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The relationship between renewable energy assets and crude oil prices

An empirical analysis with emphasis on the effects of the finacial crisis

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Master thesis in Financial Econoomics

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Abstract

In this thesis I have analysed the relationship between renewable energy stocks and the price of crude oil. As a part of my analysis I have provided a basic economic overview of the research period and how the value of renewable energy stocks and crude oil is determined. In order to analyse this relationship I have utilized a Vector Autoregressive Model (VAR) in addition to a Vector Error Correction Model (VECM). My findings indicate that the aforementioned assets follow a similar growth path between 2000 and 2007, but after 2009 their trends deviate significantly. A fundamental analysis reveal how GDP growth was responsible for the common growth prior to the financial crisis and how it has contributed to their different trends post the financial crisis. In addition I have analysed how the different sub sectors of renewable energy relate to oil prices. My findings indicate that wind and solar energy stocks are unaffected by oil prices, but biofuel commodities index is affected by changes in oil prices.

Preface

After four and half years at NHH I have come across many subjects eligible for a master thesis. However I have always desired to write my thesis on a subject which is rather unexplored. In addition I wanted to learn about industries that are important to world economy. This is why I ultimately chose to analyse the relationship between renewable energy and oil prices. Renewable energy is a rather small industry, but growing fast, and is to be reckoned with in the time to come. In addition, crude oil is the most important commodity in the world, and its development has a significant impact on global economy. Therefore I regarded it highly interesting to learn more of the market dynamics of the oil business.

During this period I have acquired useful knowledge of the renewable energy industries, the crude oil market and econometric methods. Prior to this thesis I had little knowledge of econometrics and the statistical programs required in this assignment. Therefore a thorough research was conducted beforehand to make sure that I applied the appropriate tools in this analysis. Through an empirical analysis I feel I have both have acquired valuable knowledge of econometrics, in addition this thesis have allowed me to use my financial background to interpret these results. To embrace a unfamiliar subject has been a challenge, but also very rewarding.

During this process I have encountered many persons that have been helpful and enabled this analysis. First of all I would like to thank my supervisor, Tommy Stamland, for helping me to find an interesting research subject and for helpful inputs as my work progressed. In addition I would like to thank Øivind Anti Nilsen for valuable insights on econometric analysis.

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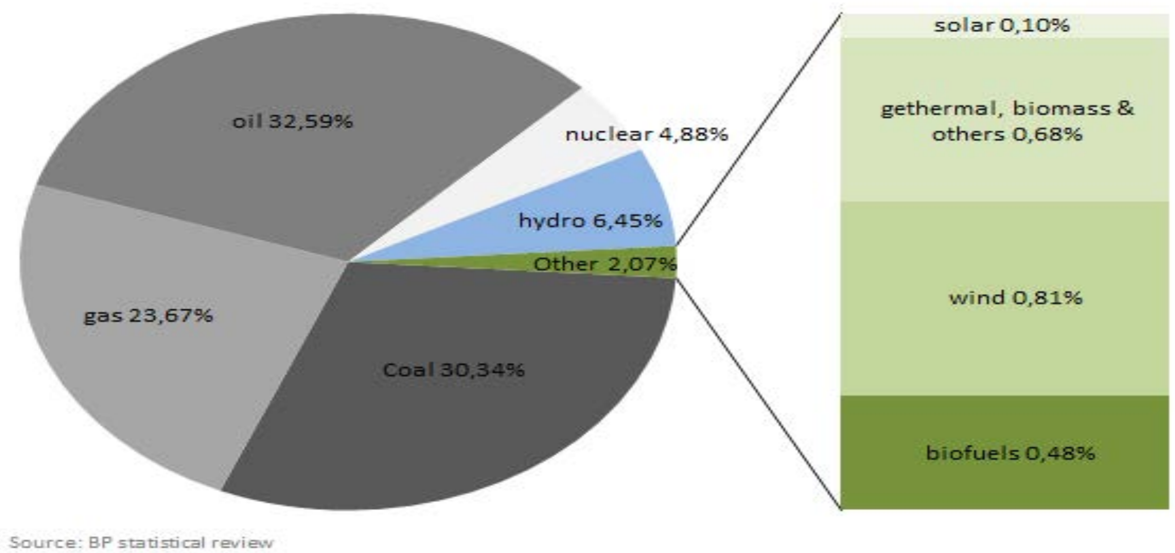
1. Introduction

In recent years, knowledge of pollution and climatic change has caused an enhanced focus on emissions and the usage of clean energy. These issues have been addressed through various agreements such as the Kyoto protocol, which is a treaty that sets binding obligations on industrialised countries in order to reduce the emission of greenhouse gasses (United Nations, 1995). Today, the main sources of energy are oil and coal, both of which are large contributors to the increase of CO2 in the atmosphere. In order to achieve these goals the dependence of fossil fuels has to decrease, consequently the importance of renewable energy sources is bound to increase.

This development is not likely to stop and according to Bloomberg new energy finance (2012) renewable power (excluding large hydropower facilities) accounted for 44 per cent of new generation capacity in 2011, an increase from 34 per cent in the previous year. The rapid expansion has been caused by a surge in renewable energy investments which reached a record high of US$257 billion in 2011, an increase of 17% from 2009 and a six fold increase on the 2004 figures. The growth in investments was only temporarily interrupted by the global and financial economic crises (Bloomberg new energy finance, 2012). Despite the strong growth, the impact of renewable energy is still limited, and only accounted for 8.5 per cent of world energy consumption in 2011, just above one fourth of the total energy derived from oil (BP, 2012). Regardless of the development in renewable energy, oil is expected to maintain its position as the primary energy source of the world for the next decades. (BP, 2013)

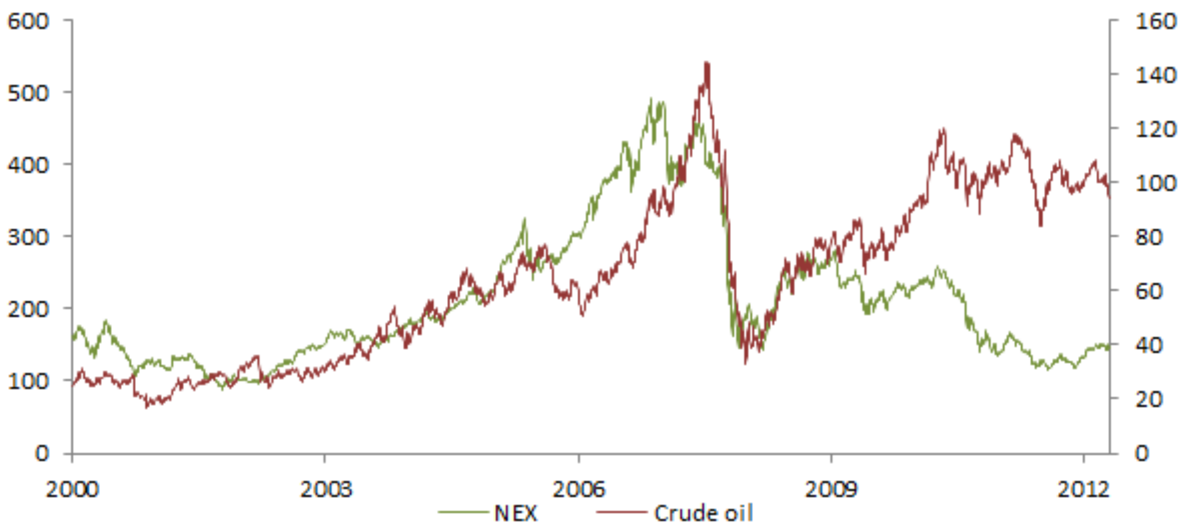
Figure 1: World energy mix, as of 2011



Renewable energy companies were for long scarce and few, and not to be reckoned with on the world's stock exchanges prior to this millennium. However, in accordance with the growth of renewable energy, multiple companies involved in these sectors have emerged. Their presence on stock exchanges worldwide has fuelled the creation of indices that aims to track the performance of renewable energy, allowing us to analyse how this sector performs compared to other assets.

Because these indices are rather new, a couple of interesting research possibilities are available. First of all, few have conducted research on how renewable energy stocks relate to other crude oil prices. Second of all, previous research focuses solely on econometric techniques, and does not try to explain their findings upon financial theory. Lastly, the recent financial crisis is arguably the first crisis in which accurate data on the performance of renewable energy stocks exists, therefore previous analysis on how renewable energy stocks cope with crisis and a subsequent recession is at best few by the numbers.

Figure 2: development in renewable energy assets and crude oil prices



Source: Bloomberg & Ardour Global Alternative energy Indices

Figure 2 provides a good overview on how these assets have developed since the expiry of year 2000. The graph is interpreted as follows; the development in renewable energy stock performance is traced using the y-axis on the left hand side, while the oil price development applies the secondary axis. What may easily be seen from this graph is how these assets seem to follow a similar growth path prior to the financial crisis, and although the price of oil peaked later than renewable energy stocks, appear to suffer equally bad from the aforementioned crisis. However as world economy and the price of oil started to recover in 2009, renewable energy stocks have shown few signs of improvement. Through this master thesis I will study whether the interaction between these assets has changed during the research period by dividing the data sample into two sample periods, before and after the financial crisis. In order to conduct this analysis, I will make use of econometric techniques and former research. I will also use financial theory to explain the results I obtain from the statistical analysis.

Based upon the introduction, I will use the following hypothesis to address these issues:

H_0: The relationship between oil price returns and renewable energy stock prices is unaffected by this crisis

H_A: The financial crisis caused a shift in the interaction between these assets

In addition, I have included indices in my analysis that aim to track performance within solar power, wind power and biofuels. Therefore I will test if these industries are similarly affected, or whether they behave differently to changes in the oil price. A second hypothesis will therefore be included:

H_0: All industries are similarly affected by changes in oil price

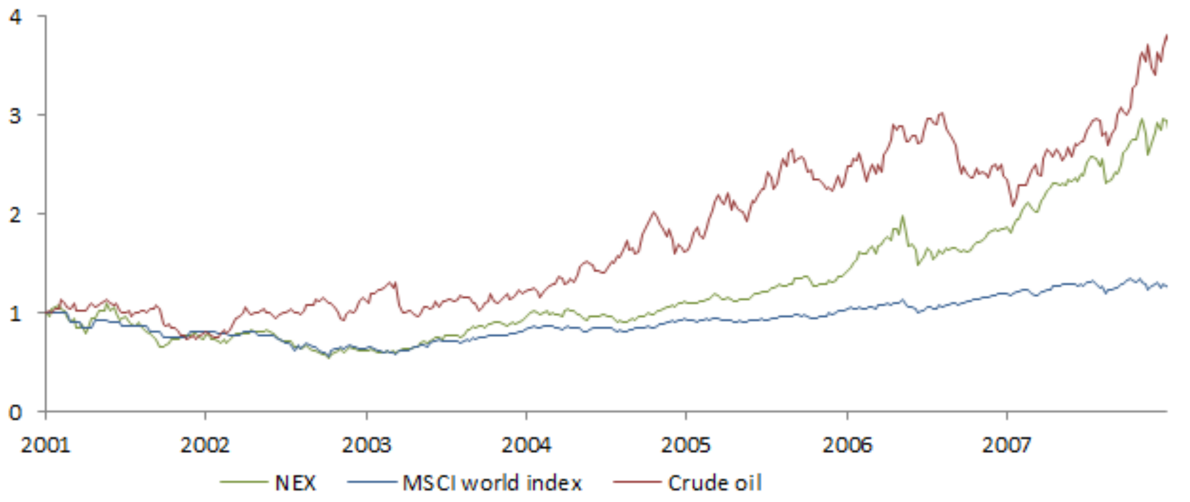
H_A: The different renewable energy sectors react differently to changes in oil price

Because I intend this thesis to have a wider scope than a common statistical analysis I will emphasise financial theory and knowledge to interpret my results.

2. World economy – a short highlight of the sample periods

2.1 2000 - 2007: Dot com recovery and the prelude of the financial crisis

Figure 3: Development in renewable energy assets, MSCI world index and crude oil prices

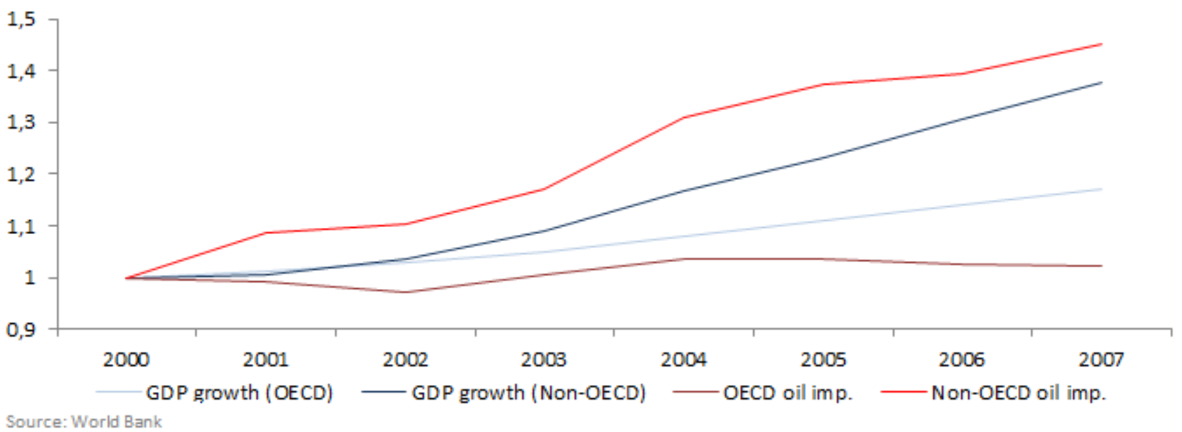


Source: Bloomberg, AGAEI & MSCI

The immediate predecessor of this time period was the dot com bubble. When the bubble busted in March 2000, a total loss of USD$5 trillion in market value on companies listed on NASDAQ, the stock market on which most hi-tech stocks are traded, occurred during the next two years. Stock markets around the world were trembling as the MSCI world index declined by 44.24 per cent during the same period of time (MSCI). As the world struggled to recover from this event, two other events accelerated the drop of stock prices. First the 9/11 terrorist destruction in 2001, then several corporate fraud scandals, with Enron as the most influential, caused billons of dollar in stockholder losses, seriously dampening securities markets and investor confidence. The financial markets recovered (these events never caused a global recession although GDP growth stagnated) in 2003, and was subject a consecutive annual growth until the financial crisis erupted (World Bank).

During this eight-year period the importance of non-OECD countries on the world economy grew significantly. China's two decades of consecutive double digit growth continued as GDP more than doubled between year 2000 and year 2007. India also faced a severe growth, and averaged 6.8 per cent annually. This contributed to a total growth of 50 per cent in GDP among the countries which not involved with the OECD collaboration. By comparing these figures with the accumulated growth of the OECD countries, whose growth was limited to a total of 17 per cent, it becomes evident that their influence on world economy has declined (World Bank). This may be seen graphically in the figure below

Figure 4: GDP and Oil imports growth



In accordance with their growing wealth, their impact on global commodity prices grew significantly. While oil imports in the industrialised countries slightly declined, it almost tripled in India and China, causing a 50 per cent growth among non-OECD countries. Thus the increased wealth clearly contributed to an increase of oil consumption in this period. Even though oil imports among industrialised countries have declined regardless of their GDP growth, their reduced imports is by far surpassed by the increase of the aforementioned countries. This contributed to a surge in global demand for oil, which during this period grew than the available supply, causing the price of oil to increase greatly. This effect is not only limited to oil prices, and emerging economies have driven the demand for various commodities causing a boom in prices (IMF, 2008)

However these events would later be overshadowed by the financial crisis. Therefore I will in the following paragraphs focus on how action taken post the dot com crisis served as a precursor to the financial crisis. In addition, I will emphasize the tree reasons I regard as the most important contributors to this crisis, namely a loose monetary policy, subprime mortgage problems and Complex securitization.

In the aftermath of the dot com bubble financial measures were taken in order to limit the extent of the crisis. One of these precautions turned out to become one of the most important reasons for the crisis. Facing the dot com crisis the Federal Reserve System (FED) cut interest rates below what historical experience suggested the policy should be according to the Taylor rule (this rule suggests that the Fed increases interest rates in times of high inflation, or when employment is above the full employment levels, and decreases interest rates in the opposite situations.). During 2003 to 2006, the biggest deviation since the troubled 1970s was recorded (The Economist, 2007). Therefore there is a clear evidence of monetary excess in the period leading up to the housing boom. Total mortgage debt outstanding increased from USD$6.9 billion in early 2001 to $14.6billion by the beginning of 2008 (Federal Reserve, 2009). With low money market rates, housing finance was very cheap and attractive, leading to a 25 year high in real estate prices. They remained high until the sharp decline began in early 2006 (Taylor, 2009). The monetary excess and low interest rates also contributed to a huge increase in asset prices as world stock markets grew by 43 per cent during the same period (MSCI, 2013).

While the boom in housing prices contributed to the surge in asset prices, the later bust in 2006 had a negative impact on financial markets. The rapidly increasing housing prices, caused a decline in foreclosures. This is because the benefits of holding on to a house are higher when prices are rising rapidly, leading to a more favourable credit rating for these loans. On the other hand, when prices started to fall, the incentives to pay your debt quickly turned negative as the prices of the house fells below the mortgage. Therefore a slight decline caused the rate of delinquencies and foreclosures to increase severely, enhancing the decline in housing prices. These effects were amplified by several complicating factors including the sub-prime mortgages.

The Sub-prime mortgage problem was severely amplified by the securitization of these assets. They were packed into mortgage-backed securities of great complexity and sold to investors and institutions all over the world (which generally explain why this crisis became a global recession, rather than only causing a decline in US economy). The risk of these assets were underestimated by rating agencies, which had an inherit difficulty in assessing the risk due to its complexity. Therefore financial institutions, determined to avoid increasing their exposure to the now toxic mortgage-backed instruments, grew leery of lending to one another. Credit all but froze and the money supply contracted (Taylor, 2009)

As the financial markets plummeted, the US government instituted a new round of easy money. This above all undermined the dollar, causing the oil price to soar, and the insertion of liquidity caused a temporary gain in asset prices.

2.2 2009 - 2013: European turmoil

During the financial crisis, enormous amount of money were spent on stimulus packages to regain the confidence of the financial system needed to restore economy. In the United States only, a total of USD$2.8 trillion were spent in an attempt to prevent a prolonged recession (CNN, 2010). These measures included lump-sum transfers, tax deduction schemes and government founded public work projects to create jobs. All over the world similar actions were taken. The overall result of the fiscal stimulus was a growth in real GDP in 2010, following the steep decline in late 2008 and 2009 (World Bank). In addition, world stock market hit rock bottom in early 2009, and has since then gained more than 100 per cent (MSCI).

Even though these political actions contributed to stop the rapid weakening of economic activity, the large fiscal position deteriorated significantly across the board leading to high fiscal deficit and a rapid increase of government debt (Nickel & Tudyka, 2013). In other words, the bail out of distressed companies transferred the debt from private to public books. This caused an increase in sovereign debt within the Eurozone from 66.4 per cent in 2007 to 80 per cent in 2010 of gdp (Eurostat). In the United States it increased by 64.1 per cent during the same period (World bank).

