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Master Thesis Financial Economics

The Interaction Between Macro-Economic Variables and The Renewable Energy Equity Market – A 10-year case study.

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Abstract:

This thesis investigated the effect of four macroeconomic factors: GDP, unemployment, inflation and monetary policy on the renewable energy stock market and the effect, the price of oil has on both the macro-economic factors and the renewable energy stock market during 2004 to 2014. The main findings are that renewable energy equity performance is uncorrelated with the unemployment rate, inflation and monetary policy and is negatively impacted by GDP. The oil price has been found to unaffect the renewable energy stock market directly but an indirect correlation has been observed through oil's impact on GDP. These findings provide corporations and renewable energy shareholders with a better understanding of renewable energy stock dynamics. Also, government policy makers can design more effective incentive strategies for the renewable energy sector as influential factors of the renewable energy industry are better comprehended.

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1 Introduction

This research enquires how the renewable energy stock market correlates with macro-economic determinants like GDP, inflation, the unemployment rate and monetary policy. The researched period ranges from November 2004 until December 2014.
To accurately determine this, another major economic factor is taken into account: the oil price. Accordingly, this study also assesses the explanatory effect of the crude oil price on both the macro-economic predictors and the renewable energy securities.

1.1 Problem analysis

Renewable energy is increasingly becoming more important in our societies. As problems related to the environment and global warming are becoming more imminent, people increasingly raise concerns about climate change and more and more, governments are pressured by civilians and international activist groups who urge them to transition to alternative energy sources (Climate Reality Project, 2016).

Renewable energy is collected from energy sources that are naturally existent and replenished by earth's atmosphere such as, sunlight, wind, biomass, tidal waves, and surface water and moreover do not have the same harmful effects to the environment like fossil fuels. The sustainable energy industry is relatively new and some technologies are still in development and others are more in use. According to the Ren21 (2016) report, in 2015 8.9% of global energy consumption came from traditional biomass like wood and waste, 4.2% used as heat energy came from modern biomass, geothermal and solar heat, 3.9% originated from hydroelectricity and 2.2% was generated from wind, solar, geothermal and biomass.

Previous high oil prices may have additionally spurred this increased attention for renewable energy as those subjected civilians and governments to a higher cost of living and operations. As the price of crude oil plummeted the last three years and is at near-record lows, this substituting effect has probably diminished but this could again become an important factor when the price of oil significantly rises.

Renewable energy development

However, even without the reinforcing influence of a high oil price, the advent of sustainable energy can clearly be seen in recent statistics: according to the Renewables Global Status

Report (2015), renewable energy provided approximately 19.1% of global energy consumption in 2013.

In 2014, renewable energy sources represented an estimated 58,5% of added global power capacity with wind, solar and hydro power being the most essential sources and at the end of the year, renewable energy sources represented approximately 27.7% of the world's power generating capacity.

Scandinavian countries appear to be at the forefront of this energy revolution. Recently, Sweden announced its prospects to be the first fossil fuel-free nation in the world (Andrews, 2015) and Denmark has perhaps even higher ambitions by enunciating it wants to be free of fossil fuels within 15 years and run completely on green energy within 20 years (Staufenberg, 2015). Added to the political support for the sustainable energy market, a substantial growth has emerged in the numbers of residential 'pro-sumers' or electricity end users who generate their own energy in Europe, Australia, Japan and North America.

Along with the growing political backing, substantial investments in this sector have been stimulated by legislation and subsidies that have resulted in significant developments of renewable energy technology, global capacity increases and significant cost reductions through economies of scale. A recent study (Ecofys, 2014) reveals that in 2012 within all EU-28 Member States, the total number of government subsidies and investments in renewable energy was €99,2 Billion and the total number of subsidies for the renewable energy market is expected to rise to about $250 billion in 2030 (World Nuclear Association, 2015).

The business world catches up

Besides the expanding interest for renewable energy from governments and the wide public, in business too there is widening interest in this market as companies recognize that great opportunities lie ahead in this sector especially with respect to the fact that a large part of the world's population today is still living without proper energy supply. As the prospects for this market are bright with growing worldwide demand and political support, stock market investors increasingly become attentive towards this market.

In the past years, the renewable energy stock market already progressively gained interest from mutual- and pension funds as civilians in western societies increasingly voice their concerns about corporate social responsibility, especially regarding their financial assets and how these are invested by financial institutions they have been entrusted to (Grady, 2016). In the Netherlands for instance, companies like Rabobank and Aegon have ceased to invest in armament manufacturers and controversial mining companies that violated human rights due to public pressure (RTL nieuws, 2015). A recent study (Griffin & Sun, 2012) that found that voluntary disclosure of a company's greenhouse gas emissions produced positive shareholder returns wconfirms that investors seem to give weight to the 'green side' of their investments.

Another display of growing concern for corporate responsibility is the initiation by Amnesty International of the 'Eerlijke Bankwijzer' which is an enquiry of banks that also assigns ratings based on how their investment policies score on societal issues like climate change (RTL Z, 2014).

The renewable energy equity market

All in all, since western societies increasingly value corporate responsible investing and the renewable energy sector has a prosperous future on account of enlarging political backing and expanding worldwide demand, the question arises whether the renewable energy stock market is the appropriate place for stock market investors in pursuit of attaining positive nominal excess returns.

Given the increasing importance of this specific equity market, very little empirical studies scrutinized the reciprocity between renewable energy stocks and systemic risk factors. There is some research that examined the causality between oil prices and renewable energy stocks (Broadstock, Cao & Zhang, 2012; Henriques & Sadorsky, 2008; Managi & Okimoto, 2013) but no exploration exists of the impact of other principal macro-economic factors on the renewable energy stock market as well as the mediating effect oil may have in this interrelationship.

1.2 Research goal

This thesis aims to fill this gap in the existing literature by enquiring how renewable energy stocks interact with leading macro-economic indicators and how the price of oil corresponds with this interaction. This will provide investors with better means of predicting renewable energy market trends and estimating and pricing the downside risk of their clean energy securities.

This is also of importance to strategy executives who need to comprehend how the renewable energy industry is affected by macro-economic trends in order to devise more effective policies. Thirdly, governments should take this causal structure into consideration with regard to quantifying subsidization programmes. Government budgets intended to steadily reduce reliance on finite energy sources could be put together more efficiently if market and oil price dynamics are better understood as they may provide useful supply- and demand stimuli for the sustainable energy (equity) market.

1.3 Problem statement

First, the relationship between GDP, inflation, the unemployment rate, monetary policy and renewable energy shareholder returns will be analysed. This leads to the following research question:

What is the interaction between GDP, inflation, the unemployment rate, monetary policy and renewable energy stock values?

In order to analyse how renewable energy securities correspond with the macro-economic predictors, other interdependent influences must be taken into account. Therefore, the relationship between the oil price and both the macro-economic variables and the renewable energy stock market is researched. Thus, this study further aims to answer the subsequent sub question:

What is the interrelationship between the crude oil price and both renewable energy equity returns and the macroeconomic indicators: GDP, the rate of inflation, the unemployment rate and monetary policy?

To answer the above-mentioned questions, a linear regression will be performed to empirically test the correlation between the macro-economic variables, the crude oil price and renewable energy equity returns. 10-year macro-economic data ranging from 2004 to 2014 is used as well as stockholder returns of 131 renewable energy securities, narrowed down from a sample consisting of 242 funds provided by thesis supervisor M. Kilic.

Structure of this report

The research questions will be further explored with a literature review in section 2. In section 3, the expected results are discussed followed by the methodology in section 4. In section 5, an analysis of the regressions is given. The conclusion of this thesis is provided in section 6 followed by a discussion on the results in section 7.

2 Theoretical Background

In this section, relevant research for this study is reviewed. First, literature on the effect of macro-economic metrics on the renewable energy security market is discussed. Secondly, literature regarding the effect of the oil price on these macro-economic variables and the renewable energy equity market is analysed.

2.1 Macroeconomic predictors

GDP, the unemployment rate, inflation and monetary policy can be directly as well as indirectly correlated with the security market; They are indicators of economic trends, likewise the stock market can be regarded as an overall gauge of an economy. Therefore, the macro-economic factors and the renewable energy stock market can have a direct connection as they arguably all are reflective signs of an economy's state.

However, they can also be indirectly linked as changes in these macro-economic factors can have a specific impact on the renewable energy industry or subsectors thereof which would in turn impact stock returns. For instance, subsectors that are more reliant on r&d funding could potentially be more responsive to inflation as this has been observed to induce credit rationing or to monetary policy as rising interest rates raises the cost of r&d funding.

Also, these metrics can have a signalling effect to markets about the sustainable energy industry as investors may draw conclusions based on these statistics on the present or future outlook of renewable energy companies, sectors (e.g. solar, wind) or markets thereby influencing their security market behaviour.

One important note on these supposed interconnections is that causal relations between correlated factors remain difficult to determine. For instance, when rising unemployment is accompanied with lower equity market wealth, it could be that unemployment affects the equity market or vice versa that declines in stock market wealth causes unemployment.

2.1.1 Gross Domestic Product

The effect of the gross domestic product on the renewable energy stock market is expected to come from both private as well as public effects.

Private influences

A straightforward explanation connecting the renewable energy sector with the gross domestic product of an economy is that economic growth results in more investable financial resources in the private sector, perhaps further induced by subsequent government tax cuts, of which the renewable energy industry could be a beneficiary. The increase in capital investments could impact the sustainable energy sector domestically as well as internationally through stock market trades or cross-border investments by investors seeking relatively high yield and low risk opportunities. Additionally, growth in GDP numbers could have a signalling effect to investors about future market developments in this sector affecting their market behaviour that way.

Public effects

Also, the renewable energy equity market may be correlated to this indicator in another way. Above, information was given about the enormity of incentives for the renewable energy sector provided by governments. In the specific case of stock prices of renewable energy companies, factors related to financial stimuli by governments in the form of investments and subsidies may play a significant role. As the renewable energy sector is still an infant industry, companies operating in this market may be more reliant on such government stimuli.

In addition to earlier provided information on subsidies, it has been estimated that in 2014, the total number of subsidies for the renewable energy sector were $135 billion (World Nuclear Association, 2015). Such sizable incentives presumably have a considerable effect on the renewable energy (equity) market even if companies do not rely on these subsidies to stay profitable since they boost corporate profits and in turn stock returns.

Because the primary gains of investments and subsidies for sustainable energy, which are clean energy production and energy cost reductions in the long run, mainly yield benefits in the future, nations that have to bring down government spending (for instance caused by economic downturns), may be inclined to cut down on renewable energy budgets.

The recent cost-cutting of Spain and Germany since 2014 of about $2.5 billion and $3.5 billion per year on subsidies for the renewable energy market could be examples of this correspondence (World Nuclear Association, 2015). Numerous other EU countries whose economies have slowed down also recently reduced renewable energy subsidies or capped their clean energy programmes like the UK, Italy, Switzerland, Croatia, Greece, Romania, Bulgaria and various other countries.

GDP's connection with renewable energy stimuli

Hence, an assumption one can make is that when a country's economy is performing better that nation will have more financial leeway and is better capable of providing sustainable energy stimuli. Alternatively, one can presume that nations characterized by lower economic growth have an inclination to cut government renewable energy budgets as they can afford less green energy incentives and investments due to budget constraints.

