporate observations that had no or minimal missing values through the experimental period. Due to the poor data availability in the early years of 2000, I selected a shorter research period from 2017 until the end of 2022.

After specifying the observable period, I downloaded the data from Refinitive Eikon and the WorldBank's database. I filtered out all the alternative energy companies from Datastream after only searching for "equities," neglecting categories such as "warrants". Following a necessary data cleaning (dropping those observations where I received missing values in each column), the final sample consisted of 1655 publicly traded individual alternative energy companies through different sub-sectors (i.e., solar, wind, biofuel). The sample is geographically widely exposed, including numerous companies from the USA, Asia and Europe.

3.2. Variables

The relationship between oil price volatility and the profitability metrics of renewable energy companies is complex. Hence, it is crucial to select variables that genuinely enhance the clarity of the connection.

3.2.1. Dependant variable

I chose the Return on Assets (ROA) ratio as the primary dependent variable. The ROA is an accounting-based performance measure that can effectively capture the firm's operational and financial performance, regardless of the company's financing structure (Brigham &

Ehrhardt 2013). This consideration is crucial for us to understand when analyzing green energy companies because these companies usually invest enormous amounts into assets (like wind turbines or solar panels). The company's financing decisions can influence other measures like Return on Equity (ROE), whereas the ROA mainly focuses on how effectively the company operates. Therefore, using this ratio will allow me to focus on the core operation of each company. In my thesis, it is calculated as the ratio of net income and total assets.

3.2.2. Independent variable

Overall, we can distinguish between two widely used oil prices according to different scopes of studies. These two main types are the Brent and WTI. Brent is a unique blend of crude oil from the North Sea, whereas WTI is stored in Cushing, Oklahoma (Sugár, 2012). Regarding their physical features, in terms of density and sulfur content, WTI has better values, making it a slightly higher-quality mixture. Consequently, it is reasonable to anticipate slight differences in the spot prices of these oil blends (most of these differences can be explained by the additional costs incurred during refining). In the following figure, you can observe the historical prices of the two benchmarks:

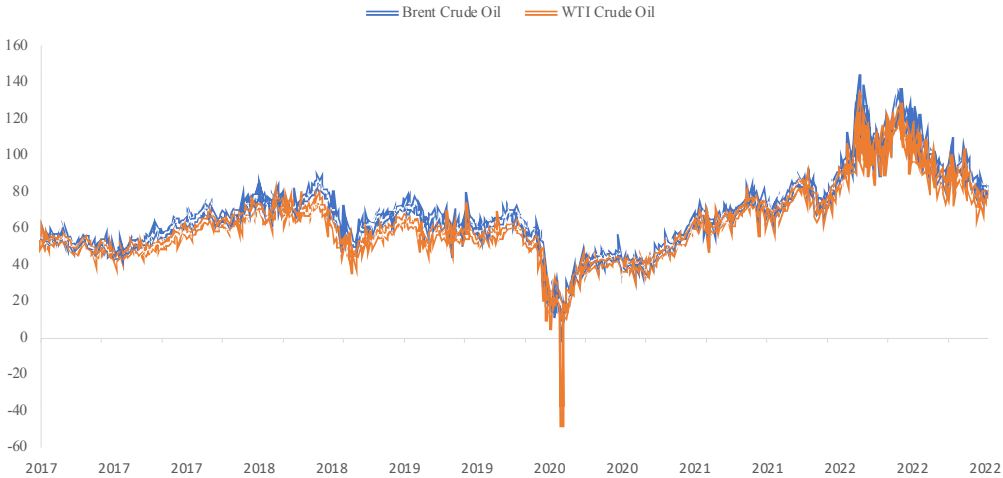


Figure 4: Spot prices of the benchmarks, created by the author based on Refinitiv Datastream

As evidenced by the data presented in the chart, around the early days of 2017, both benchmark prices followed almost the same trend. However, after 2018, regardless of the actual market conditions, Brent stayed slightly above the WTI. Even during the Covid crisis, Brent could secure its position despite the highly volatile market environment. WTI was hit significantly because the storing issues at Cushing raised serious concerns among WTI futures contract holders. Ultimately, it led to a rushed sell-off of WTI's future contracts (Bruegel, 2020).