Even though the US politicians faced some problems raising the debt ceiling (the maximum amount of government debt allowed) prior to the fiscal stimulus (US Government Info, 2011), the economy has to a certain extent recovered, and growth prospectus of the US economy is decent. When considering Europe, the increase in sovereign debt has caused severe problems and social instability. Especially Greece has suffered ad multiple downgradings of Greek credit ratings followed in the wake of this instability. By July 2011, Greek government debt was rated as junk bonds (BBC, 2010). In addition, Italian, Spanish and Portuguese government debts were later downgraded, causing a severe increase in funding costs for these already troubled economies (Bloomberg, 2011). In fear of a collapse of the euro, several bailout programs was initiated for EU member states under the European financial stability support mechanism, which in in collaboration with the IMF, offer a safety net and economic support to distressed countries within the Eurozone (European Commission, 2012). In order to be subject for this support, strict requirements regarding government savings and reduction of deficit is imposed upon the borrower. These actions have managed to dampen the panic, but the economic situation remains uncertain. As a consequence of these events, European recovery has been limited post the financial crisis.

While western countries have struggled during this period, non-OECD countries, led by China and India, quickly recovered after the financial crisis, and have experienced a severe growth for the latter years. It is these countries that have accounted for the majority world growth during the time period 2009 to 2013.

3. Market analysis

In order to study this relationship I have to analyse how prices of crude oil and renewable energy stocks are determined. Throughout this chapter I will therefore provide a basic insight of the respective markets, and address crucial factors when the prices of these assets are determined. There are other aspects that may affect the price of oil and renewable energy shares that have not been accounted for, but because I aim to analyse the relationship between these assets, not create a pricing model, I will rely on this simplified framework.

3.1 Oil

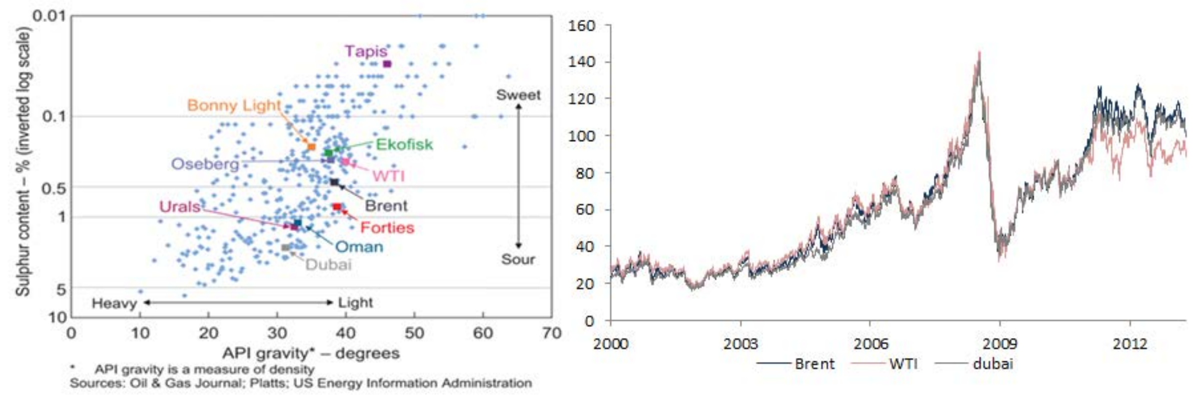
3.1.1 Basic introduction

Crude oil has played a unique role in the economy and history of modern times. No other resource has had such an impact on shaping the destiny of nations. This has resulted in oil becoming the largest traded commodity whether measured by value or volume (Bloomberg, 2012).

As few commercial participants can make use of crude oil, the need for crude oil is decided by the demand of refined oil products such as gasoline. While refined products are traded as homogenous goods, there are several different prices of oil on the world market. This is because oil form different locations have different qualities, i.e. oil extracted in the North See is not similar to Saudi Arabian oil. The quality of the oil is established through an "assay" (lab testing), which established the percentage of different products that can be extracted. Further the quality of oil is defined by its' chemical composition. The key terms in this context is the density and sulphur content of the oil. The density (volume-to weight ratio) is measured as API gravity value. A high API value implies that the crude oil is less dense ("light"), which yields more distillates. On the other hand a low API indicates "heavy" crude oil. This is more difficult to refine, and has lower yields than the light crude. Secondly the quality of crude oil is determined by its sulphur content. Oil with low sulphur contents is referred to as sweet crude, this is opposed to sour crude which require more processing/energy in the refining process. Last the viscosity, or thickness, of the oil is decided. All these characteristics contribute to the price of crude oil. The light and sweet crude have the most favourable qualities, and is therefore sold with a premium compared to the heavy and sour crude. In addition transportation costs are also accounted for, thus the location of extraction has impact of the oil price (Ådland, 2013)

The oil quality differs from oil field to oil field, but in general the oil extracted from the same regions share more or less the same characteristics. Therefore it is common to use a certain type of oil as a reference point/benchmark for many other available types of crude. There are currently three primary benchmarks in the world, West Texas Intermediate (WTI), Brent Blend, and Dubai. The development in prices of the respective crude types is highlighted below

Figure 5: Crude oil quality overview and price development



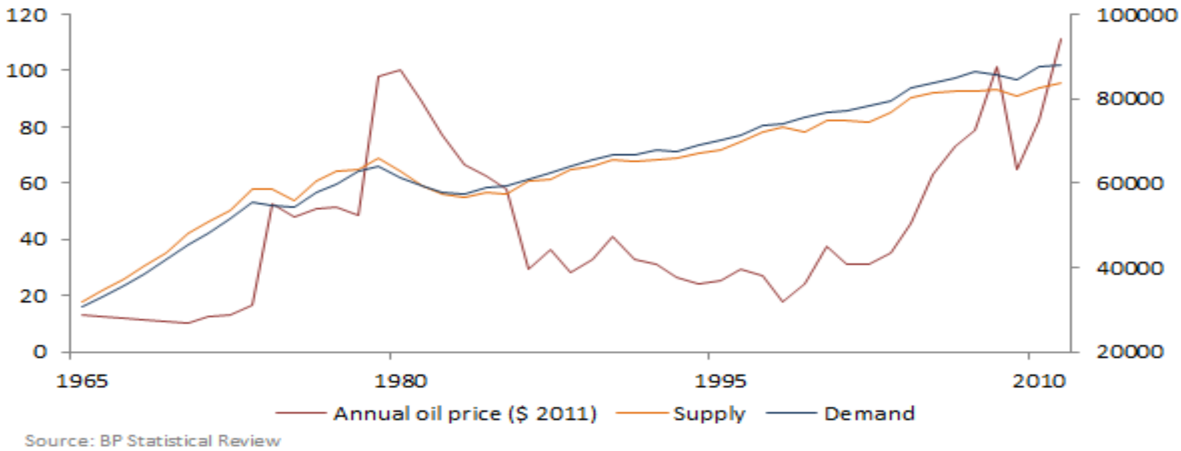
There are three principal energy-generating uses for oil include transportation, heating and power generation. Transportation fuels, including gasoline and diesel, account for the majority of the expected growth in both OECD and non-OECD countries. Gasoline is the most commonly used transportation fuel in North America whilst diesel is more dominant in Europe.

Furthermore, the composition of crude oil demand by sector is highly variable across countries, where well-developed distribution infrastructure and high levels of private vehicle use characterize mature economies. Accordingly, gasoline and distillate form the bulk of end-product demand in these countries. Seasonal trends also affect the end-product demand, where the American driving season holds gasoline demand high in the summer while heating oil experiences greater demand from the northern hemisphere during the winter.

What decides the price of oil?

In order to investigate how the price of crude oil is decided I will first go through the key drivers of demand and supply, because it is the interaction between these factors that determines the price.

Figure 6: Development in oil price (lhs) and the supply and demand of oil (rhs)



Demand

The worldwide demand for oil has experienced sustained growth for 17 years, with the financial crisis in 2008/2009 being the exception from the rule. This rise was initially caused by the development of industrialised countries, dependent on oil to fuel their growth. In recent years however, their demand for oil have stagnated, but oil demand has still been rapidly rising. This is mainly due to the economic growth in non-OECD countries in Asia, in particular China and the Middle East where energy intensive industries account for most of the economic growth. This trend is expected to continue, and according to the International Energy Agency (2012) consumption of oil shall to rise from its current level of 88 million barrels per day in 2012, to 99.7 million barrels per day in 2035 (International Energy Agency, 2012). This surge in oil supply is among others a consequence of an increase of global GDP, which is generally considered as one of the most influential factors on oil price. Increased economic activity causes a rising demand for oil and the price increases (OECD, 2004).

The demand for Oil is also affected by the relative strength of US dollar. This is a consequence of oil being quoted in dollar. Foreign investors have to purchase dollars in order to buy oil, which implies that a strengthening dollar compared to other currencies, will increase the price of oil for a foreign investor even though the price in dollar terms remain unchanged. Therefore the demand of oil will decrease, and consequently the price of oil will decline. This observed inverse correlation has led to the claim that US dollar weakness in recent years has contributed to the upward pressure in oil prices (IEA, 2012).

Strategic petroleum reserves refer to crude oil inventories held by the government of a country as a safety precaution. If oil supply is low, oil from the reserves may be released, and total quantity demanded from refineries will decrease, limiting the upward pressure on oil prices. On the other hand if supply is high, the government may use this opportunity to build oil stocks, causing the overall demand to increase. The application of these strategic reserves may have a significant effect oil prices. This is ironic, because the intention of these reserves is to reduce price fluctuations. If the stocks are lower than anticipated, this is usually anticipated as a sign of higher demand than supply of oil. Consequently the oil price will rise. If the stocks are higher than expected, the oil price is likely to decline.

Private participants may also keep storage to ensure their supply of oil. Oil is an input in many processes, and to maintain a safe supply may be essential for the daily operations of the company. In addition companies may keep stocks of oil for financial reasons. If the price is low compared to the forward price, it may be beneficial to purchase the oil now, and store it yourself, rather than buying forwards. This will increase the demand of oil because participants purchase oil for both storage and consumption, and prices will increase. If the forward prices are low compared to spot prices the opposite is likely to occur.

Supply

The total supply of oil has increased greatly since 1965 (figure 6). Improvements in technology has allowed producer to locate new oil fields, increase oil recovery rate, and have enabled extraction of oil that earlier was unavailable, such as deep water oil and shale oil.

The most important supplier of oil is the Organization of the Petroleum Exporting Countries (OPEC). It is an oil cartel whose mission is to coordinate and unify the petroleum policies of its member countries and ensure the stabilization of oil markets in order to secure an efficient, economic and regular supply of petroleum to consumers, a steady income to producers and a fair return on capital for those investing in the petroleum industry (OPEC, 2012). They currently hold more than 80 per cent of total global reserves, and produce about 40 per cent of the world`s crude oil (OPEC, 2012). Therefore it goes without saying that their output decisions have a major impact on total oil supply.

By decreasing supply OPEC may contribute to an increase in the oil price. However too high prices in the long run may weaken oil's position as the primary energy resource of the world, thus they apply this tool with care. If OPEC desire a reduction in oil prices they may increase supply, however to execute this option has become increasingly hard because the amount of spare capacity within the organisation is limited, thus OPEC's effect on oil price has declined during recent years.

With respect to the non-OPEC access to crude oil has become increasingly challenging during the latter years because the majority of the easy accessible oil fields are already in the production process. As a consequence we have seen an increasing trend towards more unconventional oil production such as deep water and oil sands. The unconventional oil has a higher marginal cost, which should imply limited extraction of these resources if oil prices decline.

The oil supply may also be affected by geopolitics. There are many developing countries with large oil reserves, and as we recently have seen in Algeria and the Arabian spring operating in these countries is risky. Terrorism, political tension and even resource nationalism displays the risks operating in unstable political environments, which will limit the amount of oil supplied.

Environmental regulations due to an increase in environmental awareness may restrict the available supply. In addition Natural disasters, that may cause production to shut down and reduce the refining capacity, will limit the availability of petroleum products.

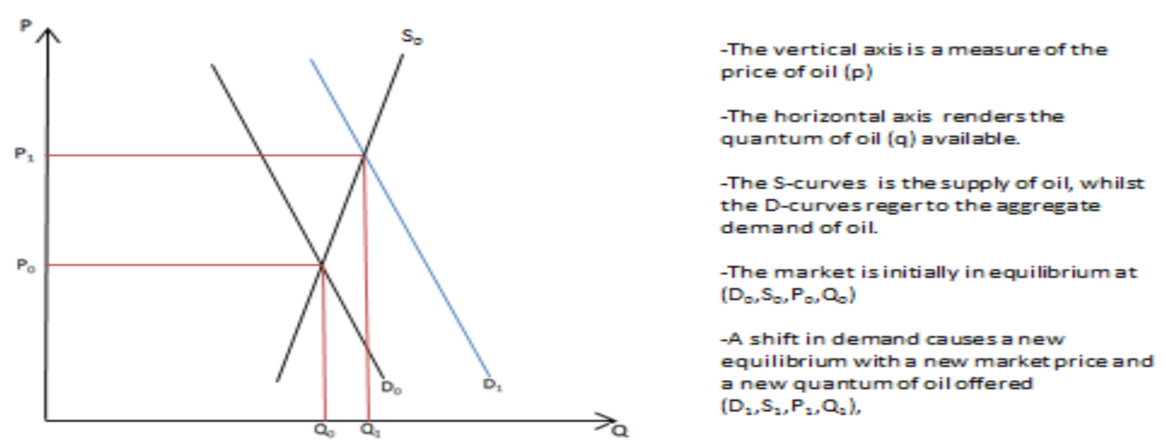
Oil price shocks– a matter of substitution

From figure 6, it is easy to see how supply has gradually increased in along with demand, and these graphs appear to be highly correlated, yet oil prices seem to fluctuate greatly. From January 2007, prices increased from approximately $50 to a peak of $145.29 in July 2008 before declining to $35 in early 2009. These fluctuations are hard to explain using fundamental market analysis, therefore a field of oil shock research has emerged. This research aims to explain how these extreme fluctuations occur.

Using the simplified framework of figure 7 these fluctuations may be explained using elasticities. In the short term the amount of crude oil is primarily decided by the production capacity of oil wells currently in production, whilst demand is limited to the capacity of oil refineries. In addition, the amount of oil extracted is generally unaffected by output prices because the cost involved with shut down and restart of production exceeds the potential gains from speculating in short term price fluctuations. In other words, the supply of oil is inelastic in the short term.

Because oil is the most important natural resource in the world, and to have adequate supply of oil is therefore essential to maintain daily operations for thousands companies worldwide. These companies will have small possibilities to replace oil with other input factors in the short term. To shut down production is very costly; consequently companies want to avoid this alternative virtually regardless of the price of oil. Therefore the demand of oil is inelastic with respect to price. This is illustrated the figure below.

Figure 7: Crude oil price shocks



A small shift in demand $(D_0 \rightarrow D_1)$ will therefore cause a huge change in prices, but change in supplied quantum is small. This is supported by former research, which reaches the conclusion that both short-term supply and demand are inelastic (IMF, 2011).

3.2 Renewable energy

Figure 8: Renewable energy stock development

3.2.1 Basic introduction

Renewable energy is not subject to a distinct definition, but in this thesis I will rely on the definition by IEA which defines renewable energy as all energy derived from natural processes (e.g. sunlight and wind) that are replenished at a higher rate than they are consumed. Therefore I will propose that renewable energy comprise of these sectors:

- Wind power
- Solar power
- Biofuels
- Hydro, Wave and tidal power
- Geothermal energy sources

Wind power is the conversion of wind energy into a useful form of energy, and currently accounts for 0.81 per cent and 1.88 per cent of world's total consumption of energy of electricity respectively (BP, 2012). The top wind producers are China, which strides to incorporate alternative energy into their economy, and the US, which seek to reduce its dependency of crude oil. (Cummans, 2011)

Solar power is the conversion of sunlight into electricity. Its impact is limited, and solar power only accounts for 0.1 and 0.24 per cent of total world energy and electricity consumption respectively. However its importance is gradually increasing as production costs have been falling consistently over the past three decades (Brown, Müller, & Dobrotkova, 2011), which has contributed to a more than ten times increase in output capacity from 2007 to 2012 (Parkinson, 2013)

Biofuel is the production of liquid and gaseous fuels derived from biomass or waste feedstock (including ethanol and biodiesel). Global production has been growing steadily over the last decade from 16 bn. litres in 2000 to more than 100 bn. litres in 2011. Today, biofuels provide around 3% of total road transport fuel globally (on an energy basis) (IEA).

Hydro wave and tidal power refer to energy generated by hydropower, the production of electrical power through the use of gravitational force of falling or flowing water. It is the most widely used form of alternative energy and accounts for 6.45 and 16 per cent of world energy and electricity generation respectively (BP, 2012).

Geothermal energy is heat from within the earth which can be recovered as steam or hot water, used to heat buildings and generate electricity.

Because performance of hydro and geothermal energy cannot be measured through an index, I am unable to investigate how they are affected by the price of oil and vice versa. Therefore I will not emphasize these sources of energy any further in this thesis.

Apart from biofuels, which is mostly used for transportation, the primary output from alternative energy is electricity. Due to this focus, renewable energy produces 20 per cent of total world electricity supply, a significant proportion relative to the previously mentioned 8.5 per cent of global energy supply.

What decides the price of renewable energy stocks

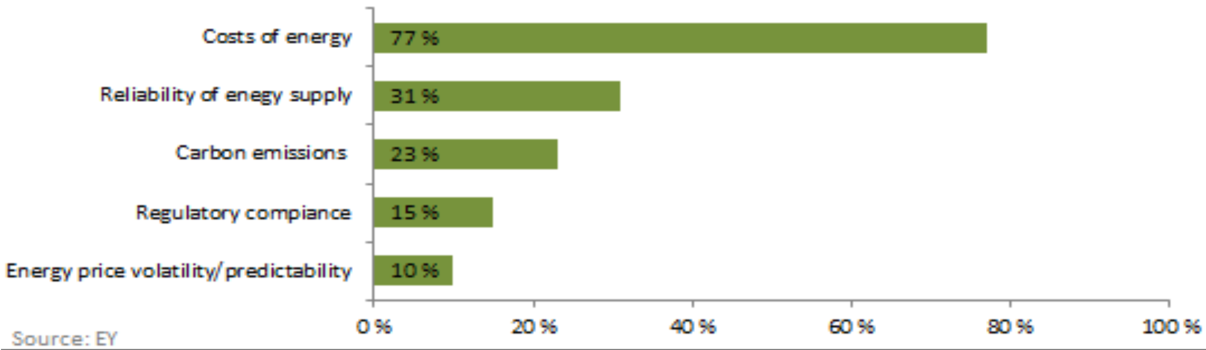
Being a diverse group of industries it goes without saying that different factors apply when the stock prices of the different renewable energy subsectors are determined. However, because my primary research question involves an analysis of the whole renewable industry I am obliged highlight their common features. Throughout this analysis you may also learn that there are many similarities with respect to which factors that may influence stock performance within the different industries.