This expectation is partially supported by research from Chang, Huang and Lee (2009) who concluded that states with higher economic growth (the threshold is 4.13% of a one-period lag in the annual gross domestic product) are better able to react to high energy prices, by increasing their use of renewable energy, than countries characterized by lower economic growth which tend to be much less responsive to changes in energy prices. This supports the assertion that countries with higher economic growth are better able to allocate resources to sustainable energy development than countries detailed by lower economic growth.

Another paper investigating this relationship in the Baltic states congruently found evidence that economic growth, reflected by GDP growth, causes an in increase in sustainable electricity consumption (Furuoka, 2017). Nonetheless, several other enquiries that examined this relation in Australia, New-Zealand and numerous Asian countries concluded no cointegration between GDP growth and renewable electricity consumption. (Yang, 2000; Fatai et al., 2004; Chen et al., 2007; Tang, 2008;). However, these contradictory findings may be due to the investigated time period as the examined period ranges from prior to 2004 and arguably, more recently has global awareness significantly risen for this matter.

Presuming that government budgets for renewably energy investments and subsidies are tied to a country's economic prosperity, a suitable predictor of renewable energy budgets and consequently stock returns would be GDP growth numbers of the previous year.

While in this research, it is suggested that economic growth has a positive effect on government expenditure on renewable energy in the form of subsidies and investments, another study that analysed the effects of renewable energy on GDP for 116 economies, established that renewable energy also has a significant positive effect on GDP resulting from an increase in capital formation (Chien & Hu, 2008). These findings are confirmed by Payne and Apergis (2010) whose results show that there is a bidirectional causality between renewable energy consumption and economic growth both in the short- and long run. Their research suggests a correlation, which holds that a 1 percent increase in renewable energy consumption increases real GDP by 0.76 percent.

2.1.2. The Unemployment Rate

A potential other predictor of renewable energy equity returns is the unemployment rate. Rising unemployment could indicate a pressured economy which would result in negative stock responses as corporate profits would be adversely affected.

Present research

The existing literature lacks empirical research on the predicting factor of unemployment on stock markets and none exists on the interaction specifically with the renewable energy equity market. Prior studies mostly focused on the predicting role of stock markets on unemployment. Applicable studies and implications on the interaction between unemployment and renewable energy stock values are reviewed below.

First, Phelps (1999) observed the correspondence between the equity market with unemployment as he noted that the steep stock market growth in the 1990s came along with a decline in unemployment. A similar interaction was found by Fitoussi et al. (2000) in several European countries between equity market wealth and the unemployment rate.

More recently, in a case study analysing events preceding and during the Great Recession, Farmer (2012) concluded that a high negative interaction exists between the value of the stock market and the unemployment rate in the U.S. which is observed as follows: when the stock market rises, household income increases causing an expansion in aggregate demand that results in decreasing unemployment. Analogous, it is presupposed that a rising unemployment rate negatively influences aggregate demand and thereby the (renewable energy) equity market.

Debate

Holmes and Maghrebi (2016) dispute these findings and offer another insight as they assert that the interaction between the stock market and unemployment is not wholly understood. Their reasoning is that during the 2008 global financial crisis, stock markets dropped substantially and were accompanied with an increase in unemployment but several other stock market crashes did not come along with such large unemployment. They conclude that the unemployment rate is adversely impacted by stock market *volatility*.

In addition, they conclude that equity market shocks have positive and negative adverse effects in the short term on unemployment (Holmes & Maghrebi, 2016). Reasoning backwards from Holmes and Maghrebi's conclusions (2016), changes in unemployment may affect stock market volatility considering it may be a reflection of markets experiencing problems.

Signalling effect

Other research has linked equity market performance with *news about unemployment* which validates the relation between stock market wealth and unemployment (Boyd, Hu & Jagannathan, 2005; Cenesizoglu, 2011). Boyd et al. (2005) conclude that on average, announcements of rising unemployment are beneficial news for securities during economic growth and detrimental news during economic contractions. They put forth that such news induces the stock responses because it provides the equity market with information about prospective interest rates (see 2.1.4 monetary policy), business revenues, dividends and equity risk premiums.

Cenesizoglu (2011) additionally established an interaction between the stock market and news regarding unemployment and he further takes market cycles into account. His data shows that at the daily level, portfolios sorted according to size – and value factor respond adversely to higher than predicted employment data during economic growth but not during economic contractions whilst responses from small and value firms are broadly insignificant. At a monthly level, large and growth firms maintain to respond negatively to news about employment in expansions of the economy, however returns of small and value firms also become positive and significant while portfolios formed according to the size- and BM-factor maintain to have insignificant reactions during economic contractions.

2.1.3 Inflation

Another macroeconomic variable affecting the renewable energy equity market may be inflation, as a substantial body of evidence implies that a persistent high rate of inflation can have detrimental effects on a country's long-term real growth or real activity (Boyd, Choi & Smith, 1996; Boyd, Levine & Smith, 2001; Huybens & Smith, 1998; Huybens & Smith, 1999). These inflationary influences on the whole economy would also negatively affect the renewable energy industry and stock market.

Existing theoretical studies have extensively illustrated mechanisms through which even forecastable rises of inflation affect the capability of the financial sector to assign resources efficiently (Boyd et al., 2001). The communal aspect of the theoretical framework of these studies is that they assume important informational frictions within credit markets whose effects are endogenous. Presuming these knowledge asymmetries, a rise of inflation forces the real rate of return of (financial) assets down. The connoted decrease in real returns augments financial market frictions. Since these economic frictions induce credit rationing, credit conditions become more rigid as the rate of inflation increases. Consequently, the financial market provides fewer loans, making resource allocation less effective, tempering inter-agent borrowing which has negative implications for capital investments in an economy (Boyd et al., 1996).

The contraction of capital formation adversely affects both long-term market growth and equity market movement (Boyd et al., 1996; Huybens & Smith, 1999). Findings by Boyd, et al. (1999) substantiate this theory as they provide evidence that shows that a significant, and economically important, adverse interaction exists between the inflation rate and both banking sector growth and security market activity. Furthermore, the interaction is non-linear. When the rate of inflation increases, the marginal effect on bank borrowing activity and security market performance subsides considerably.

Lastly, although the data does not suggest that greater inflation is paired with larger nominal stock returns in economies with low inflation, nominal equity responses move almost symmetrical with marginal hikes of inflation in countries characterized by high inflation (Boyd, Levine & Smith, 2001).

Inflation's effect on the renewable energy (stock) market

The renewable energy (stock) market maybe even more adversely impacted than other sectors because renewable energy is still a relatively new industry and is greatly dependent on research and development funding and thus on loan provisions by the financial sector. Third-generation renewable energy technologies (these include: biomass gasification, bio refinery technologies, hot-dry-rock geothermal power, and ocean) are still being developed. Moreover, existing renewable energy technologies have not yet matured into viable solutions capable of replacing a notable share of global energy production via fossil fuels and further development thereof will too require vast financial resources.

2.1.4 Monetary policy

As was noted above in paragraph 2.1.3, the renewable energy industry is vastly evolving and relies heavily on research and development funding. Hawkish monetary policies by central banks, that entail higher interest rates, increase the cost of capital and consequently the cost of research and development. This presumably has an adverse effect on renewable energy companies and securities.

Equity markets

Research has demonstrated that monetary policy by the Fed is perceived as a risk factor in equity markets (Jensen et al., 1996; Thorbecke 1997). Bernanke and Kuttner (2004) examined the interaction between Fed program announcements and US security markets and put forth that the effect of FOMC press releases on equity price variability should to a small degree be accredited to the actual programs from the Fed and their effects on the real interest rate.

Instead, the influence of monetary action on equity returns appears to come from its impact on anticipated prospective excess returns or expected forthcoming dividends. Their results indicate that more severe credit conditions negatively affect share prices due to an increase of expected equity premiums. Alternative explanations of the interaction between surplus returns and FOMC policy announcements are overreaction and over-sensitivity of the stock market (Bernanke & Kuttner, 2004).

Fed's target

Prior research however does point to a more direct connection between stock markets and monetary strategies as prior research suggests that equity markets frequently have been a motivation for monetary strategies by the Fed. Weller (2002) studied the period of 1980 to 1990s and his results imply that the Fed reacted to stock prices and that fiscal action had a substantial interference in the security market. His results also suggest that the importance of the equity market as a determinant of financial policy increased. More specifically, his data shows that lower rates ensued swiftly after share prices declined, and that lower rates assisted to boost the stock market significantly in a short time span.

A recent study by Hung and Ma (2017), which measured the effectiveness of fiscal policy on security price stability, confirms the conclusions from Weller (2002) and Bernanke and Kuttner (2004) that emanating from stock market expectations, a tight monetary policy can induce stock price declines and that countries with over- and undervalued stock prices use this correlation to maintain price stability in equity markets.

Presently, since the Fed has raised its short-term interest rate by 25 basis points in December 2016 to a range of 0.50% and 0.75%, interest rates are almost zero and near all-time and this may therefore be a significant determinant of recent equity market returns (notable period ranges from 2009 onwards as interest rates since then have always been 1% or lower). Affirmations of this correspondence may be the current record-heights of the Dow Jones Industrial Average, the S&P 500, the NASDAQ and the recent all-time heights of the FTSE 100 and the Dax indices.

Central banks' expanding options

An interesting note here is that according to a Bloomberg news article (Jones, 2013), various central banks currently directly intervene in equity markets by buying stocks, some of which include the central banks of Switzerland, Japan, Israel and the Czech Republic.

In this thesis, the influence of monetary policy on share returns is taken into account only by analysing the effect of key interest rates on equity returns. However, the influence of central banks that directly intervene in equity markets is substantially greater and thus this effect may be underestimated in this research.

While the Fed today does not have a mandate to buy stocks, former Fed chairman Bernanke (2002) did discuss the possibility of the Fed acquiring stocks as a real instrument of achieving their target inflation rate of 2%. ECB chairman Draghi also discussed this as an actual potentiality so this may become a more important factor in the future (ECB Press conference, 2014).

2.2 Oil's impact on renewable energy equities

The oil price is expected to positively interact with the renewable energy stock market because it plays an important part in actuating the profitability of the renewable energy sector. High oil prices incentivise the use of alternative energy sources like renewable energy whereas low oil prices discourage the use of (more expensive) clean energy.

Despite this central role in determining the viability of the renewable energy sector, relatively few empirical studies investigated the correspondence between the crude oil price and sustainable energy securities. Below the main aspects of the literature on the interaction between oil and sustainable energy equity prices and their implications are summarized.

Causality analysis

Henriques and Sadorsky (2008) documented the existence of a Granger causality of the price of crude oil on the equity values of renewable energy businesses listed on primary US stock exchanges. The Granger causality test is used to analyse whether a cause happened before an effect and not vice versa, by measuring whether one time series is useful in predicting another. Henriques and Sadorsky (2008) thus observed that oil prices impacted renewable energy stock values.

This research was broadened by Managi and Okimoto (2013), who looked into Markov-shifting effects in order to allow for potential formational changes in the interrelationship of oil and alternative energy stock values. The results demonstrated a structural break at the end of 2007. Before, the crude oil price did not affect renewable energy share values but after, their evidence shows that a significant higher oil price positively affected renewable energy equities.

Another paper revealed that oil price fluctuations affected renewable energy equities in China, specifically after the beginning of the previous global financial depression when the reciprocity developed significantly (Broadstock et al., 2012).