Considering the broad geographical scope of my data, I selected Brent as the benchmark crude oil because of its global relevance in financial markets. However, instead of using the

average annual oil price as the primary independent variable, in line with many studies, (Cao, Guo and Zhang, 2020), incorporating oil price volatility is generally preferred due to its more complex nature. Oil price fluctuations can unpredictably impact the source of the input cost of oil, leading to a spillover effect that creates uncertainty around firm profitability, valuations, and investment decisions (Henriques and Sadorsky, 2011). In the literature, two commonly used methods exist for measuring oil price volatility. One is to compute the annual standard deviation of daily oil price returns, and the other is a GARCH (1,1) model proposed by Henriques and Sadorsky (2011). In my analysis, I will follow the first approach because of its straightforwardness; however, for more complex models, the second approach would be preferred in the future.

3.2.3. Control Variables

I will incorporate control variables to enhance the robustness of my analysis. Including these variables is based on the assumption that there might be factors correlating with the variable Y. In line with Wooldridge (2010), these variables are deliberately kept fixed, as they do not link to the hypotheses being tested. They help reduce potential omitted variable bias, and by incorporating them, we can “cut out” a piece of variation from the error term, which is generally unexplained by the model. So, to say, we implicitly reduce the error term. Based on these theoretical considerations, the chosen control variables are the following:

Market Value

Fama & French (1995) proved that firm size influences profitability through different financial models. In this study, I will use the market value of the companies as the indicator variable for firm size since all the companies are listed on different stock exchanges. Generally, larger firms tend to have better operational processes, thus a better availability to access financial markets, making them more resistant to oil price fluctuations (it is no different in the case of alternative energy companies; we can find dominant companies with extremely high values and the opposite as well). Using the natural logarithm of each firm's market value will help me work with more standardized and manageable data.

Capex-to-total assets

Capex itself represents the amount of capital that a company invests in tangible and intangible assets. Alternative energy companies require a high level of capital investment. This increased capital intensity is related to the reduction of direct costs (Choudhry et al., 2015), implying that these firms invest in improved and efficient technology today (which is, of course, more capital intensive). Therefore, they can reduce their energy production expenditures in the

long run. Dividing the CAPEX by the total book value of assets shows how aggressively a firm reinvests in its operation.

Current ratio

Brigham & Houston (2009) pointed out the importance of the current ratio as a fundamental proxy for a company's short-term financial health and ability to manage operational costs in fluctuating market conditions. Since the alternative energy market can be turbulent and the current ratios can vary extensively among companies, I will also include this ratio as a control in the empirical analysis (calculated as the ratio of current assets divided by current liabilities).

Asset Turnover

The relevance of including this ratio is given by Nissim & Penman (2001), who studied efficiency ratios such as asset turnover, and they provided valuable insights in capital-intensive industries and concluded that these drivers could be meaningful variables when determining the drivers of a firm's profitability. In my thesis, I computed the ratio of sales to total assets.

Debt-to-Equity ratio

Modigliani and Miller (1958) described that in an ideal world where bankruptcy costs, taxes, and asymmetric information do not exist, the value of firms is unaffected by their capital structure. However, these assumptions tend not to hold in real market conditions, making the debt-to-equity ratio relevant in empirical analysis. It is calculated as the ratio of total debt and shareholder's equity in my thesis.

Inflation rate

I must also take into account the damaging effects of (growing) inflation on purchasing power and real returns. As I mentioned, when an economy's inflation rate rises, it encourages its central bank to increase the interest rate. Regardless of the industry we are dealing with, the impact of inflation on the actual profitability of companies cannot be overlooked. Consequently, it is advisable to account for inflation in analyses of firms' profitability, even within a green market context. The proxy I used is the real inflation (measured as the Consumer Price Index) rates.

GDP growth rate

GDP growth rates give us an insight into the financial health of an economy so that we can state that this variable, just like inflation, cannot be a negligible factor from any financial performance analysis. In the case of alternative energy companies, significant economic growth can lead to greater investments in more advanced infrastructure, yet the picture is complex. In

align with this complexity, based on Barro's (1996) highlights, I also controlled for the GDP growth rate when analyzing renewable firms' profitability.

3.3. Data structure

The input data of the empirical analysis will be arranged in a panel structure. Panel databases have cross-sectional and time-series dimensions (long format) (Woolfridge, 2010). Consequently, it provides additional information compared to solely cross-sectional or time-series data series. It allows us to account for heterogeneity across variable groups and to introduce individual-specific effects.

Since a panel uses three parameters (groups, time series, and values of the variables), their structure must be the following: the value of the variables (both dependent and explanatory variables) in columns are displayed in such a way that they follow one after the other arranged in chronological order by group data. The database contains a group identifier as well as a time series identifier. However, when I initially retrieved data from Refinitive Eikon, the data was in a different format. To address this challenge, I had to set up various rules to organize the data in the correct systematic format. By using Microsoft Excel Power Query, considering the substantial size of our file, I managed to arrange the data accordingly.