Because all these assets are listed, there are several effects that may decide the prices of renewable energy stocks. First and foremost they are determined by market fundamentals which are decided by the relative attractiveness of the renewable energy industry. This is emphasized through an analysis of the supply and demand effects in the renewable energy market in the following sections. In addition stock prices are determined by the outlook of the industry and world economy. Interest rates and inflation may also have a significant effect, but I will regard the last two effects as limited compared to the aforementioned factors.

Demand

According to the renewable energy country attractiveness indices (Ernst & Young, 2012), the key drivers of energy mix are cost of energy, reliability of energy suply, carbon emmisions, regulatory compliance and energy price predictability/volatility. All of which are highlighted in the figure below.

Figure 9: Key drivers for energy mix



This survey concludes that the price of energy is by far the most influential factor when it comes to the selection of which sources of energy a company prefers. This is one of the reasons why the demand for renewable energy is limited. Renewable energy has historically been more expensive than power derived from fossil fuels, and because the application of renewable energy entails a cost disadvantage compared to competitors, companies are reluctant to pay extra to obtain clean energy. Therefore most companies only meet a small proportion of their energy needs by purchasing renewable energy. On average, corporations derive approximately 10 per cent of its energy needs from renewable sources (Bloomberg, Vestas, 2012). Of course there are exceptions, and several companies with a distinct eco profile will demand clean power regardless of the price gap, but they are still few by the numbers.

Due to improvements in knowledge and technology however, the spread between fossil and renewable energy costs is continuously declining. E.g. electricity generated from wind power has been subject to a 5 per cent annual reduction in costs during the past decades (Eneco). The current cost of electricity generated by onshore and offshore wind turbines amounts to 8.8 cents/kWh and 13.7 cents/kWh respectively, whilst the market price of electricity is 2.9 to 5.8

cents/kWh. (ECN, 2013). The technology improvements in this sector are expected to continue, whilst electricity generated from fossil fuels is becoming increasingly expensive due to a more expensive extraction process. Because price energy mix decisions are primarily made on the basis of prices, a decline in the spread between fossil fuels and renewable energy costs will most likely boost demand for the latter.

The second most important decision factor is the reliability of energy supply, which reveals a second reason of why renewable energy sources struggle compared to fossil fuels. Renewable energy sources make use of natural forces to generate electricity. These forces cannot be managed, moved or stored for later utilization. As their presence varies in time, electricity has to be generated whenever and wherever the weather conditions allows for it. In the case of total absence, the production of electricity drops to zero. Improved technology has to a certain extent limited this risk, because new facilities require less input in order to be fully operational. E.g. Modern wind turbines already start to generate electricity at wind forces as low as 2 to 3 (3 to 4 meters per second) and are at full capacity at wind force 6. However, most models switch off when the wind speed exceeds 25m/sec (well above wind force 10) for longer than 5 seconds because they are not designed to cope with such speeds (Eneco). This illustrates the importance of optimal conditions in the generation of renewable energy. Therefore a high dependency on these energy sources may involve a certain degree of uncertainty when it comes to electricity supply.

This problem is amplified by the limited possibilities for storage of electricity. Because it is hard to storage efficiently, electricity has to be consumed consecutively in line with generation, unless it will be wasted. For companies highly dependent on energy to function this may involve a huge risk, and would often require them to rely on other energy sources because the costs of a failure in power supply could be too great. This limits the demand for renewable energy.

According to the aforementioned survey carbon emissions play a rather important role when the energy mix is decided. Because renewable energy primarily has been developed to provide an alternative to the emitting fossil fuels, they electricity generated from these sources are considered emission-free, eco-friendly and regarded as harmless to the environment. As environmental issues become increasingly important, the enhanced focus will increase the demand for clean energy, even though it suffers from several disadvantages. Recent surveys also show that consumers favour environmentally friendly energy sources, and are willing to pay a premium to obtain this energy (Font, 2012).

Supply

The supply of renewable energy has surged during the recent years, and investments hit record levels in 2011(Bloomberg new energy finance, 2012). The most important reason is various treaties that oblige countries to increase their dependency on renewable energy. Among others, the Kyoto treaty and a binding agreement within the European Union forcing all member countries to reach a 20 per cent market share of renewable energy by 2020, thus capacity has increased significantly for the latter years. In 2011 renewable energy accounted for 44 per cent of new output capacity (Bloomberg new energy finance, 2012). Output capacity combined with how efficiently the electricity is extracted decides the available supply.

Because the installation costs for renewable energy facilities are high, renewable energy cannot compete with the price of electricity derived conventional sources of energy. Consequently renewable energy is rarely adopted in the market without a subsidy, and the available supply is highly dependent on government funding and tax deduction schemes (Ernst & Young, 2013). Consequently the supply of renewable energy is dependent of economic development. During recessions, governments may scale back these subsidies making the alternative energy less attractive. On the other hand the subsidies may increase when economy is booming.

In addition, electricity cannot be transferred from one power grid to another. Therefore the supply of renewable energy in a regional market is limited to the size of the power grid. Proper in infrastructure in place to transport the energy from where it is generated to where it is used is required. Consequently the size of the power grid imposes huge restrictions on the development of renewable energy (Deloitte, 2011). In 2008 approximately 30 per cent of all alternative energy projects suffered from insufficient grid capacity, illustrating the extent of the problem (Coenraads, et al., 2008). Due to limited transportaton possibilities, electricity contain of regional markets in which prices are decided by local market conditions. This is opposed to oil, gas and coal that is easily transported all around the world, and are therefore globally traded commodities.

The supply is also decided by the availability and price of metals which all sources of alternative energy, apart from biofuels, are dependent on. China produces more than 97 per cent of the world's supply of neodymium (a metal essential for the construction of turbines), and two thirds of total silicon supply (key input in solar panels), allowing them to control the market availability (Milmo, 2010). Geopolitics is therefore a significant factor in the supply of alternative energy. E.g. the looming dispute between the European Union and China may limit the construction of new output facilities (Reuters, 2013)

3.3 How are these assets connected?

Throughout this chapter I have provided an overview on how key fundamentals may determine the price of the respective assets. Even though there are some exceptions, different fundamental factors seem to apply when the prices of crude oil and renewable energy stocks are determined. This favours a limited correlation between these assets.

In addition, even though the price both assets are heavily dependent on the demand for energy, different industries demand the energy derived from crude oil and renewable energy respectively. Crude oil accounts for 32.6 per cent of total energy, but it is mainly used for transportation and heating. Renewable energy on the other hand only accounts for 8.5 per cent of world energy supply, but because it is almost solely used to generate electricity; almost 20 per cent of electricity consumption is derived from renewables. This makes it the third largest source of electricity, and by far exceeds oil which only accounts for 4.5 per cent of total production. Therefore these assets do not appear to affect each other on a daily basis.

However empirical results indicate a relationship between the price of crude oil and renewable energy stocks. During the 1970, several events in the OPEC countries caused a surge in prices of oil. In accordance with this increase, public expenditure in the area of energy research development and deployment in the OECD countries showed a significant upward spike. These expenditures peaked in line with the peak in oil price in 1980, before declining significantly. Although the exact figures from private spending are not available, it is likely to assume that it follows the similar growth path. This is supported by the National Science Foundation's annual survey of industrial R&D which indicates that total funds (public and private) for industrial energy showed an almost continual decline during the 1980s and 1990s, with the 1999 levels about one fifth of 1980 values in real terms (Gallagher, Holdren, & Sagar, 2006). By looking at oil price development for the same period, these expenditures in renewable appear to be highly dependent on the price of oil. Increased spending in R&D will, according to former research, yield an excess share price return for hi-tech companies (Eberhart, Maxwell, & Siddique, 2002). Therefore it is likely that the increased price of oil had a positive effect on stocks involved with renewable energy.

4. Former research

In order to explain the relationship between renewable energy stocks and oil price further I will look into the findings of previous research papers. The emission of greenhouse gasses and environmental issues is a rather now concern, and research on this subject and its relation to economics is rather scarce. According to my knowledge, not much research of the relationship between oil price and the performance of renewable energy stocks has been conducted. There are two main reasons for this, first of all the field of renewable energy is a rather new phenomenon, second of all the data material which is required to perform such an analysis has been limited. The first indices were created around the millennium, but the majority of the ETF and indices only have a track record from 2007/2008. This has made it hard to research this subject earlier.

However there are some articles that investigate this relationship. Henriques & Sadorsky (2007) highlights the need of alternative energy and emphasise the risk of being too dependent of oil due to the huge geopolitical risk caused by the fact that five countries account for 60 per cent of proven oil reserves. They utilize a Vector Autoregression to empirically investigate the Granger causality between specific alternative energy ETF's and oil prices. What they seek to investigate is how shocks in oil prices affect alternative energy companies. According to the test, movements in oil prices, have some power in explaining the movements of the stock prices of alternative energy companies. In addition they investigate, through simulation, how shocks in technology stock prices and oil prices influence alternative energy. They find evidence of how shocks in technology share prices have, whilst shocks in oil price do not have, a significant effect on renewable energy stocks (within a 95 per cent confidence interval).

Trück & Inchaupse (2008) extends the research of Henriques & Sadorsky (2007) by utilizing a dynamic multi-factor setting based on a state-space model with time-varying coefficients. In the study, they find that sharp increases in oil have little influence on investments in renewable energy markets, and that the Wilderhill New Energy index considered in this paper seems to be highly influenced by the Standard & Poor's 500 Index and technology stocks such as the Pacific Stock Exchange Technology Index.

In another article, Schmitz (2009) use a multi-factor market model to investigate the relationship between oil prices and alternative energy shares. The research is carried through using CAPM-GARCH (General Autoregressive Conditional Heteroscedasticity) multi-factor market model to investigate the relationship between oil prices and renewable energy indices. Results show that an increase in oil prices and the broad market have a statistically significant and positive impact on renewable energy stock returns. Interestingly the oil price beta for MAC is nearly twice that of alternative energy indicating that solar sector returns are more sensitive to changes in oil prices than the broad alternative energy market. According to the report this is most likely due to the large percentage of volatile small cap stocks and solar companies that comprise of the solar index used by Schmitz.

Huang et.al (2010) applies a Vector Error Correction Model (VECM) to investigate the relationship between crude oil prices and stock performances of renewable energy companies (from 2001-2010). They have divided the sample period into three sub-periods with the two Middle East wars (Iraq and Lebanon) as natural divisions. The research indicates that the oil prices behaved differently during these sub-periods, but no significant relationship between oil prices and renewable energy stocks were detected in the first two periods. However in the last period, post 2006, when oil prices reach historical high and crash back with volatile dynamics, oil price behaviour has a significant effect on performances of alternative energy companies.

5. Statistical theory and methods

In order to investigate the relationship between the development in the oil price and the performance of stocks within the alternative energy sector I have to make use of econometric methods. Econometrics is the interaction of economic theory, observed data and statistical methods. Defined by Samuelson, Koopmans, & Stone (1954) as "The integration of economic theory, mathematics, and statistical techniques for the purpose of testing hypotheses about economic phenomena, estimating coefficients of economic relationships and forecasting or predicting future values of economic variables or phenomena"

Before quantifying and interpreting these relationships I have to test certain features of my data set to see whether they can be applied in my intended model. Due to the complexity of the method applied in this assignment, a thorough review is needed. In addition I will in this chapter explain the intuition used to obtain results in addition to highlight the knowledge required to interpret and understand the conclusion. Therefore this chapter is of special interest to readers with a certain understanding of econometrics.

5.1 Vector Autoregression

Vector autoregressive models were first popularised in econometrics by Sims (1980) as a generalisation of univariate autoregressive model. A VAR system is a systems regression model (i.e. there is more than one dependent variable) that can be considered as a hybrid between the univariate time series models and the simultaneous equations models. These models have often been advocated as an alternative to large-scale simultaneous equation structural models. In general a VAR model is a multi-variate way of modelling time series approach and enables to test the reciprocal influence of two variables, that is how changes in a particular variable are related to changes in its lags(previous values) and to changes in other variables and its lags. The VAR treats all variables as jointly endogenous and does not impose any restrictions on structural relationships.

Bivariate Vector Autoregression illustrates the model in its simplest form, in which it only consist of two variables y_{1t} and y_{2t} whose value depend on different combinations of the previous p values (lags) of both variables and error terms:

$$y_{1t} = \beta_{10} + \beta_{11} y_{1t-1} \dots + \beta_{1p} y_{1t-p} + \alpha_{11} y_{2t-1} \dots + \alpha_{1p} y_{2t-p} + u_{1t}$$

$$y_{2t} = \beta_{20} + \beta_{21}y_{2t-1} \dots + \beta_{2p}y_{2t-p} + \alpha_{21}y_{1t-1} \dots + \alpha_{2p}y_{1t-p} + u_{2t}$$

In this system it is assumed that both dependent variables are stationary, u_{1t} and u_{2t} are uncorrelated white noise disturbances with standard deviation of σ_{1t} of σ_{2t} respectively. The simple two-variable first order VAR model may be expanded to a multivariate higher order where the variables are allowed to affect each other. The terms, used to capture immediate feedback effects, are called contemporaneous feedback terms. This is a measure on how the present value of a variable may affect the present value of the other variable, in our case how the unlagged value of y_{1t} may affect the present value of y_{2t}.

$$y_{1t} = \beta_{10} + \beta_{11}y_{1t-1} + \alpha_{11}y_{2t-1} \dots + \alpha_{12}y_{2t} + u_{1t}$$

$$y_{2t} = \beta_{20} + \beta_{21}y_{2t-1} + \alpha_{21}y_{1t-1} \dots + \alpha_{22}y_{1t} + u_{2t}$$

By stacking up the terms into matrices and vectors, and moving the contemporaneous term to the left hand side these equations may be rewritten as:

$$\begin{pmatrix} 1 & -\alpha_{12} \\ -\alpha_{22} & 1 \end{pmatrix} \begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix} + \begin{pmatrix} \beta_{11} & \alpha_{11} \\ \alpha_{21} & \beta_{21} \end{pmatrix} \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$$

Or

$$Ay_t = \beta_0 + \beta_1 y_{t-1} + u_t$$

Where

$A = \begin{pmatrix} 1 & -\alpha_{12} \\ -\alpha_{22} & 1 \end{pmatrix}$, $y_t = \begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix}$, $\beta_0 = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix}$, $\beta_1 = \begin{pmatrix} \beta_{11} & \alpha_{11} \\ \alpha_{21} & \beta_{21} \end{pmatrix}$ and $u_t = \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$

Through a premultiplication by A^{-1} the VAR model in standard form is obtained

$$y_t = A_0 + A_1 y_{t-1} + e_t$$

This VAR contains only predetermined values on the RHS (i.e. variables whose values are known at time *t*), and so there is no contemporaneous feedback term. This VAR can therefore be estimated using OLS.

5.1.1 Requirements of the VAR model

In order for the VAR to yield credible and plausible results there are some statistical properties which must be satisfied:

1. The expected value of the error component is zero, $E(u_{1t}) = 0$.

2. Time series used in models must be stationary.

3. No serial correlation.

5.1.2 Stationarity

Stationarity is an essential property to define a time series process. This term is commonly separated this term into two parts, strict and weak stationarity. Strict stationarity is a stochastic process whose joint probability distribution is unaffected by change of time origin. Consequently, parameters such as mean and variance do not change in time. In other words, a stationary data series tends to return to its mean value, and fluctuates around it with more or less constant range.

Because one usually only is concerned with the mean, variance and covariance of a time series, it is sufficient that these movements are independent of time, rather than throughout the entire distribution. This is referred to as weak stationarity, or covariance stationarity. According to Brooks 2009 a stochastic process is weak stationary for $t = 1,2, \dots \dots, \infty$ if it satisfies certain requirements:

1. $E(y_t) = \mu$

2. $E(y_t - \mu)(y_t - \mu) = \sigma^2 < \infty$

3. $E\left(y_{t_1} - \mu\right)\left(y_{t_2} - \mu\right) = \gamma_{t_2 - t_1} \ \ \forall t_1, t_2$

Conditions one and two require the process to have a constant finite mean and variance, while the third states that the autocovariance depends only upon the distance in time between the two observations. The mean, variance and autocovariance are thus independent of time. While mean and variance are familiar terms, autocovariance may be unknown to the common reader. Autocovariance is a measure of the dependence between observations, i.e. how y is related to its previous values. Further in this assignment I will use the term autocorrelation instead, which are the autocovariances normalised by dividing by the variance. More on this follows in chapter 5.1.5.

Weak stationarity, or covariance stationarity is usually referred to as stationarity in the literature unless otherwise is specified, and this thesis uses the same terminology.

If the time series does not meet these requirements, it is referred to as non-stationary. The mean differ at different points of time and the variance is often increasing. It is easy to see that this requirement of stationarity is rarely fulfilled when dealing with economic time series expressed in their original unit of measurement. They tend to follow a random walk, with unpredictable movements up and down. The difference is illustrated in the figure 10 and 11.

Figure 10: the random walk

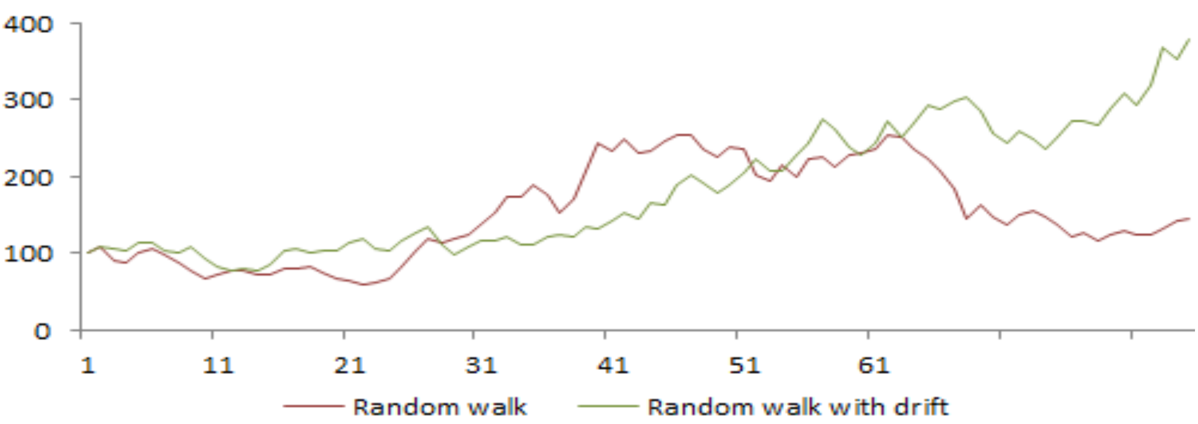
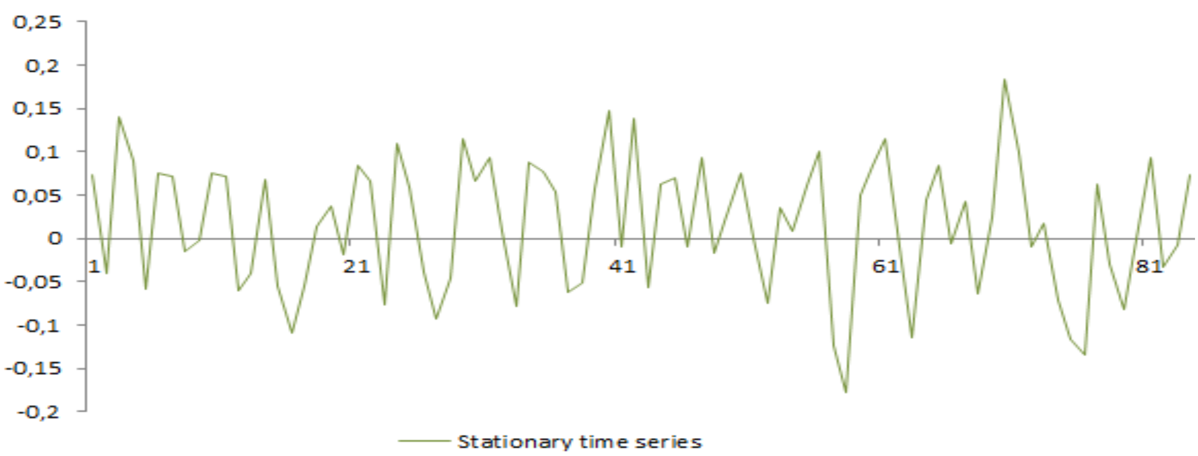


Figure 11: Stationary time series



To determine whether the variables are stationary is important to avoid the possibility of spurious regression. This occurs if two stationary variables are generated as random series with one of the variables regressed on the other, the t-ratio on the slope of the coefficient is expected not to differ significantly differ from zero, and the R^2 is expected to be low. However if the variables exhibit a trend a regression of one on the other could have a high R^2 even if they are completely unrelated. In other words, if standard techniques are applied to non-stationary data, this may lead to a regression which appears to yield good result, but in fact is valueless (Brooks, 2008).