Sadorksy (2012a) studied the relationship between oil and renewable energy stocks by investigating cascading volatility effects and found significant evidence of volatility spill overs between the oil price and clean energy stocks. This means that volatility in the oil market moved over to the renewable energy security market.

Contrarily, other research (Sadorsky, 2012b) observed that an increase in the price of oil positively affected the riskiness of alternative energy stocks. This study thus does not observe a cascading effect but does however conclude an interaction between both the oil market and the sustainable energy stock market.

Wen et al. (2014) additionally investigated volatility spill-over effects between non-renewable energy stocks and Chinese clean energy equity values and found evidence on a daily level, that clean energy and hydrocarbon shares were substituting assets, with substantial mean and risk cascading effects between them though alternative energy equities carried more risk than fossil fuel stocks. Ortas and Moneva (2013) examined the time-varying risk movement of sustainable-technology stock indices with the oil price, and found that these indices bore more risk and attained higher returns than regular share indices.

Theoretical structure

The commonality between the previous studies is that they examined average reactions of clean energy share values on oil prices and volatility but not however, the entire causal framework. Reboredo (2014) takes a different approach to investigate the oil-renewable energy stock relationship by ascertaining where both sectors are significantly dependent or independent on average or during extraordinary market shifts and by analysing the intrinsic volatility effect of oil price changes on clean energy stock values.

Reboredo (2014) analysed this interaction by investigating the effect of extreme oil price shocks on three world-wide clean energy equity indices (the S&P Global Clean Energy Index, the Wilder Hill Clean Energy Index and the European Renewable Energy Index) and three renewable energy sectoral indices (The NYSE Bloomberg Global Wind, Solar Energy and Smart Technologies indices) which displayed a time-varying positive average dependence and symmetric tail dependence with almost all green energy indices. The explanatory factor was around 30% implicating that, on average, a strong oil price movement increased the VaR of the sustainable energy indices by 30%. These results are incongruent with the presumption that the oil - and the clean energy sector are adversely correlated. On the contrary, the results suggest that both markets experience upswings and downturns together with the exception of the solar energy index.

The solar energy market exhibited a different systemic risk pattern as it reacted negatively to extreme oil price changes and asymmetrically as there was a greater upward reaction (81% on average) in comparison to downward (58% on average). Reboredo (2014) posits that this divergent response is presumably because photovoltaic energy has a longer development record than alternative new-energy technologies and because solar energy assets are often positioned in hydrocarbon energy based portfolio investments.

Additionally, Reboredo (2014) remarks that generally, the solar energy market has been granted the most financial stimulus from government agencies whose management actions were impacted by oil prices. Following Reboredo's rhetoric, solar energy stocks may react heavier to how an economy is faring, based on the discussed assumption that government incentives for the renewable energy market may be tied to an economy's state.

2.3 The effect of the crude oil price on the macro-economic variables

One of the novelties this research presents is that the effect oil has on the covered macro-economic variables is researched next to its causal impact on renewable energy equities. As one of the most significant commodities globally, crude oil is essential for the world economy. Empirical studies on the interaction between oil prices and macro-economic development have developed in some three dozen or more investigations, conducted in both the western as the eastern continent by scientific and other investigating organizations, NGO's and multilateral agencies (Abel & Bernanke, 2001; Brown & Yücel, 1999; Bruno & Sachs, 1982; Burbidge & Harrison, 1984; Darby, 1982; Hamilton, 1988; Lardic & Mignon, 2006; Mork et al., 1994). Their findings convincingly show that crude oil price rises and their fluctuations yield adverse macroeconomic results including declined output, increased unemployment and inflation and a loss to financial and other assets.

The majority of the existing research validated oil prices to significantly impact economic aggregates but discrepancies emerge when the effects of oil price shocks on producing economic output fluctuations are substantiated. What impact the price of oil exerts on an economy is also dependent on its reliance on oil and whether a market is a net importer or exporter. As none of the investigated countries are significant exporters of oil, like member states of OPEC, it is presumed that all countries are net importers of oil. Other factors like political development, economic conditions and general supply and demand influences may alleviate or amplify the impact of oil price shocks (Bernanke, 2004). Empirical studies investigating co-movements of oil and market variables are reviewed in the following sections.

2.3.1. GDP

The effect oil has on a states' GDP has been empirically tested by growing contributions of academic literature that decisively suggest that oil price hikes and volatility stifles macroeconomic activity in oil consuming nations (Hamilton, 1988; Darby, 1982; Bruno & Sachs, 1982; Burbidge & Harrison, 1984; Mork et al., 1994).

Next to transferring wealth from oil consuming nations to exporting economies, oil price fluctuations impact macroeconomic development in several other ways. A climbing oil price results in higher costs for businesses that decreases production output and wages and results in inflated consumer prices (see inflation) and interest rate rises which lowers aggregate demand with increasing unemployment as an aftereffect (Abel & Bernanke, 2001; Brown & Yücel, 1999).

Additionally, oil price volatility generates uncertainty that diminishes the value of (financial) assets and strains investments. A revealing study on this causality found that increasing oil prices preceded seven out of the eight US recessions between 1948 and 1980. The results indicate that a 10% oil price rise causes losses in the range of approximately 0.5% to 1.0% of GDP, for several quarters, or even indefinitely (Hamilton, 1988). These findings confirmed the studies of Darby (1982) and Bruno and Sachs (1982) (Lardic & Mignon, 2006).

Other investigations showed that this also applied to other industrialised nations like Greece, Canada, Japan, West-Germany, France and the UK (Burbidge and Harrison, 1984; Mork et al., 1994). The ECB (Jimenez-Rodriguez and Sanchez, 2004) likewise concluded that a doubled oil price caused losses in real GDP of 3-5% for the US and the EU. This is substantiated by another study that analysed this correspondence in twelve European countries and concluded an asymmetric co-integrational relation (Lardic & Mignon, 2006).

Contrary findings

However, several other studies found no significant influence by oil price shocks on the macro-economy which contradicts the widely-held view on this correspondence. Kim and Loungani (1992) treat the energy price as an extrinsic random mechanism by incorporating oil as a driving input factor in their economic cycle model and their data indicates that the price of oil does not have a significant role in determining output movements. Dhawan and Jeske (2008) elaborate on Kim and Loungani's (1992) study by incorporating durable consumer goods. They assert that oil price shocks have a minor influence on output fluctuations.

2.3.2. Unemployment

Above, in paragraph 2.3.1, a transmission channel (Lardic and Mignon (2006) refer to '*transmission channels*') was explained through which oil prices influence the unemployment rate. However, previous studies have documented several causal mechanisms through which oil price movements influence economic activity that will be briefly laid out. First, there is a supply side impact as a higher oil price reduces output which consequently lowers the growth rate and productivity which increases unemployment (Brown & Yucel, 1999, 2002). A second causal relation is the effect of a wealth transfer which shifts purchasing power from oil consuming countries to oil exporting states which due to changes in consumer demand and price-stickiness leads to slower economic growth and lower employment in those countries (Fried & Schultze, 1975; Dohner, 1981).

The third medium through which unemployment and energy prices are connected is through the real balance effect according to which oil price rises lead to an increase in demand for money. When monetary authorities do not expand the money supply to account for the growing demand, interest rates will rise and depress the growth rate (Pierce & Enzler, 1974; Mork, 1994).

Inflation (2.3.3) is another influential factor. When inflation is induced by oil price-increased cost movements, a contractionary fiscal policy can strain long-term production by interest rate hikes and declined investment. This in turn increases unemployment (Tang et al., 2009).
The fifth medium of interaction works via impacts of oil shocks on production costs thereby affecting the labour market. Oil price shocks can raise marginal product costs in many sectors that are oil intensive which can bring businesses to utilize other ways to produce (Loungani, 1986). Awerbuch and Sauter (2006) draw the same conclusion as they pointed out that not all sectors are affected uniformly and that oil value movements change the relative cost of products and services, altering demand and increasing unemployment for both oil importing countries as oil exporting nations.

The sixth transmission channel through which the price of oil may affect unemployment is through the relative prices of production factors. Carruth et al. (1998) provide an efficiency wage model which implies a relationship between energy prices and employment for at least three reasons: wage changes, voluntary unemployment, and input factor prices.

2.3.3 Inflation

The effect of oil price inflation on the macro-economy was discussed above through its effect on unemployment but there are more effects regarding inflation on the macro-economy.

Consumers pay the price

Oil is a crucial resource in an economy because it is required for essential processes like transportation, in the form of gasoline for cars and jet fuel for air transportation, and for heating of homes. If the oil price rises, manufacturers will be subject to higher production costs which will be passed onto end consumers by increased prices of goods and services. Chen (2009) analysed oil's impact on inflation in 19 developed nations from 1970 to 2006 and found evidence that oil price fluctuations had a lower pass-through into aggregate consumer price inflation in 2000 than they did around the 1970's.

Gao et al. (2014) investigated this interaction in depth (1974-2014) in the US but used a different proxy for oil and for inflation (WTI instead of average world oil and total CPI with 7 subcategories instead of an aggregated CPI) and concluded that consumer prices are primarily affected by significant price rises of energy associated commodities. Valadkhani (2014) studied this effect in Canada and the US for roughly the same period as Gao (2014) with a different econometric approach and concluded similarly that the marginal impact of oil price fluctuations on consumer energy prices has risen.

Studies examining emerging markets have found similar results in Turkey, Taiwan and Thailand using a variance of proxies for oil and inflation (change in imported oil price, WTI, Brent oil price, average global oil prices; change in CPI, aggregate and disaggregated price indices, aggregate and disaggregated producer price index, harmonized index of consumer prices) and in largely the same period as the previous studies ranging from 1981-2011 (Çatik & Önder, 2011; Chou and Lin, 2013; Ibrahim and Chanchaoroenchai, 2014; Lu et al., 2010).

Oil dependency

Akanni et al. (2017) profoundly examined the oil price-inflation nexus by taking asymmetries into account and by differentiating between net oil exporting and net oil consuming nations. By asymmetry, a different impact is meant between positive and negative oil price fluctuations and so this model is used to empirically test whether inflation is impacted more by increases or decreases in the oil price.

Their results indicate that in the long-term, oil exerts a greater influence on inflation of net oil consuming states than on oil selling states. Nevertheless, oil price asymmetries appear to be more prevalent in oil exporting economies. Their findings show that the interaction between oil and inflation has a tendency to alter over time as Akkanni et al. (2017) illustrate that the reaction of inflation to fluctuations of the oil price became increasingly larger after the global financial recession. Their results are robust with respect to different proxies for oil prices and income levels.

Sek et al. (2015) made a different distinction than Akanni et al. (2017) by analysing the oil-inflation connection for countries that have a low versus high dependency on oil. This classification is based on an oil dependency index which is a measurement of the share of oil requirement relative to overall energy demand, energy diversity and economic reliance on oil (oil requirement per GDP) and the percent of net imports to oil use.

Additionally, they explore the relative impact of oil price changes in combination with other shocks like exchange rate fluctuations, domestic output and exporter's production costs. Their results reveal that oil returns have an explicit impact on the domestic inflation rate in countries that are not so much reliant on oil, however their influence is indirect on changing domestic inflation in countries that are highly dependent on oil by affecting the cost of production of exporting states. Their conclusion is that the important determinants of domestic inflation are the real exchange rate and the production costs for exporting nations (high oil dependency group) and domestic output and exporter's producing costs for the low oil dependency group.