The received structure can be identified as a balanced or unbalanced panel (Park, 2011). In a balanced panel, all entities have measurements in all periods. In contrast, when each entity has different numbers of observations, it is unbalanced (in our case, the data set is unbalanced). Fortunately, most software packages can handle both panel structures (Stata algorithms automatically account for this).

After obtaining the desired outlook, it is considered essential in most empirical studies to test if the data is stationary to avoid biased results later in the regression output.

Typically, most stock market time series are characterized by a stochastic relationship, i.e., there is no apparent connection between the time series; only some kind of tendency can be observed. However, in my case, I included annual firm-specific metrics, and, in this case, the data may be implicitly stationary, so it can happen that no further transformation will be necessary. However, later on, I will carry out a detailed implementation of the Advanced Dickey-Fuller test to determine if such modifications are necessary.

3.4. Overview of the correlation matrix

The correlation coefficient shows the extent to which two data sets are related. As a result, we always get a real number between -1 and 1. In the case of 1, we are talking about "perfect" linearity; if the result is -1, the relationship between the two parameters is inversely

proportional. The sign of the number indicates the direction of the relationship, and its absolute value outlines its strongness. In practice, the two extremes are unlikely to occur, so we usually say that the closer the number is to the limits of the interval, the stronger the relationship. Regarding the oil price volatility and the alternative energy sector profitability, I expect a negative relationship based on the two variables' substitutional nature (Sadorsky (2008)).

3.5. The course of empirical modelling

This section presents the selected empirical approach to understand the relationship between oil price volatility and alternative energy companies' performance. My chosen model is the fixed-effect model. It is advisable to employ programming software like R, Stata, or Python to perform such a regression. I created the empirical analysis using Stata software (version 17.0).

As mentioned, testing for stationarity in the panel data is crucial before making a more profound analysis. The model may give biased coefficients if this condition is unmet (Rappai, 2011). According to this, if a time series mean and standard deviation change constantly, in other words, it depends on time, then it is not stationary (Wadud, Graham, and Noland, 2009); otherwise, it is. The Augmented Dickey-Fuller Test is widely used in the literature to test this precondition. I will apply the unit root test as follows:

$$\Delta Y_t = a + \lambda Y_{t-1} \sum_{i=1}^p \theta_i \Delta Y_{t-i} + u_t \quad (1)$$

Where $\lambda = p - 1$, Y_t is variable in period t , $\Delta Y_{t-1} = \Delta Y_{t-1} - \Delta Y_{t-2}$, u_t is the white noise which is highly dependent on the past values of Y , p is the lag parameter.

For the ADF, I am checking the hypothesis $H_0: \lambda = 0$; in other words, I am testing the statement if the unit root exists in the data. If the null hypothesis is rejected, i.e., the empirical significance level (p-value) is less than 5%, we can say that the variables are stationary. Otherwise, there is a unit root, so the variables are non-stationary, suggesting data transformations.

3.5.1. Fixed effect model

After testing my panel data for unit roots, the next step is the data analysis. To clarify my choice of the fixed effect model for my thesis, I present the following logical thought:

If we were to consider the data solely in a cross-sectional manner, then the research questions could focus on comparing the profitability of companies more exposed to oil price volatility against those less exposed or not exposed at all. This approach would allow us to

understand how varying levels of exposure to oil price fluctuations impact alternative energy firms' profitability. At first glance, if a company is more exposed to the volatility of oil, we may conclude that oil will affect profitability more. However, it would not be appropriate to establish a causal relationship from this statement because several unobservable factors might correlate with a company's performance exposure to oil price volatility, resulting in potential endogeneity problems. Although we can try to control for as many parameters as possible (and we will do), but we can never be sure that we have controlled for all factors (László *et al.*, no date).

In regression analysis, one of the significant challenges is the endogeneity problem (Davidson & G. MacKinnon, 2004). A variable can be considered endogenous if it is determined within the model, similar to how the dependent variable is inherently stochastic. Contrarily, the predictor variables are assumed to be non-stochastic (fixed in nature). The problem occurs when one of the variables is correlated with the error term, leading to biased regression results unless the issue is resolved (Wooldridge, 2010)

In practice, many factors can lead to this problem, for instance, omitted variables or selection bias. In our case, omitted variables could be unobserved factors influencing both oil price volatility and the profitability of alternative energy companies. For example, global economic conditions, policy changes, or technological improvements can jointly affect oil price volatility and the performance of alternative energy companies. Suppose such variables are left out of the model. In that case, it can result in distorted coefficients, just like in the case of selection bias, which arises when the sample of alternative energy companies is not random or based on specific characteristics.