For the VAR to obtain robust results it is crucial to determine the order of integration of each of the time series and make them stationary. Applying this model on non-stationary data may lead to biased inferences. Therefore a general rule is that these time series are not suited to use for further analysis before they are de-trended. However there is an exception, if two non-stationary time series appear to follow a similar growth path in time the combined trend may in fact be stationary. This is called cointegration, and I will return to this term in chapter 5.1.4.

Stationarity testing

As highlighted earlier, there are distinct differences between a stationary and non-stationary time with respect to their graphical expression (See figure 10 & 11). Even though graphical analysis may provide us with indications of what to expect from the data, it cannot replace statistical tests. These have to be conducted regardless of the shape of the graph.

Because non-stationarity is a common problem in time series analysis, several tests on how to determine the presence of a unit root (non-stationarity) have been created. In this thesis I will apply the augmented Dickey fuller test. As the name implies, this is a modification of the initial Dickey-Fuller test, which offers higher power than the DF test and is therefore more likely to reject the null hypothesis of a unit root against a stationary alternative when the alternative is true. However this test has been criticised for a low power I against plausible trend-stationary alternatives. Therefor the results obtained needs to be handled with caution.

The Dickey Fuller test

The Dickey-Fuller test is arguably the most common method when it comes to unit root testing. This is a hypothesis test which also allows us to find out which order the variables are integrated by, if they are proven to be non-stationary. If a non-stationary time series, y_t must be differenced d times before it becomes stationary, then it is integrated of order d. This could be written, $y_t{\sim}I(d)$, which implies that $I(0)$ is a process with no unit roots, whilst $I(1)$ series contains a unit root (Brooks, 2008). This can be applied to the different non-stationary time series.

1. Random walk

$$x_t - x_{t-1} = (\rho - 1)x_{t-1} + \varepsilon_t = \delta x_{t-1} + \varepsilon_t$$

2. Random walk with drift

$$x_t - x_{t-1} = \mu + (\rho - 1)x_{t-1} + \varepsilon_t = \mu + \delta x_{t-1} + \varepsilon_t$$

3. Random walk with drift and deterministic trend

$$x_t - x_{t-1} = \mu + (\rho - 1)x_{t-1} + \lambda t + \varepsilon_t = \mu + \delta x_{t-1} + \lambda T + \varepsilon_t$$

The basic objective of the test is to examine the null hypothesis, (H_0): $\delta = 0$, which implies that the variable contains a unit root, $I(1)$. On the other hand the alternative hypothesis is, (H_A): $\delta < 1$, tells me that the variable is stationary, $I(0)$. If I am unable to reject the null hypothesis, I have to perform an additional test, (H_0): $X_t \sim I(2)$ vs. (H_A): $X_t \sim I(1)$, in which I investigate whether the variable is integrated of the second order, $I(2)$. By rejecting this test, I conclude that the variable contains one unit root. However if I still fail to reject the hypothesis additional tests are until I am able to reject the null hypothesis, and find out which degree the variable is integrated by. The rejection regions of the null hypothesis do not follow the usual t-distribution, but a non-standard distribution. These critical values are derived from simulations, and differ depending on the number of observations and the model used in the test.

The tests above are only valid if the error term ε_t is white noise. White noise implies that the error term is assumed not to be autocorrelated. If this is the case, the proportion of times a correct null hypothesis is incorrectly rejected would be higher than the nominal size used. In order to solve this problem I may apply a extended Dickey-Fuller test called augmented Dickey-Fuller test (ADF). This test adds lagged variables, $\Delta x_t = x_t - x_{t-1}$, and the lags of Δx_t now "soak up" the dynamic structure present in the dependent variable, in order to make sure that ε_t is not autocorrelated. The test can be expressed as:

$$\Delta x_t = \mu + \delta x_{t-1} + \lambda t + \gamma_1 \Delta x_{t-1} + \gamma_2 \Delta x_{t-2} \ldots + \gamma_n \Delta x_{n-k} + \varepsilon_t$$

A new problem now arises. How do I determine the optimal number of lags for the dependent variable? According to Brooks (2008) there are several approaches are available but I will rely on the number of lags that minimises the information criteria, which will be addressed in the next paragraph.

5.1.3 VAR order selection

The optimal number of lags is necessary to determine because the several of the tests I use in this thesis depend on the selected number of lags. Usually the conclusion will not be qualitatively altered by small changes in the number of lags, but this may occur. Including too few lags will not remove all of the autocorrelation, thus biasing the results, while using too many will increase the standard error of the coefficient. The final effect arises due to an increase in the number of parameters to estimate occupies the degrees of freedom (Brooks, 2008).

In order to determine the appropriate number of lags I will rely on several information criteria. The information criteria embody two factors: a term which is a function of the residual sum of squares, and some penalty for the loss of degrees of freedom from adding an independent variable. Thus, adding a new variable or an additional lag will have two opposing effects on the information criteria. The residual sum of squares will fall, but the value of the penalty term will increase. Ultimately, the object is to choose the numbers of parameters that minimises the value of the information criteria. In this process I will apply the rule of thumb proposed by Schwert (1989), set $p_{max} = \left[12 * \left(\frac{T}{100}\right)^{\frac{1}{4}}\right]$ and allow the information criteria to be calculated for each value of $p < p_{max}$ to $p = 0$. Thus the objective is to minimise this metric within the boundaries of the lags. To decide the appropriate one of lags the univariate criteria could be applied separately to each equation. But because it is desirable to include a similar number of lags in each equation, the multivariate versions of the information criteria is required (Brooks, 2008):

1. $MAIC = log[\hat{\Sigma}] \frac{2p'}{T}$
2. $MSBIC = log[\hat{\Sigma}] + \frac{p'}{T} \ln T$
3. $HQIC = log[\hat{\Sigma}] + \frac{2p'}{T} \log(\log(T))$

In these equations, $\hat{\Sigma}$ is the variance-covariance matrix of the residuals, T is the number of observations and p' is the total number of regressors in all equations, which will be equal to $k^2 p + k$ for k equations in the Vector Autoregression system, each with p lags of the k variables plus a constant term in each equation.

The question remains however, which of these is better if these tests fail to reach unambiguous results? According to Endres (2005) the SBIC will for instance punish the model harder for each additional lag added than AIC, and is also found to be a better information criterion for large data samples. In this thesis I will rely on a research conducted by Ivanov & Kilian (2005). They find that each criterion has its strengths dependent on the frequency of the time series. For monthly VAR model, the AIC tends to produce the best results. When dealing with quarterly data however, Hannah-Quinn Information Criterion is the most accurate.

5.1.4 Cointegration

If two variables integrated of order $I(1)$with an existing linear relationship that can be combined as stationary, $I(0)$ they are cointegrated. In other words a long-term continuing relationship exists, thus the variables can deviate in the short run, but will eventually always exhibit similar paths. If a series is cointegrated, then rather than using VAR, the vector error correction model is used for hypothesis testing.

Cointegration may be tested either by using the Engle-Granger two step test or the Johansen's test. When comparing these methods, the Johansen's test has a number of desirable properties, including the fact that all variables are treated as endogenous, and second the test allows for more than one cointegrating relationship, which makes it appear more applicable.

Johansen's test

It is a procedure for testing cointegration of several $I(1)$ time series based upon a VAR model with g number of variables and k lags containing these variables. This can be written as:

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} \dots + \beta_k y_{t-k} + \varepsilon_t$$

In order to use the Johansen's test, the VAR above have to be converted to a vector error correction model (VECM) of the form:

$$\Delta y_t = \Pi y_{t-k} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} \dots + \Gamma y_{k-1} \Delta y_{t-(k-1)} + \varepsilon_t$$

Where $\Pi = \left(\sum_{i=1}^{k} \beta_i\right) - I_g$ and $\Gamma = \left(\sum_{i=1}^{k} \beta_j\right) - I_g$

The VAR contains g variables in first diffeneced from the left hand side, and $\mathrm{k}-1$ lags of the dependent variables (differences) from the right hand side, each with a Γ coefficient matrix attached to it. The test circles around the examination of the Π matrix. Π can be interpreted as a long-run coefficient matrix, since in equilibrium, all the Δy_{t-1} will be zero, and setting the error terms ε_t to their expected value of zero will leave $\Pi y_{t-k} = 0$ (Johansen, Statistical Analysis of Cointegrated Vectors, 1988).

The test for cointegration between the y's is calculated by looking at the rank of the Π via its eigenvalues. There are two test statistics under the Johansen approach, which are formulated as:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{g} \ln\left(1-\hat{\lambda}_i\right)$$

and

$$\lambda_{max}(r, r+1) = -T\ln\left(1-\hat{\lambda}_{t+1}\right)$$

where r is the number of cointegration vectors under the null hypothesis and $\hat{\lambda}_i$ is the estimated value for the *i*th ordered eigenvalue from the Π matrix. Intuitively, the larger $\hat{\lambda}_i$ is, the bigger and negative $\ln\left(1-\hat{\lambda}_i\right)$ will be, and hence the larger the test statistic. λ_{max} conducts separate tests on each eigenvalue, and has its null hypothesis that the number of cointegrating vectors is r against an alternative of $r+1$. The distribution of the test statistic is non-standard, and the critical values depend on the value of $g-r$.

The first test involves a null hypothesis of no cointegrating vectors (Π having no rank). If the null is not rejected, we conclude that there are no cointegrating vectors and the testing could be completed. However if $H_0\colon r=0$ is rejected, the null that there is one cointegrating vector (i.e. $H_0\colon r=1$) would be tested and so on. Thus the value of r is continually increased until the null hypothesis is no longer rejected. Π cannot be of full rank (g) because this would correspond to the original y_t being stationary. If Π has zero rank, then by analogy to the univariate case, Δy_t depends only on Δy_{t-1} not on y_{t-1} so that there is no long-run relationship between the elements of y_{t-1}. Hence there is no cointegration. For $1 < \mathrm{rank}(\Pi) < g$, there are r cointegrating vectors. Π is then defined as the product of two matrices, α and β', of dimension $(g*r)$ and (r ∗ g) If I have a one cointegrating vector, the β matrix, four variables, the y matrix, and the amount of each cointegrating vectors, while α gives the amount of each cointegrating vector entering the vector error correction model, also known as "adjustment parameters", the matrix could be written as:

$$\Pi = \begin{pmatrix}\alpha_{11}\\ \alpha_{12}\\ \alpha_{13}\\ \alpha_{14}\end{pmatrix}\left(\beta_{11} \quad \beta_{12} \quad \beta_{13} \quad \beta_{14}\right)\begin{pmatrix}y_1\\ y_2\\ y_3\\ y_4\end{pmatrix}_{t-k}$$

and rewritten as

$$\Pi\begin{pmatrix}\alpha_{11}\\ \alpha_{12}\\ \alpha_{13}\\ \alpha_{14}\end{pmatrix} = \left(\beta_{11}y_1 \quad \beta_{12}y_2 \quad \beta_{13}y_3 \quad \beta_{14}y_4\right)_{t-k}$$

It is now possible to find separate equations for each variable Δy_t. By normalizing the cointegration vector on the chosen dependent variable, the coefficient of that variable in the cointegrating vector is one. Normalized with respect to Δy_1provides me with this equation:

$$\alpha_{11}\left(y_1 + \frac{\beta_{12}}{\beta_{11}}y_2 + \frac{\beta_{13}}{\beta_{11}}y_3 + \frac{\beta_{14}}{\beta_{11}}y_4\right)_{t-k}$$

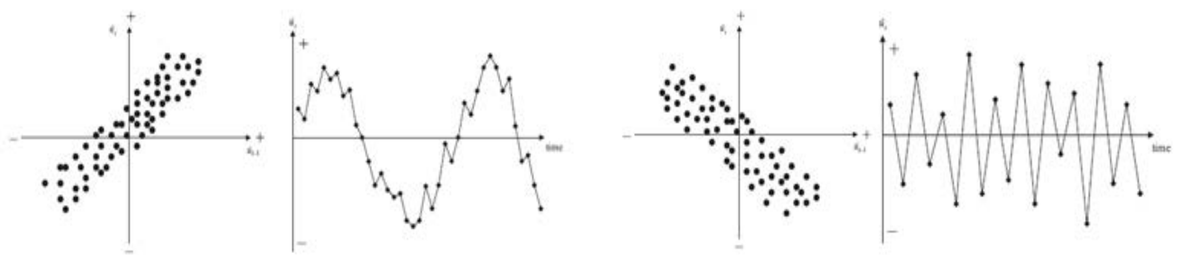
5.1.5 Autocorrelation

Autocorrelation is a common problem in time series econometrics. The term entails that the error term is correlated between different time periods in the time series. In other words the value of the previous variable will affect the value of the next.

Similar to the issue regarding stationarity, a simple graphical analysis may reveal whether the variables are autocorrelated or not. A time series exhibits autocorrelation if the residual plot illustrates a distinct pattern. If a time series suffer from positive autocorrelation, then the value of a residual, $\hat{u}_t$, is positively connected with its previous value, $\hat{u}_{t-1}$. This will result in a cyclical residual plot over time which gives clear signs on trending (at least in the short term) and does not cross the time axis very frequently. This is illustrated in the figure 12. The graphs on the left hand side reveal the residual plot of $\hat{u}_t$ vs $\hat{u}_{t-1}$ showing positive autocorrelation. In addition the plot of $\hat{u}_t$ over time illustrates the graphical expression of a positively autocorrelated time series.

Negative autocorrelation on the other hand implies that the current value of the residual is the complete opposite of the previous value, i.e. if $\hat{u}_{t-1}$ is positive, its subsequent value, $\hat{u}_t$, is likely to be negative. The result is a pattern that fluctuates over time, and crosses the time axis very frequently as can be seen below on the right hand side.

Figure 12: illustrative example of positive and negative autocorrelation



If the time series does not suffer from autocorrelation the plots are randomly scattered across all for quadrants in the residual plot showing $\hat{u}_t$ against $\hat{u}_{t-1}$, and the time series plot of the residuals over time does not cross the x-axis too frequently or too rarely.

Graphical analysis is a useful tool in cases where the data set is distinct, and you may undoubtedly tell whether the residuals are autocorrelated or not. However in most cases this distinction is difficult and I will therefore perform a statistical in addition to the graphical analysis. To check my data samples for autocorrelation the Lagrange Multiplier (LM) test based on the Johansen (1995) method.

Lagrange Multiplier

It is desirable to in include the LM-test because it allows for an examination of the relationship between $\hat{u}_t$ and several of its lagged values at the same time. It is a general test for autocorrelation up to the *r*th order, opposed to the DW-test which only measures first order autocorrelation. The model for the errors under the test is:

$$u_t = p_1 u_{t-1} + p_2 u_{t-2} \dots + p_r u_{t-r} + v_1, \qquad v \sim N(0, \sigma_v^2)$$

The null and the alternative hypothesis are:

$$H_0: p_1 = 0, p_2 = 0, \dots p_r = 0$$

$$H_1: p_1 \neq 0, p_2 \neq 0, \dots p_r \neq 0$$

If the test statistics exceeds the critical value from the Chi-squared statistical tables, I reject the null hypothesis of no autocorrelation.

5.1.6 Stability test

In order for the impulse to yield robust results, the VAR model has to be stable. If this requirement is met, the impact of a shock should gradually die away. On the other hand if this requirement is violated, some relationships are characterized as explosive, which implies that shocks increases over time and lead to unrealistically extreme short-rate projections, thus invalidating the model. The stability of a VAR-model is tested by examining its eigenvalues. If the eigenvalues are strictly lower than one, i.e. inside the unit circle the model is stable.

5.1.7 Normality test

In order to make inference of the observations the distribution of the variables must be known and a normality distribution is a standard assumption. According to Brooks (2008) one of the most commonly applied tests for normality is the Bera-Jarque (BJ) test. It is a goodness-of fit test of whether the sample data has the skewness and kurtosis similar to that of a normal distribution. Skewness measures the extent to which a distribution is not symmetric about its mean while the kurtosis measures the thickness of the tails of the distribution. Because a normal distribution is not skewed, and is defined to have a kurtosis of 3 Brooks (2008), the Bera-Jarque tests checks whether the coefficient of the skewness and kurtosis meet these requirements, i.e. whether these coefficient jointly are zero. Denoting the errors by u and their variance by σ^2, these coefficients can be expressed respectively as:

$b_1 = \frac{E[u^3]}{(\sigma^2)^{3/2}}$ and $b_2 = \frac{E[u^4]}{(\sigma^2)^2}$

As mentioned earlier the normal distribution has a kurtosis of 3, thus its excess kurtosis $(b_2 - 3)$ equals zero. Therefore the Bera-Jarque test statistic is written as:

$$W = T\left[\frac{b_1^2}{6} + \frac{(b_2 - 3)^2}{24}\right]$$

Where T is the sample size and the test statistic follows a $\chi^2(2)$ under the null hypothesis that the distribution of the series is both symmetric and mesokurtic.