Zhao et al. (2016) performed a case study to examine the effects of diversely natured oil price shocks, like supply shocks induced by political events in OPEC states, various other oil supply shocks, aggregate demand shocks for industrial commodities and demand variations due to crude oil market dynamics, on inflation and output in China and concluded short-term as well as long term effects on China's output of goods and services and inflation. Furthermore, their results demonstrate that extreme demand movements pertaining to the crude oil market contribute the most to the changes of China's inflation and output.

2.3.4. Monetary policy

The main objective of authorities concerned with monetary policy is to ensure price stability and therefore, they are continuously concerned with macroeconomic shocks and how they affect the enactment of their mandate. Since crude oil is a significant economic input factor, policy makers will likely very closely monitor the inflationary effects of oil and adjust their programmes accordingly. This is affirmed by Ferderer (1996) who noticed a significant correlation between oil price rises and counter-inflationary monetary reactions.

Bernanke et al. (1997) suggested that similar responses to major oil price shocks in 1973, 1979-1980 and 1990 let to subsequent recessions. Tatom (1993) and Balke et al. (2002) additionally observed monetary reactions towards oil price fluctuations. Tang et al. (2009) put forth that a contractionary reaction to oil price movements can also be seen in China since 2003 by continuous hiking interest rates. In contrast with the previous, Brown and Yücel (1999) put forth that previous U.S. monetary responses have been neutral to previous oil price movements. Their VAR model indicates that oil price shocks in fact lead to a decrease in real GDP, rate hikes of the federal funds rate and other interest rates as well as an increase in price levels.

3 Expected results

In the following section hypothesized interactions are discussed between macro-economic conditions, the renewable energy equity portfolio and the oil price.

3.1 Gross Domestic Product

The private sector that seeks high-yielding opportunities associated with low risk is expected to react to a growing economy by increasing their investments in the renewable energy industry. Additionally, governments are presumed to increase financial stimuli for the renewable energy sector as a result of decreased budget constraints. The increase of investments in the renewable energy sector is expected to positively impact renewable energy share returns.

The relationship between GDP and renewable energy equity responses is presumably linear as countries around the world have been investing significantly in this industry and so, increases in GDP are expected to congruently result in capital allocation by governments to the renewable energy sector.

Regarding oil, the majority of the present literature indicates a negative interaction between oil prices and GDP because of its inflationary effect on consumer goods and energy prices (Bruno & Sachs, 1982; Burbidge & Harrison, 1984; Darby, 1982; Hamilton, 1988; Mork et al., 1994). And since all investigated renewable energy companies operate in net oil importing countries, a negative linear correlation is presumed between oil and GDP.

Between the oil price and the renewable energy stock market a positive linear correlation is expected because higher oil prices enhance the viability of substituting alternative energy sectors like the renewable energy (Broadstock et al., 2012; Henriques & Sadorsky, 2008; Managi and Okimoto, 2013; Sadorksy, 2012a, 2012b; Wen et al., 2014).

This gives the following hypotheses **without** oil:
H_0: GDP has a negative or no effect on the renewable energy security market.
H_1: GDP has a positive effect on the renewable energy security returns.

With oil:
H_2: GDP has a negative or no effect on the renewable energy security market. Oil negatively affects GDP and therefore has an indirect adverse effect on the renewable energy equity market. Oil is also expected to have a direct positive effect on the renewable energy equity market.
H_3: GDP has a positive effect on the renewable energy security market. It is expected that oil has a negative or no impact on GDP and thus on the renewable energy equity market. Oil is also expected to have a direct negative or no effect on the renewable energy equity market.

3.2 Unemployment

As rising unemployment potentially signals a distressed economy and since it adversely affects aggregate demand, it is expected that an adverse linear interaction exists between the unemployment rate and renewable energy equity values.

Following previous research, the price of oil is expected to have a positive linear effect on unemployment because an increase in the price of oil raises production costs and consumer prices. This lowers aggregate demand that in turn is anticipated to raise unemployment

(Awerbuch & Sauter, 2006; Brown & Yucel, 1999, 2002; Carruth et al., 1998; Dohner, 1981; Fried & Schultze, 1975; Lardic & Mignon, 2006; Loungani, 1986; Pierce & Enzler, 1974; Mork, 1994; Tang et al., 2009).

Between the oil price and the renewable energy stock market a positive linear correlation is expected because higher oil prices enhance the viability of substituting alternative energy sectors like the renewable energy segment.

This gives the following hypotheses **without** oil:

H_4: Unemployment has a positive or no effect on the renewable energy equity market.
H_5: There is a negative correspondence between unemployment and the renewable energy equity market.

With oil:
H_6: There is a positive or no correspondence between unemployment and the renewable energy equity market. The price of oil has a negative or no correspondence with the renewable energy equity market.
H_7: There is a negative correspondence between unemployment and renewable energy equity market. The price of oil is expected to positively correspond with unemployment and the renewable energy equity market.

3.3 Inflation

Following a substantial amount of research that investigated the interaction between inflation and economic development and its impact on the stock market a negative linear interrelationship is assumed. Additionally, the notion that the renewable energy industry is largely dependent on research and development funding may add to this adverse interaction since inflation has been observed to induce credit rationing (Boyd, Choi & Smith, 1996; Boyd, Levine & Smith, 2001; Huybens & Smith, 1998; Huybens & Smith, 1999).

Oil presumably has a positive linear impact on inflation meaning that a higher oil price causes price-inflation of consumer goods through higher production costs. Oil price movements are also presumed to have a positive linear relationship with the renewable energy equity market (Çatik & Önder, 2011; Chen, 2009; Chou and Lin, 2013; Gao et al., 2014; Ibrahim & Chanchaoroenchai, 2014; Lu et al., 2010; Valadkhani, 2014).

The following hypotheses are examined:

Without oil:
H_7: There is a positive or no correspondence between inflation and renewable energy stocks.
H_8: There is a negative correspondence between inflation and renewable energy stocks.

With oil (H_6):
H_9: There is a negative correspondence between inflation and renewable energy stocks. Oil has a positive correspondence with inflation as well as renewable energy stocks.
H_{10}: There is a positive or no correspondence between inflation and renewable energy stocks. Oil has a negative or no correspondence with inflation as well as renewable energy stocks.

3.4 Monetary policy

Central bankers' preeminent concern is maintaining a stable economy which includes the stock market. Their policies and announcements thereof have shown to largely influence stock market movements. Prior research shows that looser monetary programs have a stimulating effect on stock markets as result from increased investments induced by lower costs of capital, and that tightening of the money supply by the Fed results in stock price drops. Therefore, expectations are that monetary policy negatively and linearly correlates with the renewable energy stock market meaning that looser monetary policy described as lower interest rates positively affect renewable energy share values (Bernanke & Kuttner, 2004; Hung & Ma, 2017; Jensen et al., 1996; Thorbecke, 1997; Weller, 2002).

The price of oil is assumed to have a positive and linear interaction with monetary policy meaning that inflation of the oil price is expected to induce counter-inflationary measures by central banks in the form of higher interest rates. Oil, as mentioned earlier, is presumed to have a positive linear correlation with the renewable energy stock market (Balke et al., 2002; Bernanke et al., 1997; Brown & Yücel, 1999; Tang et al., 2009; Tatom, 1993).
The following is hypothesized:

Without oil:

H_{11}: There is a positive relationship between monetary policy and renewable energy equities.

H_{12}: There is a negative or no relationship between monetary policy and renewable energy equities.

With oil:

H_{13}: There is a positive relationship between monetary policy and renewable energy equities. Oil is expected to have a positive correlation with monetary policy and with renewable energy equities.

H_{14}: There is a negative or no relationship between monetary policy and renewable energy equities. Oil is expected to have a negative or no correlation with monetary policy and with renewable energy equities.

4 Research design

This part describes the theoretical constructs, relations, the applied methods and data to investigate the effect of macro-economic determinants on the renewable energy stock market as well as the effect of the price of oil on both. To profoundly determine how the oil price affects the macro-economic factors, an in-depth research including all factors that determine GDP, unemployment, inflation and monetary policy must be performed, which goes beyond the scope of this study. This will be approached with a different method: first, linear univariate regressions are performed both with and without the price of oil included as a control variable. To examine hypothesized interactions more closely, the R&D sector and solar stock subsets are further analysed.

Secondly, a mediation analysis is performed with a multivariate model that incorporates all four independent variables and the oil price. The dependent variable in all regressions is the renewable energy stock portfolio or a subset thereof.

For instance, renewable energy sectors that make use of technology that is still in development and in need of R&D funding could be more affected by changes in interest rates than renewable energy segments that are more advanced.

renewable energy sectors that make use of technology that is still in development and in need of R&D funding could be more affected by changes in interest rates than renewable energy segments that are more advanced.

4.1 Estimated models

In this section, the regression models and the relationship between the independent variables, the dependent variable and the mediating variable are laid out.

4.1.1. Gross Domestic Product growth

The assumed positive and linear interrelationship between GDP growth and renewable energy equities, the expected negative and linear relation between oil and GDP and the positive linear correlation between oil and renewable energy stocks is described by the following estimated model:

Without the price of oil: $Y= B_0 + B_1T + E$

With the price of oil: $Y= (B_0 + B_1 T - T*Z) *Z + E$ with $Z> 0$

Where B_0 = constant, B_1 = parameter renewable energy share values, Y = dependent variable, T= GDP, Z = the oil price, and E= the error term.

4.1.2. Unemployment

The expected negative linear relationship between unemployment and the renewable energy equity market, the assumed positive linear interaction between the oil price and unemployment and the expected positive interaction between the oil price and the renewable energy market is approached with this estimated model:

Without the price of oil $Y= B_0 – B_1U + E$ (U> X)

With the price of oil: $Y= (B_0 – B_1U + U*Z) *Z + E$ with $Z> 0$

Where B_0 = constant, B_1 = parameter renewable energy share values, Y = renewable energy share values, U= the unemployment rate, Z = the oil price, and E= the error term.

4.1.3. Inflation

The assumed negative linear interaction between inflation and renewable energy equities and expected positive linear correlations between oil and both inflation and the renewable energy equity market will be approached with the following estimated model:

Without the price of oil: $Y = B_0 - B_1 V + E$

With the price of oil: $Y = (B_0 - B_1 V + V*Z) *Z + E$ with $Z > 0$

Where B_0 = constant, B_1 = parameter renewable energy share values, Y = renewable energy share values, V= the inflation rate, Z = the oil price, and E= the error term.

4.1.4. Monetary Policy

It is assumed that monetary policy has a linear and negative correlation with the renewable energy security portfolio which means that lower interest rates positively influence the renewable energy stock market. Additionally, it is expected that oil positively impacts renewable energy equities and positively correlates with monetary policy reflecting the assumption that oil price inflation leads to higher interest rates.

This gives the estimated model accordingly:

Without the price of oil: $Y = B_0 - B_1 W + E$

With the price of oil: $Y = (B_0 - B_1 W + W*Z) *Z + E$ with $Z > 0$

Where B_0 = constant, B_1 = parameter renewable energy share values, Y = renewable energy share values, W= monetary policy (interest rates), Z = the oil price, and E= the error term.