However, if we work with panel data, we can set up a fixed-effects regression model to avoid these potential issues (Wooldridge, 2010). With this model, we observe if the same alternative energy company has different profitability levels when oil price volatility is high compared to when it is low. By doing this, we can control for any observable and unobservable heterogeneity that is constant over time (between units). Practically, it means that those fixed characteristics will not influence the effect of the predictors.

In general, for a two-dimensional panel, where i measures the cross-sectional dimension (the alternative energy companies) and t measures the time (years) dimension, the equation is the following (Mummolo and Peterson, 2018):

$$Y_{it} = \alpha_i + \beta * X_{it} + \varepsilon_{it} \quad (2)$$

Where:

Y_{it} is the outcome variable for unit i in time t ,

X_{it} is the vector of the independent variables for unit i in time t

a_i is the intercept of the regression that captures unobservable time-invariant features of each unit,

ε_{it} is the idiosyncratic error term

The main objective of the FE regression is to eliminate the a_i since it captures each unit's time-invariant characteristics. “Demeaning” is a common technique to achieve the desired outcome (Mummolo and Peterson, 2018). In my thesis, I will not do it directly because, in Stata, this process is entirely automatic. In the background, Stata subtracts the mean (over time) from each variable for each panel entity and runs a standard regression on the transformed data. The desired equation in the end with crossed out a_i is the following:

$$Y_{it} - \bar{Y}_i = \beta * (X_{it} - \bar{X}_i) + \varepsilon_{it} - \bar{\varepsilon}_i \quad (3)$$

In practice, after setting up the data structure and running the fixed effect regression, I will quantify the percentage change in the profitability of alternative energy companies due to a unit change in oil price volatility, *ceteris paribus*. In addition, I will incorporate all independent variables at the first lag.

Regarding oil price volatility, according to Bastianin and Manera (2018), we oversaw that the effect of oil shock usually arrives with a delay. This delay is logical, as market participants often require time to pass increased costs (due to oil fluctuating oil prices) onto consumers or adjust their cost management strategies to preserve profitability margins. Similar reasoning applies to the GDP growth and inflation rates, whose impacts on firms' profitability are not immediate. With regards to the other firm-specific control variables, I also incorporate them with the first lag because, typically, companies make investment and budgeting decisions based on past information. Hence, assuming that the t-1 results significantly influence the current profitability is reasonable.

In the first regression, I will determine the actual relationship between the profitability of alternative energy companies by eliminating any time-invariant unobservable factor between the two:

$$ROA_{it} = a_i + Oil_{Vol} * X_{it-1} + \varepsilon_{it} \quad (4)$$

Where X_{it-1} represents the oil price volatility at the first lag. Its coefficient shows the relationship between the previous period's oil price volatility and current profitability after controlling for unobserved firm-specific factors.

In the second scenario, to mitigate potential omitted variable bias and to cancel out the effects of broader economic dynamics, I will control for macroeconomic variables. This step will enhance the robustness of our secondary regression by providing different coefficients with (potential) significance changes. The equation is the following:

$$ROA_{it} = a_i + Oil_{Vol} * X_{it-1} + \delta Z_{it-1} + \varepsilon_{it} \quad (5)$$

Here δZ_{it-1} is a vector for all the macro controls at the first lag.

In the last regression, I will incorporate all the control variables accordingly. With this step, I will refine the previously obtained results and prove that the results are not solely coincidental correlations. You can observe the third equation here:

$$ROA_{it} = a_i + Oil_{Vol} * X_{it-1} + \phi W_{it-1} + \varepsilon_{it} \quad (6)$$

In contrast with the second scenario ϕW_{it-1} represents all the control variables at first lag.

3.5.2. Diagnostic checks

After every regression analysis, it is advisable to conduct robustness tests. In this dissertation, I will perform the direct testing of multicollinearity, and implicitly, I will use robust standard errors to account for heteroskedasticity.

Multicollinearity is a phenomenon in regression analysis where two or more predictor variables are highly correlated; in other words, the variables are not linearly independent. Therefore, in a regression model, coefficient estimates may be unstable and have very high standard errors, occurring with the "wrong" sign, implausible magnitudes, or low significance levels, even if they are jointly significant (Yu, Jiang and Land, 2015). Although multicollinearity does not directly affect the predicting power of the model, it is crucial to detect if any exists, especially in panel models where the main objective is to understand the impact of variables over time or across entities.