Granger causality

A VAR model is likely to include many lags of variables, and to see which that has significant effects on each dependent variable an which do not. In order to address the issue, causality may be tested through the Granger Causality test. Consider the following bivariate VAR(3)

$$\begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \begin{pmatrix} \alpha_{10} \\ \alpha_{20} \end{pmatrix} + \begin{pmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{pmatrix}\begin{pmatrix} y_{1t-1} \\ y_{2t-1} \end{pmatrix} + \begin{pmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{pmatrix}\begin{pmatrix} y_{1t-2} \\ y_{2t-2} \end{pmatrix} + \begin{pmatrix} \delta_{11} & \delta_{12} \\ \delta_{21} & \delta_{22} \end{pmatrix}\begin{pmatrix} y_{1t-3} \\ y_{2t-3} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$$

In order to express the individual equations, the VAR could be rewritten as

$$y_{1t} = \alpha_{10} + \beta_{11}y_{1t-1} + \beta_{12}y_{2t-1} + \gamma_{11}y_{1t-2} + \gamma_{12}y_{2t-2} + \delta_{11}y_{1t-3} + \delta_{12}y_{2t-3} + u_{1t}$$

$$y_{1t} = \alpha_{20} + \beta_{21}y_{1t-1} + \beta_{22}y_{2t-1} + \gamma_{21}y_{2t-2} + \gamma_{22}y_{2t-2} + \delta_{21}y_{1t-3} + \delta_{22}y_{2t-3} + u_{2t}$$

These equations would be estimated separately using OLS to obtain the coefficients. The granger causality then use the F-statistic to test whether the independent variables are useful predictors of the dependent variable. The null hypothesis is of a value of zero for all coefficients, in other words that these regressors provide no predictive content for the dependent variable than contained in the other regressors. However, if the past value of y_2 is a useful predictor of y_1, it would be said that y_2 "granger causes" y_1.

5.1.8 Impulse responses

Even though F-test used in the examination of causality will suggest which of the variables in the model that have significant impact on the dependent variable, it does not reveal the sign of this relationship, or for how long these effects require to take place.

The impulse response function on the other hand traces out the responsiveness of the dependent variables in the VAR to shocks to each of the variables. For each variable in each equation separately, a unit shock is applied to the error, and the effects upon the VAR system are noted. Thus this test reveals whether the change in value of the variable has positive and negative effect on other variables in the system, and how long this effect is significant (Brooks, 2008).

To illustrate how impulse responses operate consider the following bivariate VAR:

$$y_t = A_1 y_{t-1} + y_t$$

Where

$$A_1 = \begin{pmatrix} 0.5 & 0.3 \\ 0.0 & 0.2 \end{pmatrix}$$

This may be rewritten as

$$\begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \begin{pmatrix} 0.5 & 0.3 \\ 0.0 & 0.2 \end{pmatrix} \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{1t} \end{pmatrix}$$

Now consider the effect of a unit shock to y_{1t} at time $t = 0$

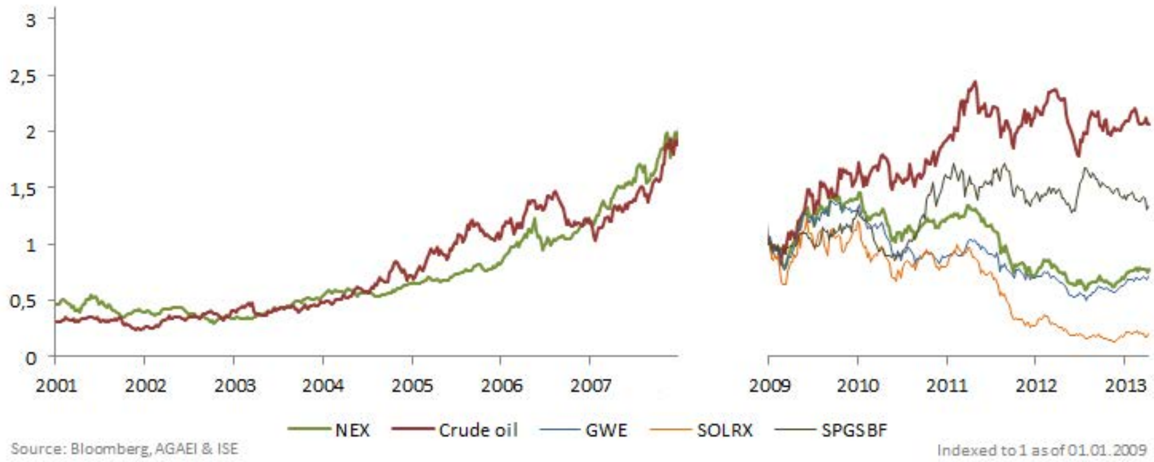
$$y_0 = \begin{pmatrix} \varepsilon_{10} \\ \varepsilon_{20} \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$y_1 = A_1 y_0 = \begin{pmatrix} 0.5 & 0.3 \\ 0.0 & 0.2 \end{pmatrix} \begin{pmatrix} 0.5 \\ 0 \end{pmatrix}$$

It will thus be possible to plot the impulse response functions of y_{1t} and y_{2t} to a unit shock in y_{1t}.

6. Data material

Figure 13: Asset price development from 2000 to 2007 and 2009 to 2013

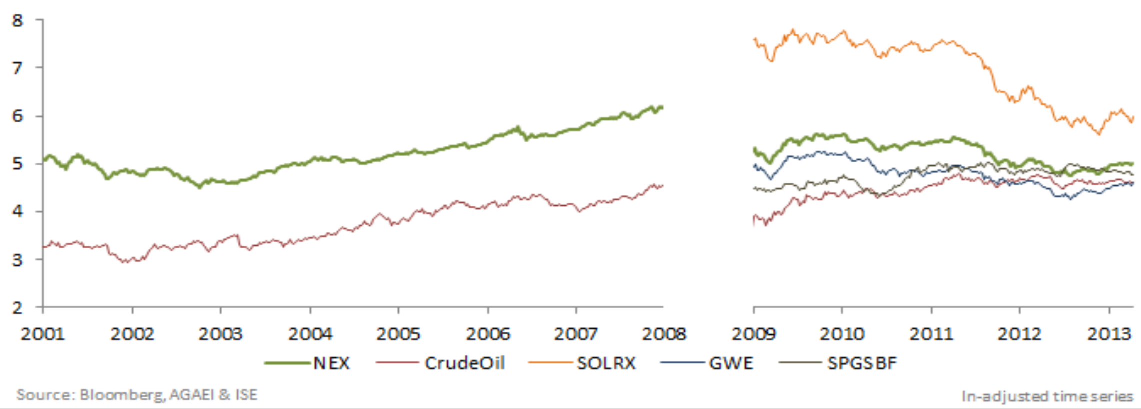


To perform this analysis I have applied a sample period from the end of December 2000 to the end of March 2013. However, as a consequence of my research question, I have not included data from 2008 in this analysis. This leaves me with two time periods, of which the first address the time period from December 2000 until the expiry of December 2007. While the second runs from early 2009 until the end of March 2013.

Because I seek to investigate how oil prices and renewable energy stocks may affect each other in the long run I have include a data interval which allows for the market participants to adjust for fundamental changes. Consequently I have included both monthly and quarterly data intervals in the statistical analysis. This is mainly because I believe quarterly data is the ideal interval when it comes to analyse long-term changes of both assets. However this approach limits the number of observations to 29 and 17 for the two sample periods respectively. The limited amount of data samples may restrict the statistical validity of my analysis both because outliers will have a disproportional huge impact on my analysis, and because statistical analysis may struggle to obtain significant results. As a consequence I have performed an identical analysis using monthly interval data. This increased the available amount of observations to 85 and 51 respectively. Even though applying weekly data may have solved the problem regarding a limited amount of observations I believe that the intervals chosen provide a better foundation for the financial analysis of my findings.

In the introduction and the market analysis I have used weekly returns of the assets indexed to one at the beginning of my sample period, and as of 18th of July 2007 to provide the reader with a good overview on how these assets have developed in accordance with each other. However in order to perform a statistical analysis I have to express all the variables in natural logarithms. This is necessary to reduce heteroscedasticity and to make the time series easier to interpret. Figure 14 illustrates the natural logarithms in its original form, before any adjustments have been made.

Figure 14: Natural logarithm of asset prices



When choosing indices to serve as a benchmark for alternative energy I have intentionally only used neutral indices which sole purpose is to adequately reflect the development within the alternative energy sector. I.e. to illustrate the performance of all companies directly involved with, or significantly affected by, the development within the alternative energy industry worldwide. I have on purpose excluded all kinds of actively traded funds, because they seek to beat a certain benchmark by investing according to their view of future development. Therefore the performance of an actively managed fund may to differ significantly from the general development in the industry it is investing in. All indices are also measured in total return, which means that all dividends, stock splits etc. are accounted for.

I will in the next paragraphs explain the features of the indices chosen to serve as a benchmark for the performance the renewable energy sector, in addition to the indices

I believe is a good measure of performance of the different subsectors within the renewable energy. When it comes to the selection criteria I have looked at the availability of historical data, i.e. for how long has the index up and running. The second and most important criterion is the design of the index, i.e. what are the requirements to be listed on this index, which sectors that are, how they are weighted etc.

6.1 Alternative energy

The WilderHill New Energy Global Innovation Index, hereafter called NEX is a capitalization weighted, float adjusted equity index designed to serve as an equity benchmark for globally traded stocks which are principally engaged in the field of Alternative Energy Technologies. The index was founded in December 2000 and is generally composed of between 80-100 companies. It is mainly comprised of companies with a focus on:

- wind
- solar
- biofuels
- hydro
- wave and tidal
- Geothermal and other renewable energy business
- As well as energy conversion, storage, conservations, efficiency, materials, pollution control, emerging hydrogen and fuel cells.

Only companies with a "meaningful exposure", either as technology, equipment, service of finance provider, such that profitable growth of the industry can be expected to have positive impact on that`s company performance may be included in NEX. The term "meaningful exposure" implies that at least 10% of its market value is derived from activities in clean energy. Companies that derive more than 50% of their market value from clean energy activities are biased favoured on the index, i.e. that companies with large exposure towards renewable energy has a disproportionally large impact on this index. Consequently, and owing to the fact that the clean energy industry is in the early stages of its growth cycle, the smaller-cap and mid-cap companies may have a leading role in the composition of the Index (Wilder Hill New Energy Finance, LLC)

However there are certain requirements concerning market cap (at least $100 million) and liquidity (minimum average trading of $1 million). Last the companies have to be listed on recognized stock exchange in America, Europe or Asia to be subject for this index.

6.1.1 Solar

The Ardour Solar Energy Index, hereafter named SOLRX is a compilation of global is a compilation of global solar energy stocks that are principally engaged in the business of producing solar energy. SOLRX comprises public companies in three primary solar energy sectors (Ardour Global, 2013):

- Photovoltaics
- Solar Thermal
- Solar Lighting

All companies on the SOLRX must derive 66 per cent or more of its annual revenues from its participation in the solar energy sector. At aggregate however, the income from the solar industry accounts for more than 90 per cent of total company income. In order to be eligible for this index a company has to be traded on recognized exchanges in the Americas, Europe, Middle East & Africa (EMEA) or Asia/Pacific.

Among the selection criteria include requirements include a minimum capitalization of $100m, minimum free float of $50m and minimum average daily trading volume of $1m. Last the SOLRX employs a modified float-adjusted market capitalization weighting methodology. The weight of any individual stock is capped at 10% and the combined weight of all stocks with weights over 5% is capped at 40% to limit the impact of certain stocks.

6.1.2 Wind

The ISE Global wind index was founded in 2005 and provides a benchmark for investors interested in tracking public companies that are active in the wind energy industry. It does not have a fixed number of stocks and attempts to include every stock in the industry that meets the eligibility requirements. The Index uses a quintile-based modified capitalization weighted methodology for each group of companies. The methodology sets the weight of each quintile to a multiple of the weight of the lowest quintile, based on its market capitalization. The resulting linear weight distribution prevents a few large component stocks from dominating the index while allowing smaller companies to adequately influence index performance (International Securities Exchange).

Companies that provide goods and services exclusively to the industry are given an aggregate weight of 66.67 per cent of the portfolio. Companies determined to be significant participants in the industry despite not being exclusive to the industry account for the remainder.

6.1.3 Biofuels

The S&P GSCI Biofuels index, hereafter called SPGSBF is intended in part to measure performance in the biofuel market and to correlate with its price movements. The SPGSBF is designed as a benchmark for investment in the biofuels sector and as a measure of performance of this commodity over time. It is calculated primarily on a world production-weighted basis and comprises the principal physical commodities that are the subject of active, liquid futures markets. There is no limit on the number of contracts that may be included in the SPGSBF, and any contract that satisfies the eligibility criteria and the other conditions are included (S&P, 2013).

6.2 Oil

To serve as a benchmark for oil prices I have chosen to use future prices of Light sweet crude (WTI) and ICE Brent crude (Brent), which are the two main global benchmarks for referencing the wide variety of crude oil grades and by far the most traded/liquid futures. The WTI delivered and quoted in Cushing, Oklahoma and considered a benchmark for US crude oil. On the other hand, Brent, comprising oil from 15 different fields in the North Sea, has traditionally been the leading global benchmark for Atlantic Basin crude oils. Today it serves as the benchmark for most European, African and Middle-eastern oil floating west, and is used to price 70 per cent of the world's oil supply (Fielden, 2013).

I have chosen futures contract for several reasons. First of all, in the research of Sadorsky (2001) and Scholtens & Wang (2008) they argue that futures price of oil better reflects the value of crude oil because spot prices can easily be driven by short-term supply-demand shocks. In addition, studies made by Gurcan (1998) and Crowder and Hamed (1993) conclude that crude oil futures are unbiased predictors of future spot prices. Last the spot price may be biased due to price manipulation. Currently BP, Shell and Statoil are under suspicion for manipulation of the Brent crude benchmark (Gosden, 2013). To mimic the risk of price inefficiencies that may occur due low volume in trading I will use highly liquid contracts that expires in three months from the actual date of measurement.

Until recent years, this choice to use either WTI or Brent was highly unlikely to make a difference in the analysis because historical correlation between these oil qualities exceeds 99 per cent. However, due to a large change in market dynamics that occurred in 2010 has caused the price of WTI to decline relatively to that of Brent. (I will not dig deeper in this matter, because to further investigate this shift is a potential thesis on its own.) As a consequence their correlation has sharply declined, thus I cannot exclude one of the oil qualities without damaging my analysis. With that in mind I will rely on the average prices of these crude qualities throughout the analysis. Table 1 provides the descriptive statistics of my time series:

Table 1: Descriptive statistics of data sample

Monthly data intervals (2000-2007)

Variable	Obs	Mean	Std. Dev	Min	Max
nex	85	5,219	0,440	4,556	6,182
crudeoil	85	3,717	0,451	2,968	4,551

Quarterly data intervals (2000-2007)

Variable	Obs	Mean	Std. Dev	Min	Max
Nex	29	5,223	0,457	4,556	6,182
crudeoil	29	3,721	0,462	2,986	4,551

Monthly data intervals (2009-2013)

Variable	Obs	Mean	Std. Dev	Min	Max
nex	51	5,237	0,263	4,771	5,593
crudeoil	51	4,469	0,229	3,848	4,788
solrx	51	6,951	0,700	5,703	7,718
gwe	51	4,784	0,266	4,298	5,238
spgsbf	51	4,744	0,192	4,344	5,023

Quarterly data intervals (2009-2013)

Variable	Obs	Mean	Std. Dev	Min	Max
nex	17	5,232	0,278	4,853	5,593
crudeoil	17	4,479	0,207	3,931	4,726
solrx	17	6,923	0,740	5,882	7,714
gwe	17	4,778	0,272	4,369	5,238
spgsbf	17	4,740	0,191	4,376	4,954

7. Statistical validity of my models

Before analysing the interaction between renewable energy stocks and crude oil price, I will investigate the stochastic properties of the series included in the Vector Autoregressive Models. This is necessary to determine which models to apply in the analysis, and to see whether adjustments have to be made for my models to become statistically valid. I have to make sure of this before analysing the relationship between renewable energy stocks and the oil price. Using a wrong model will cause misleading results, thus the conclusions drawn from this analysis would not provide me with any useful knowledge. In order to investigate whether my model is statistically valid I will make use of the test mentioned in the methodology chapter.

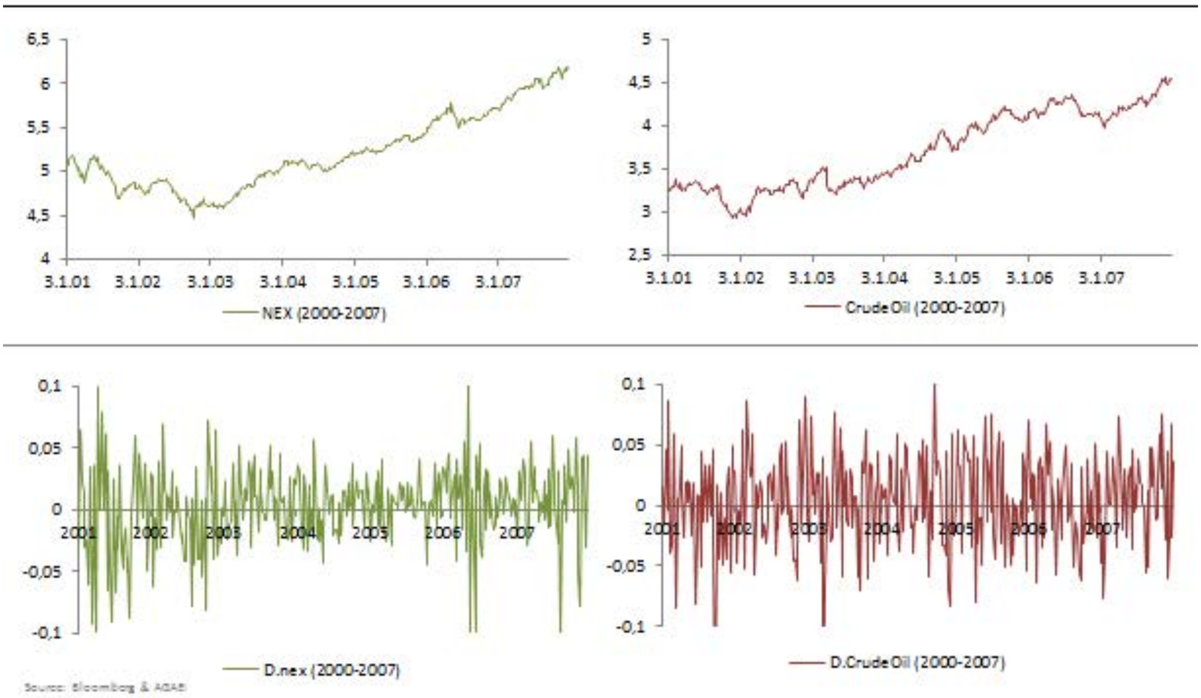
7.1 Unit root tests

In figure 14 the development of both renewable energy stocks and crude oil prices for both my sample periods is illustrated. A graphical analysis reveals how the time series in all sample periods appear to contain a unit root. This is in accordance with expectations because time series, and especially stock prices, usually contain unit roots. Since the early beginning, the stock market has been subject to a significant growth, only stalled by certain setbacks. Crude oil prices on the other hand have for longer periods of time remained constant in real terms. However during the latter years there is a distinct trend of gradually increasing prices. This is evident in the period prior to the financial crisis, as both assets exhibit a clear positive trend. During the second sample period crude oil recommences the positive growth path, while renewable energy stocks do not seem to be increasing at all. For illustrative purposes figure 15, is included. The upper graphs show the development in the NEX index and crude oil prices during the first sample period, and it is evident that development of these assets follows a positive trend.