4.1.5. Mediation analysis

To further examine the hypothesized correlations, a mediating interrelationship is considered between the observed predictors where an intervening variable (*the mediator)* influences the relationship between two other variables. Mediation presumes a time-related and causal interaction between the three investigated factors (cause, intervene, response). Since determinants in a causal relationship can be both a cause and an effect, structural equation modelling (SEM) offers an applicable theoretical paradigm because variables are not beforehand identified as (in)dependent variables. SEM incorporates factors that are both endogenous and exogenous which makes it more suitable to determine dynamic multivariate relationships compared to a normal regression model.

Endogenous variables function as a dependent variable in one of the SEM equations and act as an independent variable in another equation within the structural equation model. Exogenous variables act only as an independent variable. SEM also allows for multiple independent, mediating or dependent variables in contrast to a normal regression that requires combined models to make inferences on indirect and total effects.

Thus, the causal interactions of hypothesized relationships, the coincident effect of indirect and direct effects and the dual nature of mediators being both a cause for the result and an effect of the intervening factor are more accurately approached with a structural equation model than a regular regression analysis. (Baron & Kenny, 1986, Fairchild & Mackinnon, 2009; Kazdin et al., 2001).

In the context of this analysis, oil is treated as the independent variable, the four macro-economic variables as the mediators and the renewable energy stock portfolio as the dependent variable. The SEM model is depicted in the following path diagram:

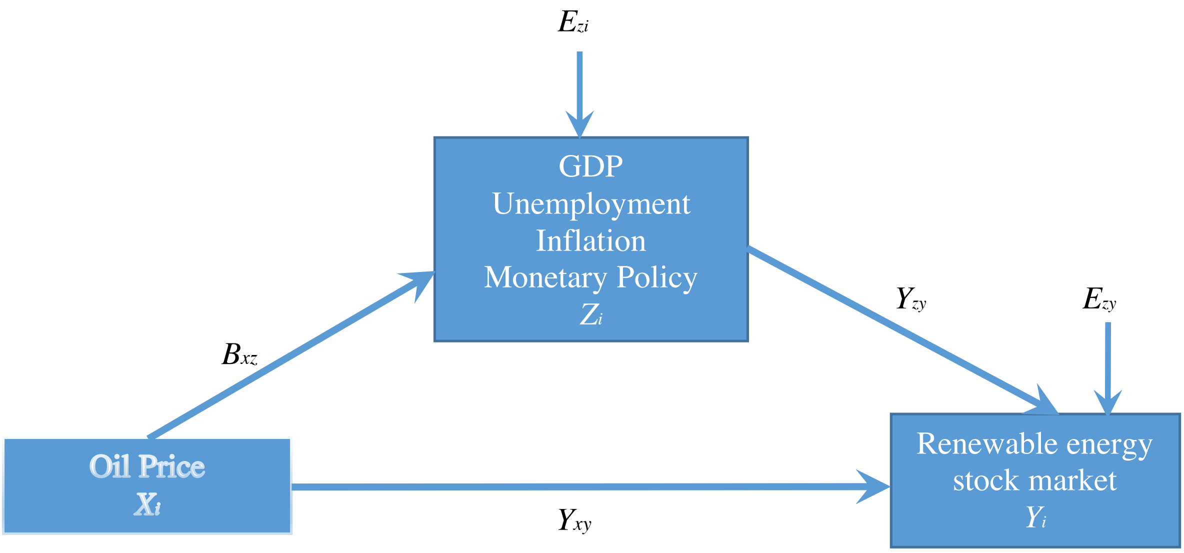


Figure 1: path diagram mediation analysis

The SEM for this mediation model for the *i*th subject ((1 ≤ *i* ≤ *n*) is given by:

$$\boldsymbol{Z_i = B_0 + B_{xz}x_i + E_{zi},}$$
$$\boldsymbol{Y_i = Y_0 + Y_{zy}Z_i + Y_{xy}X_i + E_{yi}}$$

The error terms (E_{zi}, E_{yi}) are assumed to be uncorrelated which is consequential for causal inferences. Multivariate normality for the error term is assumed. The two structural equations are combined and inferences on them is coincident in contrast to two independent normal regression models.

The *direct effect* is the pathway from the exogenous factor to the dependent variable which is depicted in the path diagram with Y_{xy}. The *indirect effect* is described by the pathway from the exogenous determinant to the independent variable through the mediator which is B_{xz} and Y_{zy}. The *total effect* is the sum of the direct and indirect effects of the exogenous variable on the outcome, $Y_{xy} + B_{xz}Y_{zy}$.

The mediation analysis reveals whether the impact of the intervening factor on the dependent variable can be mediated by another factor. In a completely mediated interaction, the relationship is fully affected by the mediating variable and given the presence of the mediating determinant, the pathway from the independent variable to the dependent factor is completely disconnected and so, the intervening variable has no direct impact on the end result. With partial mediation, the independent variable has some residual direct impact even after the introduction of the mediating variable.

In terms of testing the primary hypothesis of interest, we start by examining a reduced regression equation without the mediator: $\boldsymbol{Y_i = Y^*_0 + Y^*_{xy} X_i + E^*_{yi}}$

If the null hypothesis is accepted (H_0: $\gamma^*_{xy}=0$) for this reduced model, then the intervention and outcome (denoted as x and y) are uncorrelated and no mediating effect exists. In that case, the SEM is determined with the mediation equation. A completely mediated correspondence, which means that the intervening variable has no direct impact on the end result, is reflected by the following null hypothesis, H_0: $\gamma_{xy}=0$. If the null hypothesis is rejected, partial mediation can possibly be observed with inferences on direct, indirect and total effects (Sobel, 1982).

4.2 Data

This section explains the data that has been used to analyse the effects of the macro-economic variables on the renewable energy stock market. Furthermore, the chosen data regarding oil is discussed.

4.2.1. The renewable energy stock portfolio

The renewable energy security portfolio has been provided by thesis supervisor M. Kilic. The received information contained the names of the corporations, background information including the sub industry they are involved in (biomass, wave/ocean, photovoltaics, concentrated solar, geothermal, wind, hydro, energy efficiency, energy storage, other), the geographical location they are situated, different roles they assume in the value chain (R&D, manufacturing, re-assembly, services, energy generation, transportation to last recipient) and whether or not they are 'pure' which indicates whether a corporation is solely operational in the renewable energy sector and does not have a mixed diversified business model. The portfolio is comprised of 261 stocks, 31 of which have been deleted due to lack of available data because of de-listings, mergers and acquisitions.

This thesis only investigates 'pure' stocks (131) because those historical stock returns show more accurately how renewable energy equities react to changing macro-economic conditions compared to share values of companies that have assorted business models with non-renewable energy branches. Including those stocks could give biased results as stocks of diversified companies would be impacted by more factors than just variables that pertain to the renewable energy sector and furthermore, they would be less dependent on macro-economic conditions that affect the renewable energy sector.

The historical stock values have been downloaded from Yahoo Finance. Because stock returns differ amongst trade exchanges, there has been looked at picking the most appropriate stock exchange. As much as possible, the same stock exchanges have been selected and also there has been looked at picking stock exchanges that are based in the corporations' home country because arguably, local stock exchanges better reflect changes in company performances due to information asymmetries.

When local stock exchanges were unavailable, German stock exchanges (Frankfurt, Stuttgart, Xetra) have been used for several reasons. Firstly, the majority of the equities trade on German stock exchanges so in order to pick the same stock exchanges, Stuttgart, Frankfurt and Xetra were most suited. Secondly, Germany is a prominent market for the renewable energy sector and Germany provides a solid proxy for global economic conditions as it serves as the largest European economy and is a prominent global trading partner.

R&D and solar

To further examine the hypotheses, regressions are also performed with only solar industry – and r&d stocks. If the hypothesized interactions are valid, these sub segments could be more affected by certain macro-economic variables in comparison to the whole portfolio and show stronger reactions.

The solar industry and its relationship with GDP growth is examined because growth in GDP is assumed to decrease government budget constraints and increase renewable energy incentives and subsidies. With regards to Reboredo's (2014) assertion that the solar sector has been the largest recipient of government stimuli, this could show itself in a stronger connection with growth in GDP. Further, the r&d segment is investigated with regards to monetary policy and inflation. The renewable energy sector is presumed to be highly reliant on available and affordable sources of liquidity due to the need for r&d, capacity increases and economies of scale. Increasing interest rates (see: monetary policy) increase the cost of capital and therefore are expected to strain r&d companies more in comparison to the whole portfolio.

Additionally, r&d companies and their correspondence with inflation is examined. Above, the premise that r&d companies are reliant on r&d funding and thus, on available and affordable sources of liquidity was explained. Since inflation has been observed to prompt credit rationing (Boyd et al., 1996), r&d companies are expected to be more strained by inflation than the stock portfolio as a whole.

The investigated time period, which ranges from 2004 to 2014, has been chosen to obtain a large dataset that incorporates different economic conditions (the 2008 financial crisis is included). Monthly data is used because the highest available frequency of macro-economic data is monthly.

In the following sub segments, data on the macro-economic determinants is discussed. German economic data has been deemed as the most appropriate proxy for the macro-economic determinants for the reasons that the majority of the security returns are taken from German stock exchanges and domestic stock exchanges are assumed to better reflect effects of regional changing economic conditions. Furthermore, Germany is a notably important market for the renewable energy industry and the global economy.

4.2.2. Gross Domestic Product

Economic growth, reflected by an increase in GDP, may have positive effects on the renewable energy industry through sub sequential increases in private domestic and foreign investments as well as increases in public stimulus for the renewable energy industry due to higher government budget limits. Since the researched businesses are situated in different markets globally, it is important to determine which country's gross domestic product number is most appropriate. German GDP data from 2004 to 2014 is used and has been downloaded from the Eurostat website.

This regression is also performed exclusively with solar energy securities to ascertain how they correlate with GDP growth compared to different equity subsectors. According to the hypothesis that renewable energy securities may be tied to a countries' GDP through increased investments in this sector, potentially induced by government incentives, and Reboredo's (2014) assertion that the solar energy industry is the largest recipient of government stimulus, this sector is expected to have a stronger relation with GDP than other renewable energy sectors.

4.2.3. Unemployment

Rising unemployment is expected to pressure an economy and strain the renewable energy (equity markets) due to lower aggregate demand. To examine its effect on the renewable energy equity market, German data has been selected ranging from 2004 to 2014, which is supplied by Eurostat.

4.2.4. Inflation

To scrutinise the impact of inflation on the renewable energy stock market, German consumer price index numbers are used that are downloaded from the Eurostat website.
The CPI statistics, that range from 2004 to 2014, are indicated in units of percent change. The presumption that the renewable energy sector suffers from inflation comes from the observed incitement of credit rationing by inflation (Boyd et al., 1996) and the notion that the renewable energy sector is dependent on sufficient and affordable funding to maintain developing existing and new technologies. To further investigate this premise, this regression is performed with stocks only from research-and-development companies to research whether this sub segment is more correlated with inflation in comparison to the pure portfolio.

4.2.5. Monetary policy

In order to assess the influence of central bank policy on renewable energy securities, the ECB key interest rate is used. The Refinancing Tender is the interest rate at which depository institutions have access to liquidity at the ECB, which in turn affects the interest rates financial institutions charge to the private sector and thus to the renewable energy industry. Furthermore, the ECB steers the European economy, including Germany, which is a major market for the renewable energy industry.

4.2.6. Crude Oil price

The data on oil that is used is the spot price in dollars per barrel crude oil. Crude oil is the most traded form of oil and therefore presumably has the most explanatory value in the matter of the impact of oil prices on the renewable energy equity market. Data is provided by US Energy Information Administration and ranges from 2004 to 2014.