A common technique in the literature to detect multicollinearity is to compute the VIF (Variance Inflation Factor) test. Even though this method was initially designed for classic linear models (Yu, Jiang and Land, 2015), it can still give valuable insights into the abovementioned issue. It is calculated the following way:

$$VIF_i = \frac{1}{1 - Ri^2} \quad (7)$$

Where Ri^2 is the determination coefficient (R-squared value) obtained by regressing the i -th predictor on all other predictors.

Usually, as the cut-off value, the literature proposes the rule of thumb: if the VIF value is larger than 10, it indicates a significant multicollinearity problem within the model (Kutner et al., 2004); otherwise, the model can be considered unbiased from multicollinearity.

Regarding the presence of heteroskedasticity, it can also distort the regression results. The issue arises from the typical standard error formula assuming that regression residuals are independent. However, in practice, this assumption is often untrue (deHaan, 2020). Although fixed effects do not necessarily correct standard errors for these correlated residuals, by using robust standard errors, we can mitigate the potential bias caused by the non-independent residuals (Gow et al., 2010). As I mentioned at the beginning of the section, I will not directly calculate tests to account for heteroskedasticity. Instead, I will include the command “vce(robust)” in the code to signal Stata to calculate robust standard errors.

4. Results

4.1. Descriptive Statistics results

Before conducting a deeper empirical analysis, it is essential to observe the data descriptively. In the appendix, you can see the descriptive statistical results.

The average return of ROA indicates that, in general, the sample firms operate at a loss (-1,53), yet their lower median value refines the picture (close to zero). Alongside a relatively high annual standard deviation (25,43), we can infer significant differences in Asset size and Profitability metrics among the sample companies, which is unsurprising in the alternative energy sector. Additionally, given that the ROA is a critical measure for our analysis, all observations were deleted below the 1st and above the 99th percentile (to avoid outliers). For other variables, mainly control variables, I declared that it is unnecessary because these variables' objective by their nature is to adjust the model for additional variance; therefore, keeping the entire data set for controls made sense to me, and apparently, they did not unreasonably influence the results.

Regarding the oil price volatility, I received a relatively high standard deviation with an average of 47,35 and a max of 112,87 (in COVID-19). We can conclude that the oil market environment can confidently be characterized as volatile in the monitored time frame. In such a market atmosphere, alternative energy companies face challenges and opportunities. A possible alternative for renewable energy companies is that they can act as hedging instruments against the price of oil (Rentschler, 2013). In contrast, they can also experience uncertain periods when investors' sentiment is negatively affected.

Additionally, it is worth noting that in almost every case, the variables are highly skewed, and the kurtosis is above 3, which suggests a non-normal distribution of the residuals. However, unlike in a simple linear regression analysis where it is a precondition that the distribution must be normal, in the case of a fixed effect regression, the model is resilient even though the distribution is non-normal. The reason is that this model type uses within-unit transformations that focus on overtime variations rather than across units' variations (Wooldridge, J.M., 2010).

4.2. Correlation matrix results

Next, I calculated the correlation coefficients between the time series. The results are displayed in the appendix:

I measured the highest correlation coefficients between the Oil volatility and the Annual Inflation Rate and GDP Growth, confirming the literature discussions about the strong interconnectedness between oil prices and macroeconomic variables. For example, the strong negative correlation (-0,701) with GDP growth indicates that higher oil prices are associated with slower economic growth in the observed period. The same phenomena can be observed in the general price levels (-0,133), but the correlation is significantly weaker.

The same weak negative correlation patterns can be observed in the context of the main variables. I received -0,071 correlation coefficients between ROA and Oil price volatility, which can imply that higher uncertainty in oil prices may negatively impact the alternative energy companies' profitability in the observed period, possibly due to increased operational costs or investor risk aversion. Still, we cannot state it since the relationship is weak. In contrast, we can state that, based on the direction and strength of the relationship, it supports the growing literature that reports on the weakening effects of oil and that the relationship between the two is no longer as straightforward as it was back in the 60s and 70s.

Moreover, in the case of other control variables, the correlation coefficients also do not show a strong linear relationship with ROA within the observed sample. It might suggest that the relationship is non-linear or that there are interacting factors that cannot be captured in a correlation analysis (Cortina, 1993).

In addition, it is noteworthy to be aware that correlation does not indicate direct causal consequences, so if we receive a weak correlation, it does not mean that these variables are unnecessary. They may still have significant effects when interacting with each other or with oil price volatility; that is why we need an intricate regression framework to discover the more complicated interrelations.