However the graphical analysis is not sufficient to decide whether the data is stationary or not, thus I have to further analyse their order of integration through unit root tests. The test results from the augmented Dickey Fuller test may be found appendix 1 and 2. One may notice how crude oil is statistically significant as stationary within a 90 per cent confidence interval when monthly data intervals in the period 2000 to 2007 is applied, and both trend and constant is accounted. However in this thesis, I use a 5 percentile rejection region and thus reject the null hypothesis of stationarity. Therefore all tests confirm my suspicion of non-stationary time series for both periods when considering both monthly and quarterly data intervals.

Because the time series turned out non stationary, I have to determine which order they are integrated by. Hence, a rerun of the tests with differenced variables is necessary. This allows me to reject the null hypothesis, revealing that all time series are integrated of order $I(1)$. Figure 15 reveals the relationship between the initial time series plot of the NEX index and oil prices respectively, and its differenced values. Because first order differencing impies a subtracton of the value of a veriable with its immediate former value, the graphs at the bottom of figure 15 expresses the returns (of the natural logaryithm) that these indices genereate on a monthly/quarterly basis. Therefore by differencing, I create stationary time series that fluctualte around zero, and even though there are certain spikes in these time series , they quicly return to their mean values.

Figure 15: Natural logarithm and first order differenced NEX and Crude oil time series



7.2 Lag length & Cointegration

To decide the appropriate number of lags I have used information criteria to decide. By using Schwerts (1989) rule of thumb I limit put restrictions on the maximum limit of lags allowed when computing the information criteria. The criteria are calculated for all lag values and until the number of lags reaches zero. In most cases, the information criterions generate the same number of lags. When the appropriate number of lags differs between the different criteria I have relied on the MAIC and HQIC due to the former research conducted by Ivanov and

Kilian (2005), who claim that these criteria yields the best results when the data samples contain monthly and quarterly data respectively. Through this operation I arrive at the optimal lag levels illustrated in the below.

Table 2: Optimal number of lags according to the information criteria

Monthly optimal number of lags for VAR and ***VEC***	Crudeoil	ΔCrudeoil
ΔNEX (2000-2007)	-	3
ΔNEX (2009-2013)	-	1
ΔSOLRX (2009-2013)	-	1
ΔGWE (2009-2013)	-	1
SPGSBF (2009-2013)	***2***	-

-The bold and italic typing defines optimal number of lags in The Vector Error Correction Model

Quarterly optimal number of lags for VAR and **VEC**	Crudeoil	ΔCrudeoil
NEX (2000-2007)	***3***	-
ΔNEX (2009-2013)	-	2
ΔSOLRX (2009-2013)	-	1
ΔGWE (2009-2013)	-	3
SPGSBF (2009-2013)	***4***	-

-The in bold and italic typing defines optimal number of lags in The Vector Error Correction Model

From this figure one may notice how I have in one occasion for monthly data, and in two occasions for quarterly data computed the optimal number of lags for the Vector Error Correction Model. This is because these time series were proven to be cointegrated through Johansens test for cointegration. As mentioned in the methodology chapter, the Vector autoregressive models may in the case of cointegration, i.e. when two $I(1)$ time series exhibit a stationary trend, provide biased inferences. The VAR model has to be adjusted in order to account for this, which entails the creation of a Vector Error Correction model (VECM).Therefore when working further with these regressions, I have to apply a slightly different approach for the cointegrated time series.

7.3 Autocorrelation

In order for my model to be statistically valid, the residuals cannot exhibit autocorrelation. It is therefore necessary to determine whether the VAR and VECM models do not suffer from this when the number of lags estimated by minimising the information criteria is applied. From table 3, an observant reader may notice how number of lags differs from what I earlier calculated. This was necessary because autocorrelation was proven in the model analysing the quarterly relationship between solar stocks and the oil price and the VECM investigating the interaction between biofuel stocks and oil price. In order to avoid this problem the number of lags was increased until the zero hypothesis of zero autocorrelation could not be rejected. This approach yields a model with these appropriate numbers of lags:

Table 3: Optimal number of lags adjusted for autocorrelation

lags in monthly VAR and ***VEC*** accounted for autocoorelation	Crudeoil	ΔCrudeoil
ΔNEX (2000-2007)	-	3
ΔNEX (2009-2013)	-	1
ΔSOLRX (2009-2013)	-	1
ΔGWE (2009-2013)	-	1
SPGSBF (2009-2013)	*2*	-

-The bold and italic typing defines optimal number of lags in The Vector Error Correction Model

lags in quarterly VAR and ***VEC*** accounted for autocoorelation	Crudeoil	ΔCrudeoil
NEX (2000-2007)	*3*	
ΔNEX (2009-2013)	-	2
ΔSOLRX (2009-2013)	-	2
ΔGWE (2009-2013)	-	3
SPGSBF (2009-2013)	*5*	-

-The bold and italic typing defines optimal number of lags in The Vector Error Correction Model

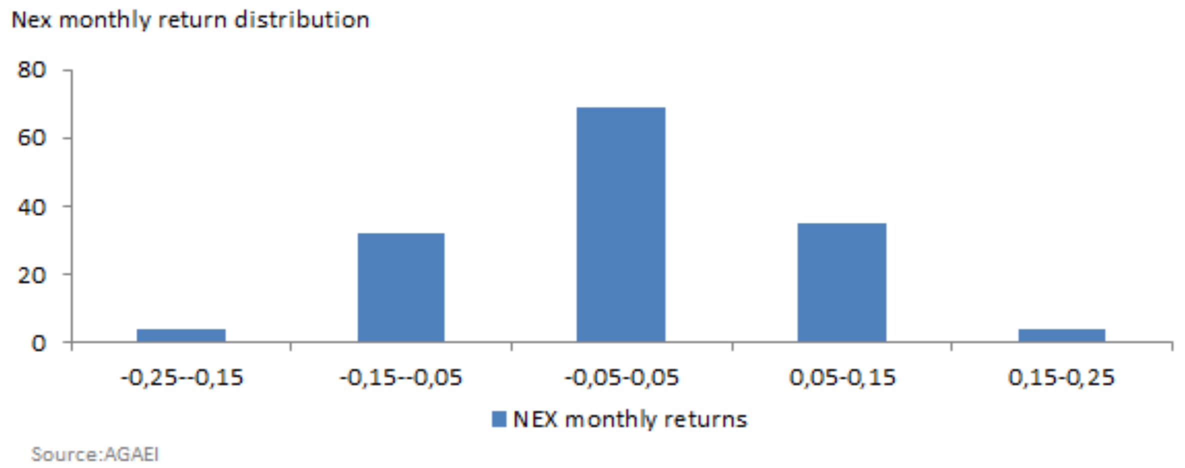
7.4 Stability

As described in chapter 5.1.6 it is important that the VAR is stable, which implies that all eigenvalues are strictly less than 1. The figure is shown in Appendix 11 and 12, confirming that my model is well within the limits, as such I do not have any explosive variables and stability is safely assumed.

7.5 Normality test

According to former research asset returns, when measured over short-term intervals (i.e. daily or weekly), has a distribution that is more peaked and has fatter tails than a normal distribution (Aas, 2004). On the other hand, the Central Limit theorem is often invoked in defence of the normal distribution for longer periods of time (Lindeberg, 1922). This theorem tells me that the sum of N is independent, identically distributed random variables converges to a normal distribution when N is large. As my data samples neither apply short-term data nor contain a large amount of observations required in order to rely on the central limit theorem, it is hard to know what to expect from the distribution of the variables in my models.

Figure 16: NEX monthly return distribution



However the return distribution, as can be seen in figure 16 provides evidence of normally distributed returns in my sample period in for renewable energy assets. The other indices and the oil price exhibit a similar pattern, although the fit does not appear this good for all indices. Because I cannot rely on graphical expression it is necessary to perform a statistical test to investigate whether my models fulfil the normality requirement. According to the Jarque-Bera normality test, I cannot in any of my models, reject the null hypothesis of normality with respect to either skewness or kurtosis.

Throughout this chapter I have performed multiple tests. The fact that neither of the time series are stationary is in accordance with my expectations. As all time series prove to be integrated at order $I(1)$ I have to make use of differenced variables in the Vector Autoregressive Models. The exceptions were the models comparing the oil price development with the Nex index (when using quarterly observations prior to the financial crisis) and the SPGSBF respectively. Because these variables were cointegrated I had to apply the slightly different Vector Autocorrection Model. By minimising the information criteria, I computed the optimal number of lags. In most cases, no further adjustments are needed. However some models still suffer from autocorrelation, which implies that I have to increase the number of lags until this is no longer a problem.

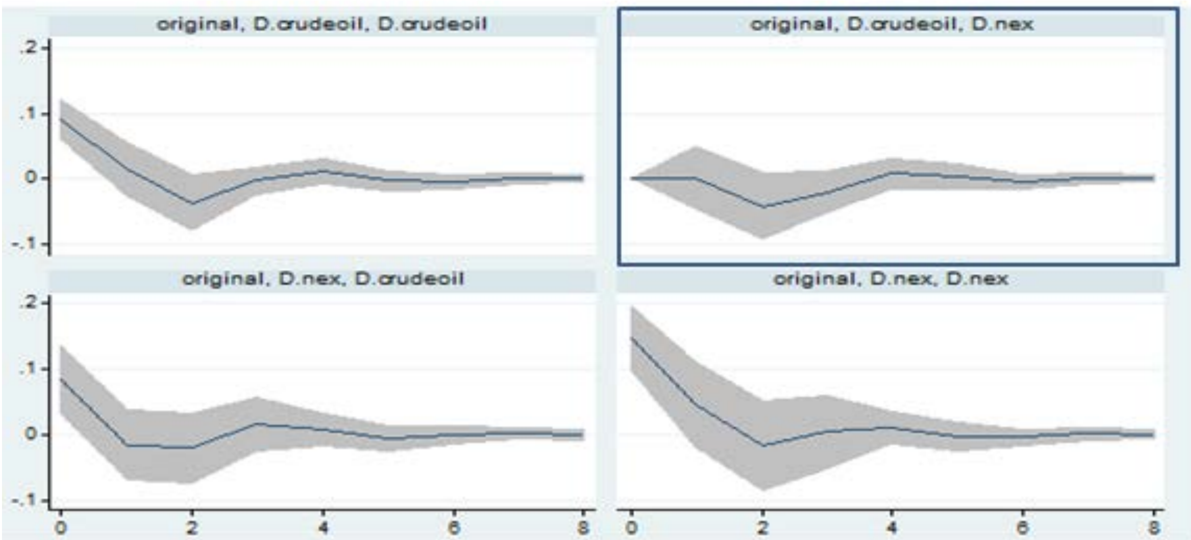
7.6 Granger Causality & Impulse response functions

These functions allow me to investigate how a shock in one of the variables will affect the dependent variables. First the granger causality tests are conducted to reveal whether there is a relationship between the variables. But because the test does not reveal the sign of this relationship, or for how long these effects require to take place I have included the use impulse response functions in this analysis. As the impulse response functions will provide the same information as the granger casualty test, the impulse response functions are presented in figure 18 and 19, whilst the results from the granger causality test is attached in appendix 13 and 14. Because Stata by default induce positive shocks, all the aforementioned figures are a measure of the response of a positive shock in one of the independent variables.

When analysing the impulse responses I will emphasize how a shock in one asset will affects the other. These relationships are much more interesting to analyse from an economic point of view than the response of an asset to a shock in the same asset.

Because the interpretation of the impulse response function is of great importance to my assignment, I will include an illustration, and provide a short explanation on how this may be interpreted.

Figure 17: Explanatory example of Impulse response function



Consider the impulse response function highlight in the blue square. This illustrates the response of NEX to a shock in crude oil prices. The blue line tracks the response in time, while the shaded grey area is provides a 95 per cent confidence interval of the response function. Because the impulse newer is significantly different from zero, the interpretation is that a shock in the oil price will not have any effect on the prices of renewable energy.

8. Results

8.1 Impulse response results

I will hereby present the results obtained in the impulse response functions (irf). Because statistical analysis does not always corresponds to financial theory some of the results may appear highly unlikely from an economic perspective. This will not be considered for now, but I will provide an economic interpretation of the statistical analysis later in this thesis. Because the irfs will be addressed frequently in this subchapter, to consecutively explain whether monthly or quarterly data is used may be confusing. Therefore I will use the notation M and Q when addressing monthly and quarterly data respectively.

8.1.1 2000-2007

The impulse response functions in this period differ significantly depending on which data interval I choose. This is because previous tests revealed that the oil price is cointegrated with the NEX index if quarterly data is used. Because stationary data is not required in the VECM, shocks may have a lasting effect on the dependent variable. On the contrary, the model derived from monthly data makes use of stationary data, thus shocks are not persistent and their effects eventually die out. The different irfs from this period are located at the top of figure 18 and 19 respectively. According to Qirf a shock in crude oil prices will have a permanent positive effect on the price of oil. The same applies for a shock in the NEX index, which has a long-run positive effect on the development of the NEX index. More interestingly however, is to analyse how a shock in either asset, will affect the development of the other. A shock in oil prices will cause an immediate decline in the NEX index, but this negative impact will pass and the long term effect of an oil price shock is positive. On the other hand a shock in the NEX index will have a lasting positive impact on crude oil prices.

When it comes to the Mirf the same shocks have limited effects. A positive shock in oil prices will cause an increase in the price of oil, but no impact on the NEX index is detected. A positive shock in NEX however will have a minor impact on oil prices, but this will not be persistent. The same applies for the impulse response of the NEX index

8.1.2 2009-2013

Throughout this period, shocks in oil price have a limited significant effect on SOLRX regardless of data interval. However the other way around, a positive shock in the SOLRX index will cause an immediate increase in crude oil prices, before the shock quickly die out. A shock in the GWE index will produce a similar reaction to oil prices. The other way around the conclusion depends on which data interval. While a shock in oil prices has no significant effect asset prices according to Mirf, a shock yields significant negative effect if quarterly data is emphasized. The responses to shocks in the other variables are generally small, die quickly, and the presence of significant results is limited. This is in accordance with the Qirfs, which calculates comparable results.

When it comes to the irfs derived from the interaction between SPGSBF and crude oil prices, the Qirf and Mirf differ in the short run, but as time passes then stabilise at an approximately equal level. According to Qirf the effects of a price shock on the dependent variable is positive regardless of whether a shock occurs in the NEX index and the respondent is Crude oil or vice versa. However Mirf does not provide the same, univariate solution. A shock in crude oil prices will cause a short term decrease in SPBF, before the negative impact gradually fades away, and a slightly positive long term effect reveals itself. In addition,

Figure 18: Impulse response function using quarterly data

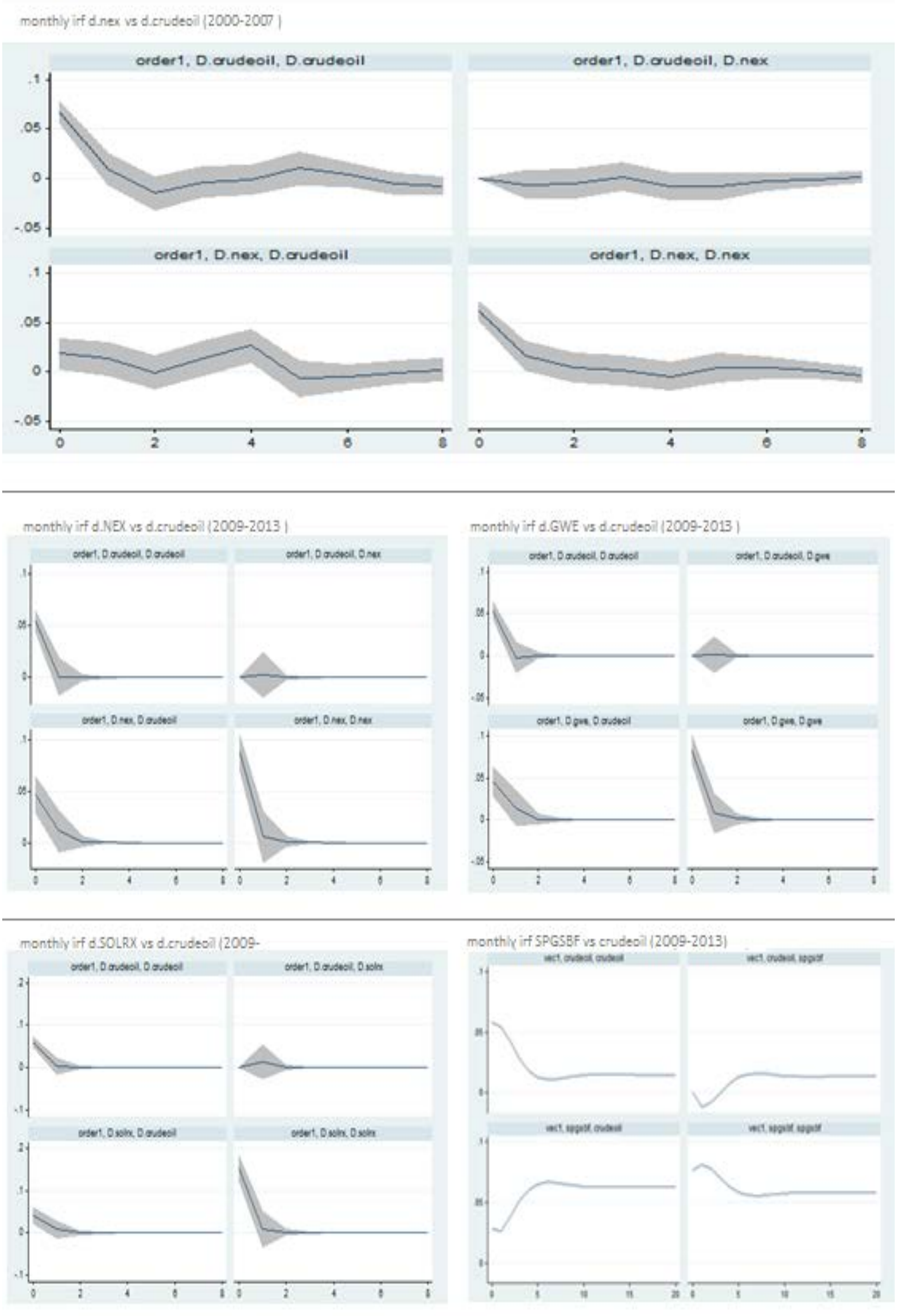
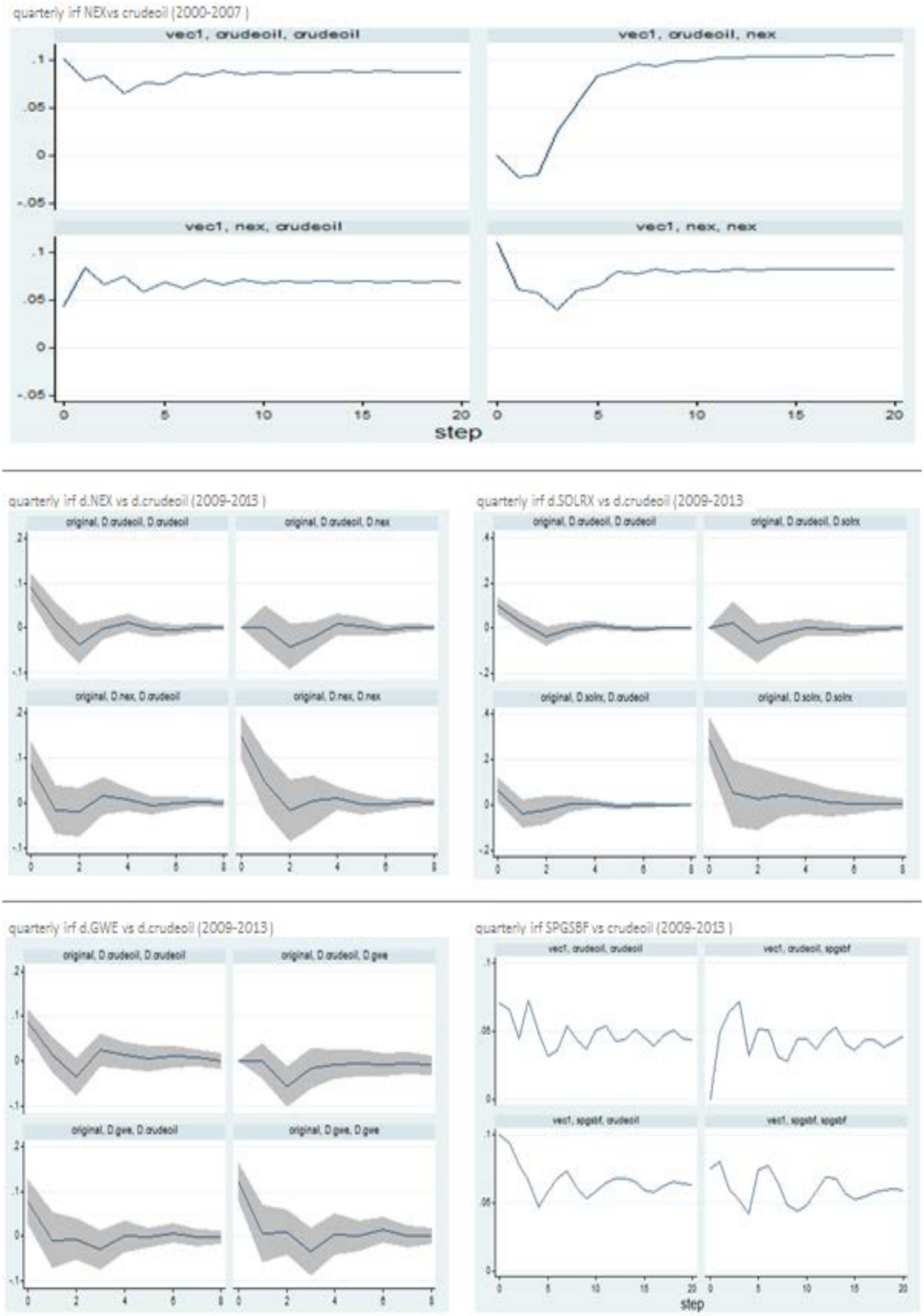