5 Analysis

The following section lays out the statistical results. First, the pure stock portfolio is discussed. Secondly, the findings regarding the solar industry and R&D stock segments are described. Stock returns are regressed using cumulative returns, average returns, adjusted cumulative returns and adjusted average returns. The adjusted returns are abnormal returns minus the European risk-free rate (30-year US Treasury bonds downloaded from the Fama and French website).

5.1 Pure stocks

The pure equity portfolio is analyzed by reviewing univariate regressions and a multivariate model. The impact of the crude oil price is examined by comparing regressions with and without the price of oil included as a control variable. Further, the entire causal framework has been approached with a structural equation model that treated each of the macro-economic variables as mediators between the price of oil and the renewable energy stock market. The descriptive statistics are shown below (Table 1 and 2).

	CR-Pure-adj	AR-pure-adj	CR-pure	AR-pure
Min.	-123.5047	-.9574	-18.9560	-.2430
Max.	137.4306	1.0654	32.4355	.6360
Obs	177	177	177	177
Mean	7.4618	0.0578	1.1550	0.0187
Std. Dev.	33.0044	0.2558	6.4988	0.0918
Variance	1089.2910	0.0654	42.2339	0.0084
Skewness	1.7978	1.7978	1.4877	1.7338
Kurtosis	10.2599	10.2599	9.6264	14.0536

Table 1: descriptive statistics of cumulative and average (adjusted) returns.

	Unemployment	Inflation	Monetary Policy	GDPgrowth	Oil	dOIL
Min.	5.8	-.9122	0.0698	0.9789	39.0877	.7175013
Max.	8.7	2.5934	5.2591	1.0121	133.88	1.226401
Obs	121	121	121	121	108	107
Mean	7.045455	.2383	1.5945	1.0049	84.34481	1.002962
Std. Dev.	.7613584	.5961295	2.007904	.0057604	18.89706	.0863359
Variance	.5796667	.3553704	4.031678	.0000332	357.099	.0074539
Skewness	.3085691	.6889758	.8513337	-1.477977	-.0751586	-.6862301
Kurtosis	2.309559	4.227821	2.014846	5.92496	2.919224	4.682004

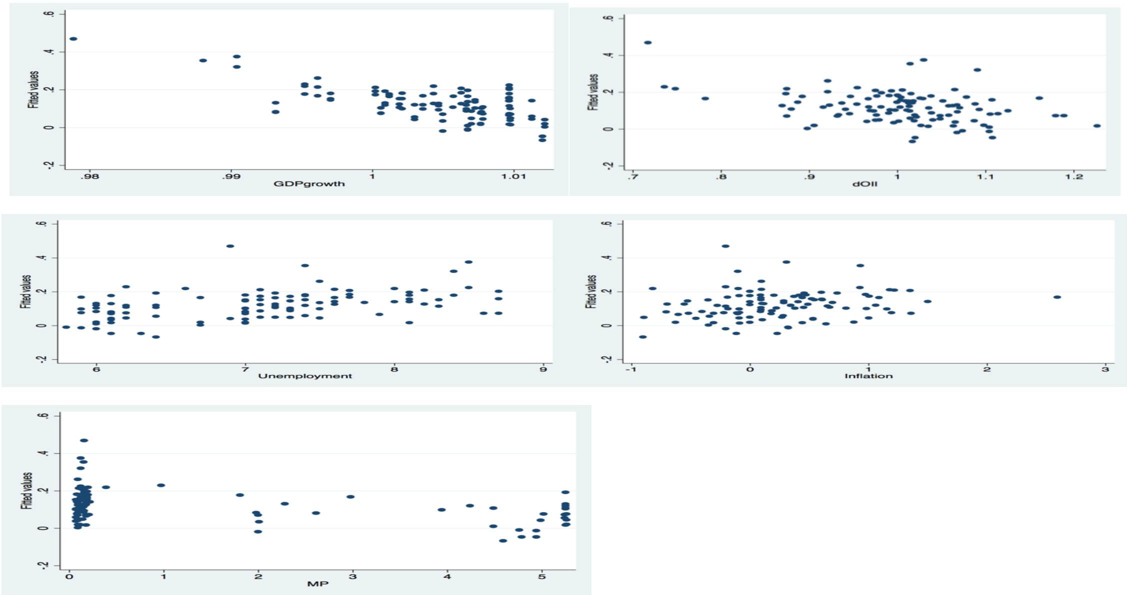
Table 2: descriptive statistics of macroeconomic predictors.

5.1.1. Testing for parametric assumptions.

The data has been tested for:

1. Linearity by examining the scatterplot of the predicted values and independent variables.
2. Independence of variables by testing for multicollinearity between independent variables. Autocorrelation in variables has been corrected with time-series regressions.
3. Normality by looking at the kurtosis and skewness of the variables and performing a Shapiro Wilk test.
4. Equality of variance by analysing the scatterplots of the residuals and a Durbin Watson test.

The residual scatterplots of the growth in GDP, change in oil price, unemployment, inflation and monetary policy all demonstrate linear correlations and non-equally distributed variances.



The provided stock returns have been corrected for data dependency which could originate from periodic stock data collections or from multicollinearity between highly correlated predictor variables, like for example: inflation, the oil price and monetary policy.

Skewness and Kurtosis have been assessed by checking against the norm values of -2 and 2. Further, the results have been tested for normality by performing a Shapiro-Wilk test.

Variable	Obs	z	Prob> z
CRPureadj	177	8.192	0.0000***
ARpureadj	177	8.192	0.0000***
CRPure	177	6.708	0.0000***
ARpure	177	6.239	0.0000***
Unemployment	121	2.500	0.00622**
Inflation	121	2.309	0.01047**
Monetary Policy	121	7.372	0.0000***
GDP Growth	121	5.591	0.0000***
Oil	108	0.831	0.20288
dOIL	107	3.046	0.00116***

Table 3: The Shapiro-Wilk test.
* indicates a p-value of smaller than 0.1, ** indicates a p-value of smaller than 0,05, *** indicates a p value of smaller than 0,01.

The Shapiro-Wilk test states that all variables except for oil are not-normally distributed. The Shapiro-Wilk test is less accurate for larger samples and might overstate the non-normal distribution here as the z-scores are not confirmed by the observed kurtosis and skewness. Therefore, the data is assumed to be near normally distributed and no transformations have been applied to the data. The following correlation table illustrates how the predictors affect the renewable energy equity returns.

GDP-Growth	Cumulative return adjusted Oil	Average return, adjusted dOIL	Cumulative return	Average return	Unemployment	Inflation	Monetary P
Cumulative return adjusted	1.000						
Average return, adjusted	1.0000	1.0000					
Cumulative return	0.0683	0.0683	1.0000				
Average return	0.0614*	0.0614*	0.9559	1.0000			
Unemployment	0.1279	0.1279	0.0450**	0.0047***	1.0000		
Inflation	0.0482	0.0482	0.1476	0.1394	-0.0617*	1.0000	
Monetary policy	-0.1336	-0.1336	0.0268**	0.1169	-0.7406	0.1210	1.0000
GDP growth	-0.2393	-0.2393	0.1829	0.1822	0.1626	0.1551	-0.0007***
Oil	-0.0736*	-0.0736*	– 0.0339	-0.1139	-0.1319	– 0.0073***	-0.3125
dOIL	-0.1267	-0.1267	0.1841	0.1520	0.1512	0.0616**	0.0899**

Table 4: correlation table.
* indicates a p-value of smaller than 0.1, ** indicates a p-value of smaller than 0,05, *** indicates a p value of smaller than 0,01.

5.1.2. Testing the hypotheses

The effects of the univariate pure stock regressions are shown below in table 5 and 6. The cumulative adjusted and average adjusted returns (adjusted with a market benchmark: 30-year

US Treasury Bonds) attain the highest significance (both 11.8%) with GDP growth as the only significant variable.

VARIABLES	CR pure Model 1	AR pure Model 2	CR adj pure Model 3	AR adj pure Model 4
Unemployment	0.813	0.0196	7.018	0.0544
	(1.417)	(0.0181)	(6.553)	(0.0508)
Inflation	1.685	0.0212	7.539	0.0584
	(1.190)	(0.0152)	(5.503)	(0.0427)
MP	0.254	0.0111	-1.211	-0.00938
	(0.535)	(0.00684)	(2.471)	(0.0192)
GDPgrowth	192.6	2.321	-1.899***	-14.72***
	(126.7)	(1.622)	(586.0)	(4.542)
Constant	-198.5	-2.470	1.870***	14.49***
	(125.0)	(1.601)	(578.1)	(4.481)
Observations	121	121	121	121
R-squared	0.050	0.073	0.118	0.118

Table 5: single factor models without the oil price included (standard errors in parentheses). *** p<0.01, ** p<0.05, * p<0.1

GDP growth has a mild negative interaction (-1.899) with the cumulative adjusted pure returns and a substantially negative (-14.72) impact on the average adjusted pure returns.

Table 6 below displays the regressions with the crude oil price included. Again, the cumulative adjusted and average adjusted attain the highest significance (11.0%), with GDP growth as the only significant factor (CR= -1.747; AR= -13.55).

VARIABLES	(CR pure) Model 1	(AR pure) Model 2	(CR pure adj) Model 3	(AR pure adj) Model 4
Unemployment	0.146	0.0134	10.32	0.0800
	(1.579)	(0.0201)	(7.280)	(0.0564)
Inflation	1.656	0.0177	7.232	0.0561
	(1.389)	(0.0176)	(6.403)	(0.0496)
MP	0.0393	0.00890	0.428	0.00332
	(0.614)	(0.00780)	(2.830)	(0.0219)
GDPgrowth	188.5	2.355	-1.747***	-13.55***
	(137.7)	(1.750)	(635.1)	(4.923)
dOIl	14.34	0.112	-54.88	-0.425
	(9.717)	(0.123)	(44.80)	(0.347)
Constant	-203.7	-2.569	1.748***	13.55***
	(135.7)	(1.724)	(625.5)	(4.849)
Observations	107	107	107	107
R-squared	0.071	0.073	0.110	0.110

Table 6: single factor models with the oil price included (standard errors in parentheses). *** p<0.01, ** p<0.05, * p<0.1

These results do not provide evidence to support any hypotheses as the explanatory power is far too low ($R^2 \leq$ 11.0%).

5.1.3. Structural equation modelling

To accurately take into account the theoretical framework between oil prices, macro-economic factors and renewable energy stock markets, a structural equation model is used. The SEM takes into account the direct effect of oil on the renewable energy stock portfolio combined with an indirect effect of the oil price on renewable energy stocks through its effect on GDP, unemployment, inflation and monetary policy. GDP growth was the only predictor that attained significant results (table 5) and therefore, oil can only have an indirect effect through its potential effect on GDP growth. Because the cumulative and average adjusted returns provided significant univariate regression results, these returns are used in the structural equation model.

Table 7, 8 and 9 show the results of the effect of changing oil prices on the cumulative adjusted pure returns.