4.3. Examining the prerequisite of the model

As a first step of the practical analysis, I used the Augmented Dickey-Fuller (ADF) test to check if my data series were stationary. The results were obtained by using EViews 12SV. I displayed them in the appendix.

In all cases, I tested the hypothesis $H_0 =$ there is a unit root. I made the decision based on the calculated t-statistics, according to which, if the computed t-stats result is a smaller number than the critical values measured by Dickey-Fuller, in that case, I reject the null hypothesis, i.e., there is no unit root, so the time series are stationary. Fortunately, this hypothesis was rejected at all usual significance levels (1%, 5%, 10%). In each case, I rechecked the results based on the empirical significance level, which converged to 0 at all usual significance levels, so the time series are stationary. Based on these, our future models will not give distorted results due to unit roots.

4.4. Fixed effect regression results

After testing the model precondition, we can be confident that the data set is ready for the regression analysis. As mentioned earlier, I will perform the entire analysis in Stata 17.0.

I ran three separate fixed-effect regressions:¹, where the dependent variable is always the alternative energy companies' profitability, and the primary independent variable is the oil price volatility. From scenario to scenario, I kept extending the number of independent variables by including relevant controls, as mentioned earlier in the methodology section. Furthermore, to ensure that my findings are not affected by heteroskedasticity, robust standard errors were calculated using the “vce(robust)” command in every scenario. The results are highlighted in the following table:

¹ I expected a substantial reduction in the total number of observations by the end of the analysis because of missing values in the dependent variable. (unfortunately, we cannot influence the data quality, as it is beyond our control).

VARIABLES	(1) Baseline model	(2) Expanded data model	(3) Full sample model
Vol_Annual_Brent	0.00209*** (0.000556)	0.00218*** (0.000757)	0.00366** (0.00162)
Market_Value			-0.149 (0.0932)
Debt_to_Equity_ratio			-5.10e-06 (9.52e-06)
Capex_to_total_asset			0.00490* (0.00275)
Asset_turnover			-0.0744 (0.0552)
Current_ratio			0.000138 (0.000251)
Annual_Inflation_rate		1.858 (2.826)	0.582 (3.753)
Annual_GDP_growth_rate		-0.237 (0.673)	0.200 (0.990)
Constant	-0.771*** (0.0264)	-0.823*** (0.0776)	-0.401 (0.449)
Company Fixed effect?	YES	YES	YES
R-squared	0.003	0.003	0.019
Observations	4,222	4,119	2,889

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure 5: Fixed effect regression results created by the author

In all models, I made the decisions about the coefficients based on a two-tailed p-value test (H_0 : each coefficient differs from zero). For the baseline model, the coefficient for lagged oil volatility (Vol_Annual_Brent) is 0.00209, statistically significant at all the usual significance levels (1%, 5%, 10%). This suggests that for each unit increase in the oil price volatility from the previous year, there is an associated absolute increase of 0,00209 in the profitability of alternative investment companies in the sample when controlling for all unobserved, time-invariant features.

In the expanded data model, the coefficient for lagged oil volatility is slightly higher (0,00218) and remains statistically significant at all the usual significance levels. This reinforces the finding from the baseline model and suggests that the relationship holds even when control for the macroeconomic environment is introduced, even though *ceteris paribus* in the observed period, the Annual_Inflation_rate and Annual_GDP_growth_rate are statistically insignificant.

In the last scenario, I achieved the most comprehensive results with the total sample model by incorporating other firm-related control variables. The coefficient for lagged oil volatility is the strongest of the three scenarios, with a value of 0.00366, and is also significant at the 5% level.

However, in the case of the Market_Value variable, the coefficient is not statistically significant. This suggests no clear evidence that market value significantly impacts ROA in this model. Also, the Debt_to_Equity_ratio has a negligible and insignificant negative coefficient, implying that the leverage level, as captured by the debt-to-equity ratio, does not significantly impact ROA in this model either. The coefficient of Capex_to_total_assets is positive and significant at the 10% level, indicating that capital expenditures relative to total assets are positively influencing the ROA (due to 1 unit increase in Capex_to_total_assets there is ceteris paribus, an associated 0,0049 absolute increase in the ROA of alternative energy companies). The same tendency can be observed regarding macroeconomic control variables, just like in the second scenario, with a lack of relevant significance, all else being equal. The remaining variables, namely Asset_turnover and Current_ratio, are also statistically insignificant in the observed period.