Figure 19: Impulse response function using quarterly data



8.2 Analysis of statistical findings

Even though economic statistical analysis enables the researcher to scientifically study economic phenomena and provide empirical evidence for economic theories, there is no guarantee that the results obtained are likely according to general economic knowledge. Therefore I will in the presentation of my results emphasise whether they are plausible or not from an economic point of view. I will start by analysing the results obtained from the analysis of the time period 2000 to 2007, before addressing my findings from the period post 2009 to 2013.

2000-2007

Cointegration is a regular phenomenon between assets that are closely related, and their value cannot deviate greatly due to an underlying economic relationship. Even though one of the tests confirmed that NEX index and crude oil share a common trend prior to the financial crisis I do not believe that they are cointegrated. Based upon the market analysis these assets do not appear closely connected, thus cannot exhibit a long-term mutual trend. However it is interesting to analyse why they are perceived as cointegrated according to statistical analysis. I will initially focus on fundamentals that determined the development of the NEX index before addressing factors that contributed to the surge in oil prices during the same period.

Between 2000 and 2007 the value of the NEX index nearly tripled and, while output capacity faced an annual growth of more than 20 per cent (Renewables Global Status Report 2011). However, this period started with a sharp decline in asset prices. Following the burst of the dot com bubble in early 2000 stock prices crashed, with Hi-tech shares facing the biggest losses. In accordance with previous research, high tech stocks have a significant negative impact on renewable energy stock, and similar losses occurred on the NEX index (Henriques & Sadorsky, 2007). However after this decline, The NEX index grew subsequently for the next 5 years. Looking back there are several explanations to why the value of renewable stocks soared.

In the market analysis I highlighted how economic growth is a key factor in the development of renewable energy. The intuition behind this is rather simple. Because renewable energy is more expensive than conventional energy, it is rarely adopted in the market without subsidies. Further on, subsidies are cyclical and dependent of economic growth. While the aforementioned crisis caused a halt in economic growth, this quickly expired, and by 2003, world economic growth was once again growing significantly (World Bank).

Even though the causality remain uncertain, i.e. whether the maturing of renewable energy technology made governments subsidise the industry to create a viable alternative of fossil fuels, or government subsidies played a key role in this technological improvement, the number of countries that granted renewable energy subsidies increased greatly. By 2005 48 countries worldwide had adopted some type of renewable energy production policy, more than half of which have of which have been enacted since 2002 (Martinot, Renewables 2005: Global Status Report, 2005), and two years later 66 countries had adopted a similar policy (Renewable Energy Policy Network, 2007). Cost reductions combined with subsidies made it possible for renewable energy to compete with the energy prices of conventional energy. This was especially evident for companies involved with solar power. From 2004 until the end of 2007 the price of photovoltaic modules remained approximately constant, while economies of scale and technology improvements allowed manufacturers to reduce their costs. The profitability of these companies soared, and according to Bloomberg New Energy Finance (2012), the 18 largest quoted solar companies followed by Bloomberg made average operating margins of 14.6 per cent to 16.3 per cent from 2005 to 2007. Consequently asset prices were booming causing an increase of the Ardour Global Solar Energy index by more than 300 per cent between 2005 and 2007 (Ardour Global Alternative Energy Indexes, 2013).

In accordance with the increased appeal of renewable energy, several high profiled IPOs were initiated. Market capitalization exceeded $100 billion in 2007 for the 135 publicly traded renewable energy companies, an increase from 85 companies in 2005 with market capitalization of $50 billion total (Martinot, 2008).

Similarly with the growth in subsidies, large commercial banks started to take notice of this industry, and started to include renewable energy investments in their lending portfolios. Large investors started to enter the renewable energy market including leading investment banks like Morgan Stanley and Goldman Sachs. The availability of commercial funding combined with low interest rates throughout this period undoubtedly contributed to the huge growth in renewable energy assets.

The price of crude oil followed a similar growth path even though it, as opposed to the NEX index, did not decline in 2002. But the arguably most important reason for the increase in the NEX index, namely GDP, was one of the most influential factors to the increase in crude oil prices (OECD, 2004).

In western countries, the consumption of oil remained virtually unchanged even though GDP grew steadily from 2000 to 2007 (U.S. Energy Information Administration, 2013). However, an increased wealth among non-OECD countries, in particular China and the Middle East, where energy intensive industries account for most of the economic growth, caused a significant increase in the world oil demand during this period, as their imports grew by almost 50 per cent. This resulted in a tightening of market conditions as production failed to offset the surge in demand, and oil prices to increased significantly (IMF, 2008).

The increase of this period was amplified by a continuously weakening dollar (HSBC, 2011), which according to IEA (2012) will cause an upward pressure on crude oil prices. Because crude oil is quoted in dollar, a relative decline in dollar entails a lower price for foreign investors, and prices will increase in dollar terms even if the demand does not change.

Based upon the previous discussion there are several different factors that contributed to the increase in NEX index and Crude oil respectively. However the most influential in this period was the increase in world gdp growth. This applies to both assets, which contributed to their similar growth path, exhibiting a mutual trend that made the statistical test identify them as cointegrated.

Because I do not believe that these variables are cointegrated I will not emphasize the impulse responses generated from quarterly data (figure 19), but rather focus on the impulse responses from the test using monthly data intervals (figure 18). That a shock in oil prices does not have any effect on the NEX index makes sense from according to the recent argumentation on how these assets relate to each other. Therefore it is surprise that a shock in the NEX index has a significant positive effect on crude oil prices. I find it hard to explain this result by using financial theory for two reasons. The first being the aforementioned argumentation on how the price on these assets are determined, and the second reason is the relative size of these markets makes this outcome highly unlikely. Even though the value of renewable energy increased significantly during this period, the overall size of this industry is a fraction of the oil commodity market. Therefore renewable energy assets lack the necessary size to influence oil markets.

2009-2013

The statistical tests confirm that the NEX index is not cointegrated with crude oil in this period. Because the result of these tests differ from the results obtained in the time period 2000 to 2007, an analysis on why their trends suddenly deviate significantly is appropriate.

While crude oil recommenced the positive growth prior to the financial crisis the value of renewable energy shares has decreased in this period.

There are several reasons why the NEX index has failed to cope with the recovery of the economy. In 2009 the NEX index gained 41 per cent before facing three consecutive years of declining stock prices. The explanation of why these assets have performed so poorly is to a certain extent the same as I provided in the period prior to the financial crisis only the effects are reversed.

European and to North American countries have been struggling post the financial crisis due to limited growth and significant fiscal challenges. As a consequence many of these countries, among them the US, Germany, Italy and UK are looking to scale back their subsidies to this industry, causing a decline in global renewables investments of 11 per cent in 2012, and the first drop in recorded investments since the financial crisis in 2008 (The Guardian, 2013). Even though some renewable sources are close to achieving grid parity (to generate energy at the same cost as conventional energy), they still face a slight cost disadvantage. As subsidies decline, the earnings potential of renewable energy stocks decrease and their prices drop. This has hit the renewable energy index hard because 24 of the 40 biggest producers of renewable energy are European or North American (Ernst & Young, 2012).

In addition, the price of renewable energy modules, especially solar wafers has dropped significantly during the last years, and declined by more than 70 per cent from mid-2011 to mid-2012 (IMS Research, 2013). This rapid decline in price was caused by a gross oversupply and highly competitive market conditions caused by the enormous growth in capacity that far out-weighed demand in 2011. Especially cheap PV modules from China contributed to this significant decline in prices.

The demand for crude oil however, has been subject to the same increase in demand that caused the increase in prices from 2000 to 2007. Non-OECD gdp started to increase shortly after the financial crisis, and their growth by fay exceed that of OECD countries. Due to the allegedly correlation between GDP growth and demand for crude oil in these countries, combined with a weakening of the US dollar, crude oil prices have reached post crisis levels.

Following this argumentation, the same factors apply to both assets prior to and post the financial crisis. Economic growth play a huge part in the development, and while the absence of growth in western countries has caused a scale back of subsidies contributing to a sharp decline in renewable energy assets, the continued economic growth among non-OECD countries entails an increased demand for oil, and consequently prices have risen to post crisis levels.

When it comes to the impulse responses, the NEX index remains unaffected by oil price shocks, but the GWE face a slight, but significant decrease in asset prices as a consequence of a positive oil price shock. This is surprising because they both primarily generate electricity, which entails a limited exposure to crude oil prices according to the previous analysis. However if there were to be affected by oil prices, I would expect either both or neither of GWE and SOLRX to be influenced by an oil price shock, rather than just one of them. On the other hand crude oil prices in this period react positively to a shock in the NEX index, I do not believe that these results are plausible from an economic point of view. The same applies to the impulse responses of crude oil to shocks in SOLRX and GWE.

Lastly the statistical tests provided me with an unambiguous conclusion that SPGSBF and crude oil are cointegrated. Because both of these assets track the performance of commodities directly, rather than offering an indirect exposure in the shape of stocks, they are more likely to exhibit a similar behaviour. In addition both of these assets are primarily used to produce liquid fuels for transportation. Currently biofuels provide approximately 3 per cent of world transportation fuels (IEA, 2013). Biofuels is either used by flexi fuel cars that can utilize a blend of containing high levels of biofuel. But because these cars are still few by the numbers, the majority of the produced biofuel is blended into regular gasoline for usage of regular cars (Biofuels, 2009). Because regular cars can utilize fuel containing small amounts of biofuels, the proportion is dependent of the price of biofuels. If prices grow too high relative to regular gasoline, the proportion of biofuel is likely to decrease causing a reduction in demand and a subsequent reduction of biofuel prices. In addition, if the price of crude oil increase, the ratio of biofuel in regular gasoline is likely to increase causing an upward pressure of biofuel prices. Therefore prices can deviate in the short run, but they will always follow a long-term relationship, i.e. they are cointegrated. This effect is evident in all impulse responses at the bottom right in figure 17 and 18 respectively. The only economic unviable result is the positive effect of a shock in SPGSBF prices on crude oil. Because the market share of biofuel is merely 3 per cent, while oil basically account for the last 97 per cent I do not believe that SPGSBF is able to affect crude oil prices.

9. Conclusion

My sample period has covered a turbulent time in world economy. While both renewable energy stocks and oil prices faced a significant growth prior to the financial crisis, they have faced different growth paths post this crisis. To obtained the necessary results required to answer my research question I have utilized the using VAR and VECM models, and interpreted my results using economic theory. My findings indicate that these assets are quite unaffected of the development of the other asset. This is evident in both sample periods. The reason why these assets seem to be closely in 2000 to 2007 is because increased GDP had a positive impact on both assets, while the financial- and the subsequent sovereign debt crisis in recent years have dampened the growth of western countries, causing a decline in renewable energy asset prices: on the other hand the high growth of Non-OECD countries has contributed to a continuously high demand for crude oil, causing an increase in prices. Based upon the research conducted in this thesis, I therefore reject the null hypothesis of the financial crisis resulting in a change in the interaction of renewable energy stocks and crude oil prices.

With respect to my secondary hypothesis I conclude that solar and wind power assets are similarly unaffected by oil prices. However the biofuel commodity index is cointegrated with crude oil prices, thus affected by its development. Therefore I reject my secondary hypothesis of crude oil having the same influence on across all the analysed renewable energy sectors.

10. Weaknesses

Even though I have adapted econometric methods in this thesis, the models I have designed are still rather primitive in many dimensions, and its quantitative results must be taken with caution. In addition the model utilizes historical data, but it is not capable to adjust for e.g. large differences in market size. Consequently, the results obtained from this model may seem highly unlikely from an economic point of view. This could to a certain extent be addressed by using constraints in my model, but as this tool would complicate matters to the point of which I would not have a thorough understanding of the statistical model, I chose not to include these in my analysis. A more robust model would have allowed me to emphasize the statistical results more, rather than using financial theory to override the results that does not make immediate sense.

In addition the biofuel index comprises of commodities and futures, rather that stocks, therefore it is not fully comparable with the other renewable sources of energy.

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Appendix

Appendix 1: Monthly dickey fuller test

ADF unit root test

monthly	#lags	characterisitcs	2000-2007	#lags	characterisitcs	2009-2013
NEX	1	trend & constant	-2,8236	1	trend & constant	-2,211
Crudeoil	1	trend & constant	-3,198*	1/2	constant	-2,416
SOLRX	-	-	-	1	-	-1,492
GWE	-	-	-	1	trend & constant	-2,465
SPGSBF	-	-	-	2	-	0,429
ΔNEX	3	-	-4,196***	1	-	-5,102***
ΔCrudeoil	3	-	-4,562***	1/-	-	-5,279***
ΔSOLRX	-	-	-	1	-	-4,789***
ΔGWE	-	-	-	1	-	-5,061***
ΔSPGSBF	-	-	-	-	-	-

-Optimal lag length when comparing biofuels and different indices varies, but as this minor change does not alter the utlimate conclution I will only present the results from crude oil with one lag.
-Crude oil and biofuels index are cointegrated, thus no calculation the value of the differenced ADF of these variables is required.
*** significant at 1 per cent ** significant at 5 per cent * significant at 10 per cent

Appendix 2:Quarterly dickey fuller test

ADF unit root test

quarterly	#lags	characterisitcs	2000-2007	#lags	characterisitcs	2009-2013
NEX	3	-	2,581	3	-	-1,155
Crudeoil	3	trend & constant	-2,685	3/2/4	-	1,275
SOLRX	-	-	-	2	-	-1,620
GWE	-	-	-	2	-	-0,947
SPGSBF	-	-	-	4	-	0,416
ΔNEX	-	-	-	2	-	-3,909***
ΔCrudeoil	-	-	-	2/1/3/-	-	-4,602***
ΔSOLRX	-	-	-	1	-	-3,447***
ΔGWE	-	-	-	3	-	-3,501***
ΔSPGSBF	-	-	-	-	-	-

-Optimal lag length when comparing crude oil with the different indices varies, but as this minor change does not alter the conclution I will only present the test results from crude oil with three lags
-In the period 2000-2007, NEX and Crude oil are cointegrated, thus no calculation the value of the differenced ADF of these variables is required.
*** significant at 1 per cent ** significant at 5 per cent * significant at 10 per cent

Appendix 3: Johansens test for cointegration (monthly)

monthly data, NEX index vs .crudeoil (2000-2007)

Johansen tests for cointegration

Trend: constant — Number of obs = 82
Sample: 2001m3 - 2007m12 — Lags = 1

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	2	205.63783	.	8.1362*	15.41
1	5	208.81524	0.07457	1.7814	3.76
2	6	209.70595	0.02149		

monthly data, NEX index vs .crudeoil (2009-2013)

Johansen tests for cointegration

Trend: constant — Number of obs = 51
Sample: 2009m3 - 2013m5 — Lags = 1

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	2	130.62416	.	9.3715*	15.41
1	5	134.09036	0.12710	2.4391	3.76
2	6	135.30989	0.04670		

monthly data, SOLRX index vs .crudeoil (2009-2013)

Johansen tests for cointegration

Trend: constant — Number of obs = 51
Sample: 2009m3 - 2013m5 — Lags = 1

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	2	98.171002	.	7.4561*	15.41
1	5	101.28722	0.11503	1.2236	3.76
2	6	101.89903	0.02371		

monthly data, GWE index vs .crudeoil (2009-2013)

Johansen tests for cointegration

Trend: constant — Number of obs = 51
Sample: 2009m3 - 2013m5 — Lags = 1

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	2	133.18783	.	10.1143*	15.41
1	5	136.58904	0.12487	3.3119	3.76
2	6	138.24499	0.06288		

monthly data, SPGSBF index vs .crudeoil (2009-2013)