Direct effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	1.401114	.8853751	1.58	0.114	-.3341897	3.136417
Inflation <-						
dOIl	.4120809	.6454384	0.64	0.523	-.8529551	1.677117
MP <-						
dOIl	2.112544	2.261472	0.93	0.350	-2.319859	6.544948
GDPgrowth <-						
dOIl	.0115028	.0065955	1.74	0.081	-.0014241	.0244298
CRPure <-						
Unemployment	.1462855	1.533946	0.10	0.924	-2.860194	3.152765
Inflation	1.656341	1.34925	1.23	0.220	-.9881416	4.300823
MP	.0393348	.5962463	0.07	0.947	-1.129287	1.207956

GDPgrowth	188.5254	133.8295	1.41	0.159	-73.77569	450.8265
dOIl	14.34159	9.440649	1.52	0.129	-4.161742	32.84492

Table 7: mediation analysis (cumulative adjusted returns pure portfolio).

Indirect effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	0	(no path)				
Inflation <-						
dOIl	0	(no path)				
MP <-						
dOIl	0	(no path)				
GDPgrowth <-						
dOIl	0	(no path)				
CRPure <-						
Unemployment	0	(no path)				
Inflation	0	(no path)				
MP	0	(no path)				

Table 8: mediation analysis (cumulative adjusted returns pure portfolio).

Total effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	1.401114	.8853751	1.58	0.114	-.3341897	3.136417
Inflation <-						
dOIl	.4120809	.6454384	0.64	0.523	-.8529551	1.677117
MP <-						
dOIl	2.112544	2.261472	0.93	0.350	-2.319859	6.544948
GDPgrowth <-						
dOIl	.0115028	.0065955	1.74	0.081	-.0014241	.0244298
CRPure <-						
Unemployment	.1462855	1.533946	0.10	0.924	-2.860194	3.152765
Inflation	1.656341	1.34925	1.23	0.220	-.9881416	4.300823
MP	.0393348	.5962463	0.07	0.947	-1.129287	1.207956
GDPgrowth	188.5254	133.8295	1.41	0.159	-73.77569	450.8265
dOIl	17.48077	8.997997	1.94	0.052	-.1549755	35.11652

Table 9: mediation analysis (cumulative adjusted returns pure portfolio).

Based on these results, no effect can be concluded of changes in oil prices (dOil) on the cumulative adjusted pure returns.

Direct effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	1.401114	.8853751	1.58	0.114	-.3341897	3.136417
Inflation <-						
dOIl	.4120809	.6454384	0.64	0.523	-.8529551	1.677117
MP <-						
dOIl	2.112544	2.261472	0.93	0.350	-2.319859	6.544948
GDPgrowth <-						
dOIl	.0115028	.0065955	1.74	0.081	-.0014241	.0244298
ARpure <-						
Unemployment	.0134374	.0194905	0.69	0.491	-.0247632	.0516381
Inflation	.0177281	.0171437	1.03	0.301	-.015873	.0513291
MP	.0089007	.007576	1.17	0.240	-.0059479	.0237493
GDPgrowth	2.355345	1.700452	1.39	0.166	-.9774805	5.68817
dOIl	.1115453	.1199539	0.93	0.352	-.12356	.3466506

Table 10: mediation analysis (average adjusted returns pure portfolio).

Indirect effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	0	(no path)				
Inflation <-						
dOIl	0	(no path)				
MP <-						
dOIl	0	(no path)				
GDPgrowth <-						
dOIl	0	(no path)				
ARpure <-						
Unemployment	0	(no path)				
Inflation	0	(no path)				
MP	0	(no path)				
GDPgrowth	0	(no path)				
dOIl	.0720291	.0517182	1.39	0.164	-.0293368	.173395

Table 11: mediation analysis (average adjusted returns pure portfolio).

Total effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	1.401114	.8853751	1.58	0.114	-.3341897	3.136417
Inflation <-						
dOIl	.4120809	.6454384	0.64	0.523	-.8529551	1.677117
MP <-						

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
dOIl	2.112544	2.261472	0.93	0.350	-2.319859	6.544948
GDPgrowth <-						
dOIl	.0115028	.0065955	1.74	0.081	-.0014241	.0244298
ARpure <-						
Unemployment	.0134374	.0194905	0.69	0.491	-.0247632	.0516381
Inflation	.0177281	.0171437	1.03	0.301	-.015873	.0513291
MP	.0089007	.007576	1.17	0.240	-.0059479	.0237493
GDPgrowth	2.355345	1.700452	1.39	0.166	-.9774805	5.68817
dOIl	.1835744	.1164134	1.58	0.115	-.0445917	.4117405

Table 12: mediation analysis (average adjusted returns pure portfolio).

Interpreting the results above, it follows that no effect of changes in oil prices on average adjusted pure returns exists.

Now, the results of the structural equation model in combination with the univariate model is discussed regarding the cumulative adjusted pure returns.

Direct effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	1.401114	.8853751	1.58	0.114	-.3341897	3.136417
Inflation <-						
dOIl	.4120809	.6454384	0.64	0.523	-.8529551	1.677117
MP <-						
dOIl	2.112544	2.261472	0.93	0.350	-2.319859	6.544948
GDPgrowth <-						
dOIl	.0115028	.0065955	1.74	0.081	-.0014241	.0244298
CRPureadj <-						
Unemployment	10.31573	7.072539	1.46	0.145	-3.546188	24.17765
Inflation	7.232276	6.220964	1.16	0.245	-4.96059	19.42514
MP	.4277913	2.749102	0.16	0.876	-4.96035	5.815932
GDPgrowth	-1747.461	617.0454	-2.83	0.005	-2956.848	-538.0745
dOIl	-54.88161	43.52783	-1.26	0.207	-140.1946	30.43137

Table 13: SEM cumulative adjusted pure returns.

Indirect effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	0	(no path)				
Inflation <-						
dOIl	0	(no path)				
MP <-						
dOIl	0	(no path)				

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
GDPgrowth <-						
dOIl	0	(no path)				
CRPureadj <-						
Unemployment	0	(no path)				
Inflation	0	(no path)				
MP	0	(no path)				
GDPgrowth	0	(no path)				
dOIl	-1.763239	21.68354	-0.08	0.935	-44.2622	40.73572

Table 14: SEM cumulative adjusted pure returns.

Total effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	1.401114	.8853751	1.58	0.114	-.3341897	3.136417
Inflation <-						
dOIl	.4120809	.6454384	0.64	0.523	-.8529551	1.677117
MP <-						
dOIl	2.112544	2.261472	0.93	0.350	-2.319859	6.544948
GDPgrowth <-						
dOIl	.0115028	.0065955	1.74	0.081	-.0014241	.0244298
CRPureadj <-						
Unemployment	10.31573	7.072539	1.46	0.145	-3.546188	24.17765
Inflation	7.232276	6.220964	1.16	0.245	-4.96059	19.42514
MP	.4277913	2.749102	0.16	0.876	-4.96035	5.815932
GDPgrowth	-1747.461	617.0454	-2.83	0.005	-2956.848	-538.0745
dOIl	-56.64485	43.61711	-1.30	0.194	-142.1328	28.84312

Table 15: SEM cumulative adjusted pure returns.

The results above demonstrate a negative effect of changes in oil prices (dOil) via GDP growth ($p < 0.1$) on the cumulative adjusted pure returns with a coefficient of (-1747.461). This interaction therefore holds that when the oil price goes up with 1.0 this, through its impact on GDP growth, ends up with renewable energy stocks going down with 1747.461. This seems to be an outlier and will be further discussed in the conclusion.

The results of the average adjusted pure returns obtained with the structural equation model in combination with the univariate model is described below.

Direct effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	1.401114	.8853751	1.58	0.114	-.3341897	3.136417
Inflation <-						
dOIl	.4120809	.6454384	0.64	0.523	-.8529551	1.677117

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
MP <-						
dOIl	2.112544	2.261472	0.93	0.350	-2.319859	6.544948
GDPgrowth <-						
dOIl	.0115028	.0065955	1.74	0.081	-.0014241	.0244298
ARpureadj <-						
Unemployment	.0799669	.0548259	1.46	0.145	-.0274898	.1874237
Inflation	.0560642	.0482245	1.16	0.245	-.0384542	.1505825
MP	.0033162	.0213109	0.16	0.876	-.0384523	.0450847
GDPgrowth	-13.54621	4.783298	-2.83	0.005	-22.9213	-4.17112
dOIl	-.4254388	.337425	-1.26	0.207	-1.08678	.2359021

Table 16: SEM average adjusted pure returns.

Indirect effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	0	(no path)				
Inflation <-						
dOIl	0	(no path)				
MP <-						
dOIl	0	(no path)				
GDPgrowth <-						
dOIl	0	(no path)				
ARpureadj <-						
Unemployment	0	(no path)				
Inflation	0	(no path)				
MP	0	(no path)				
GDPgrowth	0	(no path)				
dOIl	-.0136685	.1680895	-0.08	0.935	-.3431178	.3157808

Table 17: SEM average adjusted pure returns.

Total effects

	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
Structural						
Unemployment <-						
dOIl	1.401114	.8853751	1.58	0.114	-.3341897	3.136417
Inflation <-						
dOIl	.4120809	.6454384	0.64	0.523	-.8529551	1.677117
MP <-						
dOIl	2.112544	2.261472	0.93	0.350	-2.319859	6.544948
GDPgrowth <-						
dOIl	.0115028	.0065955	1.74	0.081	-.0014241	.0244298
ARpureadj <-						
Unemployment	.0799669	.0548259	1.46	0.145	-.0274898	.1874237
Inflation	.0560642	.0482245	1.16	0.245	-.0384542	.1505825
MP	.0033162	.0213109	0.16	0.876	-.0384523	.0450847
GDPgrowth	-13.54621	4.783298	-2.83	0.005	-22.9213	-4.17112
dOIl	-.4391073	.3381171	-1.30	0.194	-1.101805	.22359

Table 18: SEM average adjusted pure returns.

The results show a total negative effect of changes in oil prices (dOil) on average adjusted pure returns via GDP growth at p< 0.1 that goes as follows: when oil prices go up by 1, renewable energy stocks go down by -13.55 through their impact on GDP growth (.011502).

5.2 Subsets of pure stock portfolio

To better understand renewable energy stock market dynamics, two sub segments of the pure portfolio are examined in depth. Following hypothesized interactions, these security segments could demonstrate a stronger correlation with specific macro-economic determinants. A closer look is taken at the solar stock market and the renewable energy r&d equity market.

Solar

In light of Reboredo's (2014) notion that the solar industry has been the largest recipient of government financial stimulus and the hypothesized relationship between a state's welfare and its priority towards renewable energy, this indirect presumed interaction is tested by analysing the solar industry equities in the pure portfolio (63). The results are given below (table 19 and 20).