In examining the overall explanatory power of the models, you can observe the calculated F-stats:

Scenarios	(1) Baseline Model	(2) Expanded data Model	(1) Full sample Model
F-stats p value	0,00	0,00	0,00
Model is ok?	✓	✓	✓

Figure 6: F-stats values, created by the author

The F-statistic tests the null hypothesis that all coefficients in the model are jointly different from zero. If we reject the null hypothesis, the model possesses relevant explanatory power, so the results are robust. As shown in *Figure 6*, the p-values are less than 5% throughout all the scenarios, indicating that the models demonstrate collective and relevant explanatory power.

4.5. Observing the model stability

In the methodology section, I highlighted the relevance of performing robustness tests. In my thesis, I incorporated robust standard errors to correct for heteroskedasticity implicitly. I decided to carry out this approach because of its consistency (since robust standard errors do not depend on the specific form or pattern of heteroskedasticity). Instead, they have the ability

to correct for heteroskedasticity regardless of how this phenomenon is present in the data (Bell and McCaffrey, 2002). Bell and McCaffrey also underlined the implication of robust standard errors when the covariates' distribution is highly skewed.

To strengthen the reliability of the results, I investigated whether there are any issues regarding multicollinearity. You can see the VIF results in the following table:

VIF Testing	Baseline model	Expanded model	Full sample model
Vol_Annual_Brent	1,00	1,87	4,3
Market_Value			6,54
Debt_to_Equity_ratio			1,00
Capex_to_total_asset			1,00
Asset_turnover			1,07
Current_ratio			1,02
Annual_inflation_rate		2,97	3,3
Annual_GDP_growth_rate		2,02	2,78
Mean VIF	1	2,29	2,51

Figure 7: VIF test results

Overall, the single VIF tests clearly show no significant concerns about multicollinearity. Moreover, though the mean values increase from 1 in the baseline model to 2.51 in the full sample model, they are still within permitted limits. This suggests that the overall models are also unlikely to be adversely affected by this phenomenon.

5. Conclusion

In today's business, many essential aspects need to be considered, such as various energy policy questions or environmental concerns, to sustainably establish the interactions between financial markets, society, and the environment. These aspects can also create a favorable market for companies producing and distributing alternative energy. Furthermore, in this case,

I think a better understanding of the relationship between oil prices and the financial performance of the alternative energy industry will be critical in the years ahead.

To sum up my thesis, I studied two main questions. In the first research question, I explored how oil price volatility directly influences alternative energy companies' profitability. My second research question was the extension of the first one: how this relationship varies through different scenarios when controls for firm-specific and macroeconomic variables are introduced. To provide answers, I developed a fixed effect regression framework with firm fixed effects, incorporating three different scenarios.

Firstly, during the literature review, I widely described the economic factors that affect the price of oil and its volatility. I also appointed that oil, as an indicator, plays a significant role in almost all financial processes. Then, I focused on the connections between oil and the stock market. I highlighted numerous past research results on how the relationship between oil prices and stock market returns can change by examining different periods. Finally, I explained in detail how capital financing and “green trends” can be interrelated.

At the beginning of the methodology section, I described the data, its characteristics, and the collection methods. Continuing with the description of the variables, I highlighted my main variables: Return of Asset as the profitability metric of the alternative energy companies, Oil price volatility as the leading independent variable, and other firm-related and macro-related control variables that I incorporated to smooth my analysis. I also presented my data structure and explained the methodological toolkit that is crucial to follow and use to answer my research questions (including necessary empirical trials and tests).

Then, I descriptively examined the data series, concluding that several key findings needed to be taken into account before further analysis (such as stating the facts about the distribution). The next step was the correlation analysis. Generally, I found a significant weak correlation (negative) coefficient between the green sectors' profitability and the oil price volatility.

Subsequently, I observed the more complex relationships by using econometric modelling. In my thesis, I navigated the reader through various scenarios where I analyzed the dynamics between oil price volatility and the financial performance of alternative energy companies. By running several robust fixed effects regressions, my research revealed a positive and significant relationship between lagged oil volatility and the Return on Assets (ROA) from 2017 to 2022. These main findings add a new dimension to the existing literature (by providing a more tangible measure of financial performance) that primarily focuses on green stock

performance as an indicator of company health in response to oil price movements (Henriques & Sadorsky, 2008; Reboredo, 2013). Additionally, the diversity of the sample, with notable contributions from the USA (35%), Germany (9%), Canada (8%), and China (7%) contributes to the global relevance of the results.