Johansen tests for cointegration

Trend: constant — Number of obs = 51
Sample: 2009m3 - 2013m5 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	126.80491	.	20.7856	15.41
1	9	135.56502	0.29074	3.2653*	3.76
2	10	137.19769	0.06202		

Appendix 4: Johansens test for cointegration (quarterly)

quarterly data, NEX index vs .crudeoil (2000-2007)

Johansen tests for cointegration

Trend: constant — Number of obs = 26

Sample: 2001q3 - 2007q4 — Lags = 3

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	10	41.590911	.	16.4960	15.41
1	13	49.709158	0.46446	0.2596*	3.76
2	14	49.838933	0.00993		

quarterly data, NEX index vs .crudeoil (2009-2013)

Johansen tests for cointegration

Trend: constant — Number of obs = 17

Sample: 2009q1 - 2013q1 — Lags = 3

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	10	34.89594	.	14.5570*	15.41
1	13	41.414503	0.53554	1.5199	3.76
2	14	42.174461	0.08553		

quarterly data, SOLRX index vs .crudeoil (2009-2013)

Johansen tests for cointegration

Trend: constant — Number of obs = 17

Sample: 2009q1 - 2013q1 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	17.908452	.	13.9436*	15.41
1	9	23.876063	0.50444	2.0084	3.76
2	10	24.880243	0.11143		

quarterly data, GWE index vs .crudeoil (2009-2013)

Johansen tests for cointegration

Trend: constant — Number of obs = 17

Sample: 2009q1 - 2013q1 — Lags = 1

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	2	27.72181	.	11.5488*	15.41
1	5	31.871003	0.38623	3.2504	3.76
2	6	33.496215	0.17403		

quarterly data, SPGSBF index vs .crudeoil (2009-2013)

Johansen tests for cointegration

Trend: constant — Number of obs = 17

Sample: 2009q1 - 2013q1 — Lags = 4

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	14	35.952371	.	17.2485	15.41
1	17	43.255815	0.57651	2.6416*	3.76
2	18	44.576613	0.14392		

Appendix 5: LM test for autocorrelation (monthly)

monthly data, NEX index vs .crudeoil (2000-2007)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	1.1584	4	0.88490
2	1.7501	4	0.78160

H0: no autocorrelation at lag order

monthly data, NEX index vs .crudeoil (2009-2013)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	1.2668	4	0.86699
2	4.2015	4	0.37942

H0: no autocorrelation at lag order

monthly data, SOLRX index vs .crudeoil (2009-2013)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	1.1785	4	0.88163
2	1.8440	4	0.76442

H0: no autocorrelation at lag order

monthly data, GWE index vs .crudeoil (2009-2013)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	2.0970	4	0.71793
2	3.2469	4	0.51739

H0: no autocorrelation at lag order

monthly data, SPGSBF index vs .crudeoil (2009-2013)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	2.3369	4	0.67406
2	4.2715	4	0.37051

H0: no autocorrelation at lag order

Appendix 6: LM test for autocorrelation (quarterly)

quarterly data, NEX index vs .crudeoil (2000-2007)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	5.6440	4	0.22736
2	4.8777	4	0.30007

H0: no autocorrelation at lag order

quarterly data, NEX index vs .crudeoil (2009-2013)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	4.2656	4	0.37125
2	1.9113	4	0.75207

H0: no autocorrelation at lag order

quarterly data, SOLRX index vs .crudeoil (2009-2013)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	2.9139	4	0.57234
2	1.0891	4	0.89599

H0: no autocorrelation at lag order

quarterly data, GWE index vs .crudeoil (2009-2013)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	5.8096	4	0.21383
2	3.1558	4	0.53210

H0: no autocorrelation at lag order

quarterly data, SPGSBF index vs .crudeoil (2009-2013)
Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	2.9230	4	0.57080
2	1.3878	4	0.84632
3	0.4907	4	0.97440
4	3.2237	4	0.52111
5	2.0454	4	0.72741

H0: no autocorrelation at lag order

Appendix 7: Normality test, 2000-2007 (monthly)

monthly data, NEX index vs.crudeoil (2000-2007)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_nex	0.573	2	0.75104
D_crudeoil	0.841	2	0.65683
ALL	1.413	4	0.84189

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_nex	-.1091	0.101	1	0.75043
D_crudeoil	.03658	0.011	1	0.91508
ALL		0.113	2	0.94529

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_nex	2.529	0.471	1	0.49233
D_crudeoil	2.3753	0.829	1	0.36248
ALL		1.301	2	0.52186

Appendix 8: Normality test, 2009-2013 (monthly)

monthly data, NEX index vs .crudeoil (2009-2013)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_nex	3.919	2	0.14092
D_crudeoil	3.562	2	0.16844
ALL	7.482	4	0.11253

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_nex	.19032	0.465	1	0.49538
D_crudeoil	.41553	2.216	1	0.13660
ALL		2.681	2	0.26176

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_nex	1.9624	3.454	1	0.06309
D_crudeoil	2.3522	1.347	1	0.24588
ALL		4.801	2	0.09068

monthly data, SOLRX index vs .crudeoil (2009-2013)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_solrx	2.252	2	0.32438
D_crudeoil	1.304	2	0.52108
ALL	3.555	4	0.46951

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_solrx	-.51197	2.228	1	0.13554
D_crudeoil	.38987	1.292	1	0.25568
ALL		3.520	2	0.17205

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_solrx	3.1057	0.024	1	0.87758
D_crudeoil	2.9258	0.012	1	0.91388
ALL		0.035	2	0.98244

monthly data, GWE index vs .crudeoil (2009-2013)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_gwe	0.795	2	0.67212
D_crudeoil	2.224	2	0.32887
ALL	3.019	4	0.55468

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_gwe	.12848	0.140	1	0.70798
D_crudeoil	-.04508	0.017	1	0.89543
ALL		0.158	2	0.92423

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_gwe	2.4451	0.654	1	0.41857
D_crudeoil	1.9809	2.207	1	0.13739
ALL		2.861	2	0.23916

monthly data, SPGSBF index vs .crudeoil (2009-2013)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_spgsbf	0.585	2	0.74634
D_crudeoil	0.359	2	0.83589
ALL	0.944	4	0.91822

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_spgsbf	-.15778	0.212	1	0.64551
D_crudeoil	.07354	0.046	1	0.83024
ALL		0.258	2	0.87916

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_spgsbf	3.4193	0.374	1	0.54108
D_crudeoil	2.6165	0.313	1	0.57613
ALL		0.686	2	0.70961

Appendix 9: Normality test, 2000-2007 (quarterly)

quarterly data, NEX index vs .crudeoil (2000-2007)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_nex	1.612	2	0.44661
D_crudeoil	1.143	2	0.56462
ALL	2.755	4	0.59956

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_nex	-.57074	1.412	1	0.23480
D_crudeoil	.50214	1.093	1	0.29589
ALL		2.504	2	0.28591

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_nex	3.4303	0.201	1	0.65424
D_crudeoil	3.2162	0.051	1	0.82199
ALL		0.251	2	0.88196

Appendix 10: Normality test, 2009-2013 (quarterly)

quarterly data, NEX index vs .crudeoil (2009-2013)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_nex	1.468	2	0.48006
D_crudeoil	3.845	2	0.14622
ALL	5.313	4	0.25667

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_nex	-.27974	0.222	1	0.63773
D_crudeoil	.98521	2.750	1	0.09725
ALL		2.972	2	0.22629

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_nex	1.6737	1.246	1	0.26432
D_crudeoil	1.7566	1.095	1	0.29535
ALL		2.341	2	0.31020

quarterly data, SOLRX index vs .crudeoil (2009-2013)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_solrx	1.925	2	0.38198
D_crudeoil	3.144	2	0.20767
ALL	5.068	4	0.28035

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_solrx	-.81791	1.895	1	0.16859
D_crudeoil	.89525	2.271	1	0.13183
ALL		4.166	2	0.12454

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_solrx	2.7965	0.029	1	0.86398
D_crudeoil	1.89	0.873	1	0.35020
ALL		0.902	2	0.63697

quarterly data, GWE index vs .crudeoil (2009-2013)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_gwe	3.118	2	0.21032
D_crudeoil	3.264	2	0.19557
ALL	6.382	4	0.17239

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_gwe	-.32155	0.293	1	0.58833
D_crudeoil	.36457	0.377	1	0.53944
ALL		0.670	2	0.71550

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_gwe	1.0028	2.825	1	0.09279
D_crudeoil	.98112	2.887	1	0.08929
ALL		5.712	2	0.05749

quarterly data, SPGSBF index vs .crudeoil (2009-2013)

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_spgsbf	5.015	2	0.08148
D_crudeoil	2.005	2	0.36697
ALL	7.020	4	0.13485

Skewness test

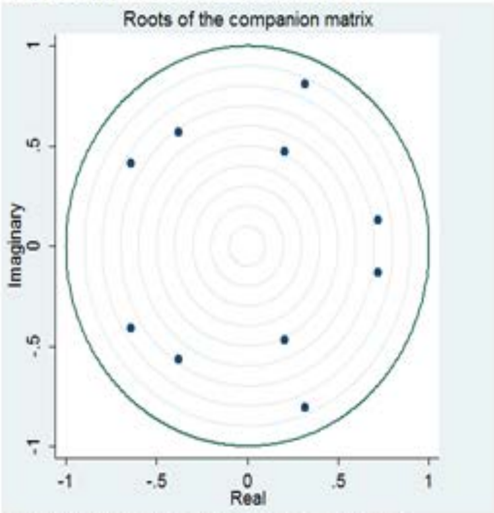
Equation	Skewness	chi2	df	Prob > chi2
D_spgsbf	-1.1118	3.503	1	0.06127
D_crudeoil	.81022	1.860	1	0.17263
ALL		5.363	2	0.06848

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_spgsbf	4.4611	1.512	1	0.21881
D_crudeoil	2.5476	0.145	1	0.70336
ALL		1.657	2	0.43667

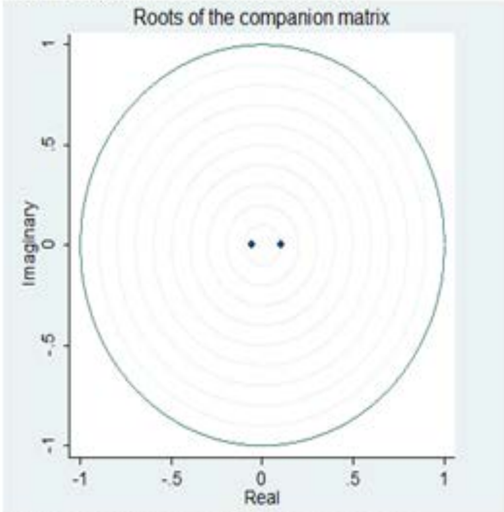
Appendix 11: Stabiliy test (monthly)

monthly data, NEX index vs .crudeoil (2000-2007)



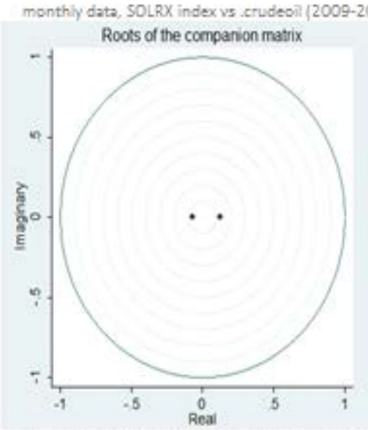
All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

monthly data, NEX index vs .crudeoil (2009-2013)



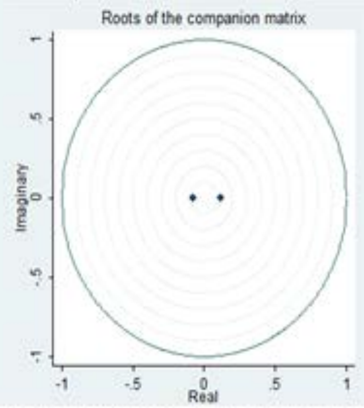
All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

monthly data, SOLRX index vs .crudeoil (2009-2013)



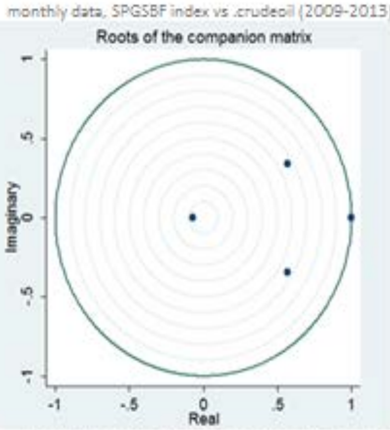
All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

monthly data, GWE index vs .crudeoil (2009-2013)



All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

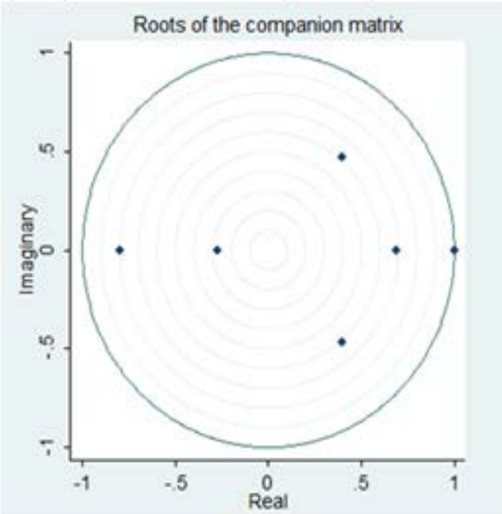
monthly data, SPGSBF index vs .crudeoil (2009-2013)



The VECM specification imposes a unit modulus.

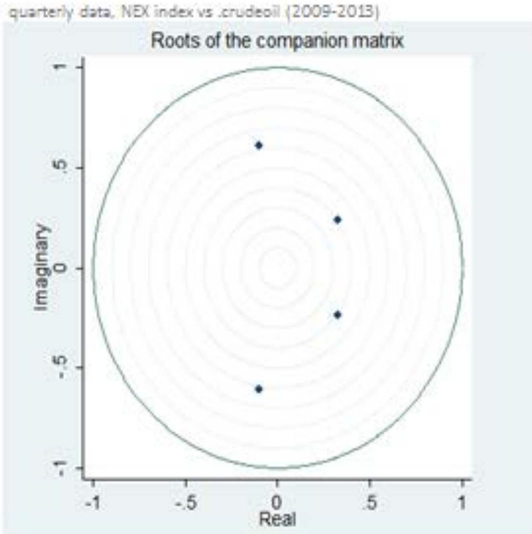
Appendix 12: Stabiliy test (quarterly)

quarterly data, NEX index vs .crudeoil (2000-2007)



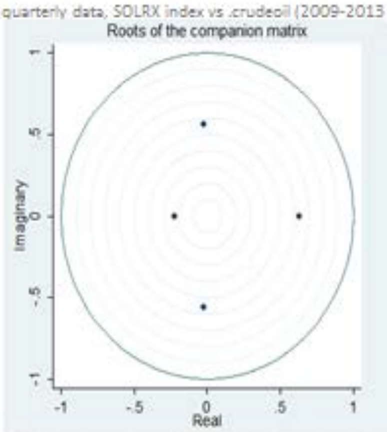
The VECM specification imposes a unit modulus.

quarterly data, NEX index vs .crudeoil (2009-2013)



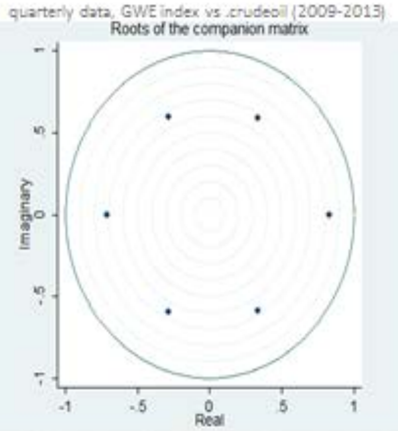
All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

quarterly data, SOLRX index vs .crudeoil (2009-2013



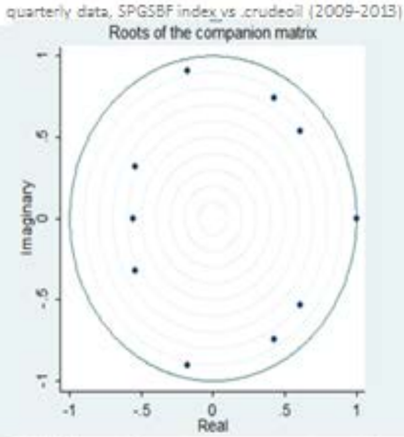
All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

quarterly data, GWE index vs .crudeoil (2009-2013)



All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

quarterly data, SPGSBF index vs .crudeoil (2009-2013)



The VECM specification imposes a unit modulus.

Appendix 13: Granger causality test (monthly)

monthly data, NEX index vs .crudeoil (2000-2007)
Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
D_nex	D.crudeoil	3.4451	5	0.632
D_nex	ALL	3.4451	5	0.632
D_crudeoil	D.nex	18.054	5	0.003
D_crudeoil	ALL	18.054	5	0.003

monthly data, NEX index vs. crudeoil (2009-2013)
Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
D_gwe	D.crudeoil	.02644	1	0.871
D_gwe	ALL	.02644	1	0.871
D_crudeoil	D.gwe	1.5848	1	0.208
D_crudeoil	ALL	1.5848	1	0.208

monthly data, SOLRX index vs. crudeoil (2009-2013)
Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
D_solrx	D.crudeoil	.4289	1	0.513
D_solrx	ALL	.4289	1	0.513
D_crudeoil	D.solrx	.25179	1	0.616
D_crudeoil	ALL	.25179	1	0.616

monthly data, GWE index vs. crudeoil (2009-2013)
Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
D_nex	D.crudeoil	.06276	1	0.802
D_nex	ALL	.06276	1	0.802
D_crudeoil	D.nex	.73569	1	0.391
D_crudeoil	ALL	.73569	1	0.391

*Because SPGSBF vs. crudeoil (2009-2013) are cointegrated, no granger test is performed on this model

Appendix 14:Granger causality test (quarterly)

quarterly data, NEX index vs. crudeoil (2009-2013)
Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
D_nex	D.crudeoil	3.1365	2	0.208
D_nex	ALL	3.1365	2	0.208
D_crudeoil	D.nex	.84366	2	0.656
D_crudeoil	ALL	.84366	2	0.656

quarterly data, SOLRX index vs. crudeoil (2009-2013)
Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
D_solrx	D.crudeoil	2.7137	2	0.257
D_solrx	ALL	2.7137	2	0.257
D_crudeoil	D.solrx	1.9636	2	0.375
D_crudeoil	ALL	1.9636	2	0.375

quarterly data, GWE index vs. crudeoil (2009-2013)
Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
D_gwe	D.crudeoil	13.522	2	0.001
D_gwe	ALL	13.522	2	0.001
D_crudeoil	D.gwe	1.0861	2	0.581
D_crudeoil	ALL	1.0861	2	0.581

*Because NEX vs Oil (2000-2007) and SPGSBF vs. crudeoil (2009-2013) are cointegrated, no granger test is performed on these models