VARIABLES	CR solar Model 1	AR solar Model 2	CR adj solar Model 3	AR adj solar Model 4
Unemployment	2.494	0.0349	6.910	0.116
	(2.085)	(0.0234)	(4.378)	(0.0855)
Inflation	0.847	0.0110	3.605	0.0857
	(1.751)	(0.0197)	(3.677)	(0.0588)
MP	0.223	0.00816	0.111	-0.00869
	(0.786)	(0.00884)	(1.651)	(0.0345)
GDPgrowth	**232.9**	**2.600**	**-1,279*****	**-22.63*****
	(186.5)	(2.096)	(391.5)	(7.646)
Constant	-249.3	-2.839	1,243***	22.07***
	(184.0)	(2.068)	(386.3)	(7.342)
Observations	121	121	121	77
R-squared	0.043	0.047	0.113	0.210

Table 19: solar energy stocks without oil (standard errors in parentheses).
*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	CR solar Model 1	AR solar Model 2	CR adj solar Model 3	AR adj solar Model 4
Unemployment	2.137	0.0308	9.009*	0.135
	(2.348)	(0.0262)	(4.903)	(0.0978)
Inflation	0.619	0.00630	3.688	0.0877
	(2.065)	(0.0231)	(4.313)	(0.0760)
MP	0.143	0.00673	1.027	0.000263
	(0.913)	(0.0102)	(1.906)	(0.0396)

GDPgrowth	**246.6**	**2.736**	**-1,210*** **	**-19.97** **
	(204.8)	(2.290)	(427.8)	(9.234)
dOIl	8.245	0.0725	-38.07	-0.491
	(14.45)	(0.162)	(30.18)	(0.498)
Constant	-268.6	-3.016	1,196***	19.74**
	(201.7)	(2.255)	(421.3)	(8.821)
Observations	107	107	107	63
R-squared	0.047	0.048	0.114	0.190

Table 20: solar energy stocks with oil (Standard errors in parentheses).
*** p<0.01, ** p<0.05, * p<0.1

The results are similar to the results with the pure portfolio. The cumulative adjusted and average adjusted returns have the highest significance (11.3% and 21.0%) and again GDP growth is the only independent determinant with a significant similar negative interaction.

R&D

R&D firms are expected to be more vulnerable to inflationary pressures than other renewable energy segments due to their dependence on R&D funding. Because inflation has been observed to strain liquidity access, a stronger negative correspondence is presumed between inflation and r&d firms in comparison to other stock segments (Boyd et al., 1996; 1999; 2001; Huybens & Smith, 1999).

VARIABLES	CR r&d Model 1	AR r&d Model 2	CR adj r&d Model 3	AR adj r&d Model 4
Unemployment	0.0312	0.00933	2.650	0.0574
	(1.186)	(0.0239)	(2.835)	(0.0539)
Inflation	**0.783**	**0.0153**	**2.630**	**0.0607**
	(0.996)	(0.0200)	(2.381)	(0.0453)
MP	-0.0564	0.00584	-0.619	-0.00552
	(0.447)	(0.00900)	(1.069)	(0.0203)
GDPgrowth	189.8*	3.490	-631.4**	-12.73***
	(106.1)	(2.133)	(253.5)	(4.822)
Constant	-189.3*	-3.551*	621.7**	12.48***
	(104.6)	(2.104)	(250.1)	(4.757)
Observations	121	121	121	121
R-squared	0.037	0.040	0.086	0.086

Table 21: r&d stocks without oil (standard errors in parentheses)
*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	CR r&d Model 1	AR r&d Model 2	CR adj r&d Model 3	AR adj r&d Model 4
Unemployment	-0.447	0.00153	3.594	0.0804
	(1.317)	(0.0263)	(3.182)	(0.0600)
Inflation	**0.682**	**0.0126**	**2.627**	**0.0558**
	(1.158)	(0.0231)	(2.798)	(0.0528)
MP	-0.201	0.00336	-0.139	0.00637
	(0.512)	(0.0102)	(1.237)	(0.0233)
GDPgrowth	202.1*	3.871*	-575.2**	-11.14**
	(114.9)	(2.296)	(277.6)	(5.235)
dOIl	9.870	0.144	-15.69	-0.393
	(8.106)	(0.162)	(19.58)	(0.369)

Constant	-207.8*	-4.017*	574.0**	11.11**
	(113.2)	(2.261)	(273.4)	(5.156)
Observations	107	107	107	107
R-squared	0.057	0.053	0.074	0.075

Table 22: r&d stocks with oil included (standard errors in parentheses)
*** p<0.01, ** p<0.05, * p<0.1

The regressions do not provide significant evidence that inflation and R&D stocks are correlated (table 21 and 22). (highest R-squared= 0.075).

6 Conclusion

This thesis aimed to reach a better understanding of macro-economic, oil price and renewable energy stock fluctuations by analysing 131 stocks, German macroeconomic data on GDP, unemployment, inflation and monetary policy (ECB) and crude oil price movements during the years of 2004-2014. Whilst there were a few useful findings based on which two hypotheses are accepted, overall the regressions did not deliver much significant evidence as none of the regressions displayed substantial explanatory power ($R^2 \leq 0.21$).

The only variable that consistently did have significant results was GDP growth (p <0.05), which demonstrated a slightly negative interaction (-1.899) with the univariate cumulative adjusted pure returns and a stronger negative (-14.72) impact on the univariate average adjusted pure returns with a p-value < 0.01. When oil was added to this model, GDP growth maintained to be the only significant factor with similar results (CR= -1.747; AR= -13.55; p-value <0.01). On the basis of these result, H_o is accepted and H_1 rejected.

The mediation analysis elaborated on the previous correspondences and found significant evidence of a negative effect from oil price changes (dOil) via GDP growth (p <0.1) on the cumulative adjusted pure returns with a coefficient of -1747.461. The coefficient is larger by a factor of a 1000 compared to the interaction found with the univariate results, which is such an outlier that it seems to be an erroneous result. However, also a significant (p< 0.1) negative interaction was found between changes of oil prices and the average adjusted pure returns via GDP growth. The p-value limit of 0.1 is accepted because the obtained p-value was near 0.05 (0.081) and GDP growth's results with the univariate model had a p-value of <0.01.

On the basis of these results, H_2 is accepted and H_3 is rejected. These results imply that the renewable energy stock segment does not have a significant direct correlation with the price of oil but that an indirect negative effect is present via oil's impact on GDP growth (.0115028).

The analysis of the solar segments gave nearly the same outcomes as the pure portfolio: GDP growth was the only significant factor with the cumulative adjusted returns (-1,210) and the average adjusted returns (-19.97). The regression models with r&d stocks exclusively did not give significant results.

In sum, the regressions delivered outcomes on the basis of which H_o and H_2 are accepted. The other hypotheses are rejected. In answer to the research (sub) question: growth in GDP has been found to interact with the renewable energy stock market (-1.899). Oil through its effect on GDP growth demonstrated to negatively interact with renewable energy stocks as well (AR = -13.55). The renewable energy equity market appears to be unaffected by other macro-economic factors.

7 Discussion

The following part describes explanations for the observed findings. Also, limitations of this research are discussed as well as the managerial implications of the conclusions and suggestions for further research.

GDP growth is the only macro-economic variable that obtained significant results. The results contradict the expected correspondence between GDP growth and renewable energy stocks since the findings suggest that growth in GDP negatively affects renewable energy stocks. It was partially anticipated as the price of oil was expected to have a negative effect on GDP growth but the net negative result was unexpected. This is mostly due to GDP growth's negative influence on renewable energy stocks and the presumed but unapparent positive impact of oil price on renewable energy stocks. Oil's somewhat neutral interaction with GDP growth (.0115028) was also surprising given the fact that Germany is an oil importing country and therefore, rising oil prices were expected to strain economic development.

A possible explanation for the negative correlation between GDP growth and renewable energy equity returns could be that a growing (German) economy still requires fossil fuels to meet energy demands as renewable energy sources still suffer from capacity and availability constraints, due to the difficulties associated with energy storage. This increase in demand for fossil fuels could strain renewable energy development and stock market wealth. Such a substituting effect has also been observed in prior research as was noted earlier.

The low explanatory power of the regression models is surprising given the correlated nature of the investigated variables. Especially, the fact that no evidence was found of a correspondence between the price of crude oil and the renewable energy security portfolio is remarkable since numerous other studies did find interconnections. Also, no observed relationship between the crude oil price and inflation, unemployment and monetary policy is strange since their interaction has been established in a large body of research.

The lack of supporting evidence can be caused by either erroneous models or biased data. The possibility that no relationship exists seems unlikely because of previous statistical findings and common economic logic that suggests that rising oil prices, being a key global commodity, increase producer and consumer prices, which lowers aggregate demand and the gross domestic product. That increases unemployment and probably induces monetary responses in order to maintain price stability.

Perhaps the reason the renewable energy stock sector illustrates no dependence on macro-economic conditions is because it is still in a (fast) growing cycle and therefore, this equity segment could be less swayed by the global economy. An important note here is that stock markets worldwide are currently at (near) record-heights and appear to be driven by the vast amounts of stimulus since the great depression of 2008 by the Fed, ECB and BoJ. The current P-E ratio of the S&P 500 is 26.15 which means that investors would have to wait more than 26 years to make a profit based on today's profit margins. By any standards the value of the stock market can be deemed very rich compared to economic fundamentals and thus, this disconnect between stock market wealth and economic factors could explain the absence of statistical evidence of relations between the macro-economic variables and the renewable energy equity segment.

Another explanation for the results could be biased data. The provided stock portfolio could be an inaccurate representation of the renewable energy equity market. This seems improbable because the stock portfolio is heterogeneous with respect to subsectors, geographical engagement, role in the value chain and years of existence.

The researched period and the size of the sample (131 securities selected from 260 provided equities) ensured a sizable dataset that incorporated a heterogeneous time period with respect to economic conditions (the financial crisis of 2008 and prior years of global economic expansion) and so, the selected time period has probably not given biased results.
Most likely, a bias in the data would have come from the macro-economic data. Germany is maybe an unsuitable proxy for the macro-economic factors and perhaps studying other countries could yield different results.

Limitations

Regarding the macro-economic data, there are a few shortcomings. Firstly, the influence of monetary policy has been incorporated by analysing the effects of the interest rate at which depository institutions have access to liquidity at the ECB (Refinancing Tender). The increase of the currency supply by means of currency creation (ECB's balance sheet expansion) is not incorporated but this has been a constantly used policy measure by the ECB since the Great Depression of '08 in the form of 'Quantative Easing' (currently €60 billion per month).
Secondly, German macro-economic data has been used as a proxy for macro-economic conditions for the renewable energy industry. Perhaps, Germany was not the right proxy for global macro-economic conditions and incorporating other countries may deliver other results.

Further, this thesis did not take into account intertwined interactions among the macro-economic variables themselves. For example, the effects of monetary policy on inflation or on unemployment (e.g. Awerbuch and Sauter (2006) concluded influences by inflation and monetary policy on GDP). This may have given a wrong representation of actual interactions and influences.

Thus, this study has several limitations; whether the insignificant results are caused by these shortcomings is something to be concluded by further investigation.

Managerial implications

During the researched period from 2004 to 2014 the renewable energy stock market seemed to have been unaffected by changing macro-economic conditions. This information is of notable value to (hedge) fund managers for estimating future market trends because it shows that the renewable energy stock market has been moving relatively unaffected by underlying economic factors (with the exception of GDP growth). This suggests that other causal factors should be considered.

Further, the indirect effect oil has on the renewable energy equity market by means of its negative impact on GDP can provide stock market players with valuable information on future stock returns and market trends.

Future research

This thesis can probably best be improved upon by increasing the robustness of the regression models by incorporating macro-economic data regarding other countries (e.g. China and the U.S.). Germany was perhaps not the appropriate proxy for renewable energy macro-economic conditions.

Further, next to its control over interest rates, another tool for the ECB to steer the economy is expanding or contracting the currency supply by buying up or selling government debt. The impact of this mechanism is not incorporated in this study since only the effect of the ECB Refinancing Tender rate has been analysed. Other research can elaborate on this study by including these influences as well, which would make for a broader and more accurate measure of monetary policy.

Another suggestion for further research is investigating interactions among the macro-economic variables themselves as that would paint a better picture of real interactions this thesis tried to approach.

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