Finally, it is crucial to point out that it would not be appropriate to withdraw straight conclusions from the results. Overall, my key findings provide an overview of the relationship between oil prices and the profitability of the alternative energy sector, which can be helpful to the reader in all aspects when considering various investment opportunities. However, it would be a mistake to encourage anyone to draw far-reaching answers from these because we would need a more complex and multi-faceted model to discover the more complicated economic relations among the mentioned variables. Therefore, the reader needs to understand that my findings, *ceteris paribus*, are to be interpreted for the given period and are incomplete answers.

To develop more complex models in the future, making the following modifications may give a more accurate picture. For example, we can obtain more robust results if we further increase the sample size (i.e., examining 10 years), but for that, we will need better data quality, perhaps it is advisable to switch to Bloomberg in this case. In addition, the green sector is very diverse, so for a higher degree of accuracy, the effects can be examined in detail down to the sub-sectors. Then, we can select indices that adequately represent the individual sub-sectors (e.g., only solar/wind energy companies) and include those constituent companies for more specific sector analysis.

Regarding model improvements, I suggest sticking to the regression approach. Choosing a framework that can account for the non-linear and asymmetric effects of oil price volatility on the ROA would be more sophisticated. For instance, regression models incorporating threshold effects can tell us at what point the impact of oil price volatility becomes significant for the profitability of alternative energy companies. Similarly, quantile regression analyses could offer insights into how the relationship between oil volatility and ROA of alternative energy companies varies across different levels of the profitability distribution.

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Appendix

Appendix 1: Summary stats

Summary Stats	ROA	Oil Volatility	lnMarket Value	D/E Ratio	Capex to total asset ratio	Asset turnover	Current ratio	Annual Inflation rate	Annual GDP growth rate
Mean	-1,53	47,35	3,15	792,40	33,20	0,32	33,84	0,03	0,02
Median	-0,30	33,41	3,42	0,00	0,00	0,00	0,57	0,02	0,02
Min	-906,74	25,71	-4,60	-47670,20	0,00	-0,06	0,00	-0,01	-0,11
Max	3,02	112,87	11,20	1636450,00	57359,90	54,06	98882,39	0,72	0,14
Std.	25,43	30,50	3,35	32011,04	1201,80	1,36	1769,77	0,03	0,04
Skewness	-29,33	1,58	-0,14	46,38	43,74	31,05	55,83	8,77	-1,19
Kurtosis	967,75	3,73	2,40	2265,95	1964,47	1149,76	3118,64	194,63	5,48

Appendix 2: Correlation matrix

	ROA	Oil Volatility	lnMarket Value	D/E Ratio	Capex to total asset ratio	Asset turnover	Current ratio	Annual Inflation rate	Annual GDP growth rate
ROA	1								
Oil Volatility	-0,071	1							
Market Value	0,077	0,102	1						
D/E Ratio	0,001	-0,012	0,005	1					
Capex to total asset ratio	0,002	-0,010	-0,009	0,000	1				
Asset turnover	-0,002	-0,031	-0,034	-0,001	-0,007	1			
Current ratio	0,000	-0,001	-0,029	-0,001	-0,001	-0,009	1		
Annual Inflation rate	0,023	-0,133	-0,004	0,010	0,005	-0,002	0,045	1	
Annual GDP growth rate	0,058	-0,701	0,038	0,021	0,009	-0,004	-0,003	0,220	1

Appendix 3: ADF test results

Variables	Dickey Fuller t distribution	Calculated t stats	Decision on H0	Conclusion
Profitability (ROA)	1%: -3,43 5%: -2,86 10%: -2,56	-64,93	We reject the H0.	The series are stationary.
Oil_volatility	1%: -3,43 5%: -2,86 10%: -2,56	-29,24	We reject the H0.	The series are stationary.
Market_value	1%: -3,43 5%: -2,86 10%: -2,56	-14,98	We reject the H0.	The series are stationary.
D/E_ratio	1%: -3,43 5%: -2,86 10%: -2,56	-49,72	We reject the H0.	The series are stationary.
Current_ratio	1%: -3,43 5%: -2,86 10%: -2,56	-31,68	We reject the H0.	The series are stationary.
Capex_to_total_assets	1%: -3,43 5%: -2,86 10%: -2,56	-30,83	We reject the H0.	The series are stationary.
Asset_turnover	1%: -3,43 5%: -2,86 10%: -2,56	-27,72	We reject the H0.	The series are stationary.
Annual_inflation	1%: -3,43 5%: -2,86 10%: -2,56	-11,31	We reject the H0.	The series are stationary.
Annual_GDP_g	1%: -3,43 5%: -2,86 10%: -2,56	-9,80	We reject the H0.	The series are stationary.

