## Abstract

This thesis analyzes the effect of crude oil on the prices of commodities. The thesis provides an overview of the oil market and of its participants, as well as how the price of crude oil and the commodities is determined and how they are traded. Using a Vector Autoregressive Model (VAR), we were able to analyze the causation relationships between the variables and compare the effect on the different industries and sectors. In order to analyze the effects from the financial crisis we made use of two sample periods, one going from 1994 through June 2008: (1) and the other from 1994 up until today: (2). What we found was that the correlations between the price of crude oil and the commodities were higher in (2) for all but natural gas and iron ore, which decreased severely through the financial crisis. We further found that leading up to the financial crisis most of the agricultural commodities, coal and gold all shared a delayed but significant causation relationship with the crude oil price. In (2) however, only soybeans and rubber of the agricultural commodities proved to have a significant causation relationship with the crude oil price whereas both the metal sector and the energy sector as well as salmon proved to have a significant causation relationship with the crude oil price. In addition, we have analyzed how economic growth affects the price of the commodities to be able to compare this to how the crude oil price affects the price of the commodities.

## Preface

This thesis is written as a finalization of our Master's degree in Industrial Economics at the University of Stavanger. The thesis has been time consuming and at times a major concern in our everyday lives, however looking back it has been a steep and exciting learning process.

Firstly, we would like to thank our supervisor Roy Endrè Dahl for his support and motivation. Whenever we have felt stuck he has pointed us in the right direction and we greatly appreciate his time and effort spent on this thesis.

Atle Øglend has been of great support regarding our analysis and the software used in this thesis; therefore we would like to thank him for his availability and knowledge throughout this period.

Finally, we would like to thank friends and family for their support and involvement with our work.

Stavanger, May 2014

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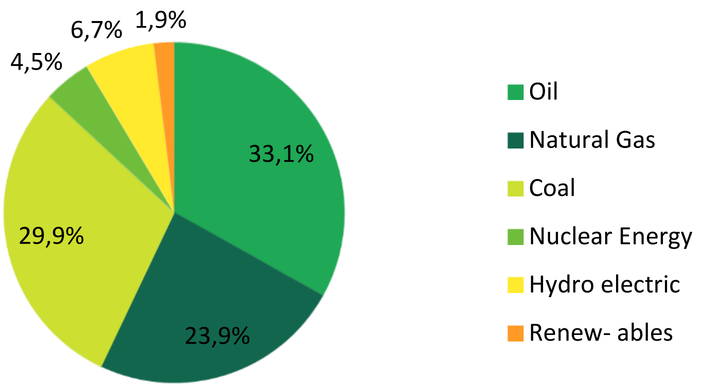
# 1.0 Introduction

## 1.1 Introduction

Since the 70s, the real price of crude oil has fluctuated significantly, from the lows in 1986 with the oil price crash to the record high levels in the pre-financial crisis in 2008. Over the years crude oil has grown into being regarded as one of the most important commodities in the world (Hubbard, 1998), being an essential part in everything from food production, building of infrastructure as well as meeting 33% of the world`s energy demand in 2012 (BP, 2013)

Figure 1: World Energy consumption 2012.

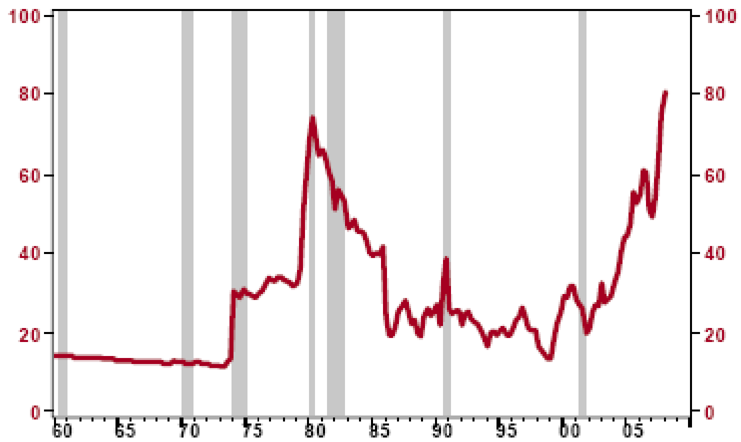



Being such an important substance that crude oil is, the change in crude oil prices has historically stimulated effective and efficient growth in all realms of the world as well as facilitated the economic status of the crude oil producing countries (Ekmekcioglu, 2012). Throughout the history of the modern oil era, there has been conducted several studies, seeking to identify which underlying causes that affects the price of crude oil as well as to what degree these underlying causes affects the price of crude oil. In this thesis, we will investigate this and try to provide a better understanding of how the price of crude oil affects the economy.

### Why is it important to look at the oil price effect on other markets?

Crude oil is used directly and indirectly in the production of thousands of products that is highly necessary in our everyday life. The food production, building of infrastructure, pharmaceuticals, and most of all transportation use, to a certain degree, crude oil or refined crude oil products. At a micro level, an increase in oil prices, typically, will lead to an increase in the production and transportation costs of various goods and services. These extra costs are most likely to be passed on to the end consumer reducing the demand for the commodity or service. At a macro level, the increase in price of certain commodities and services tends to reduce households wealth and hence the demand for various other commodities reducing trade in the economy and hence suppressing economic growth. However, not all oil price shocks have had the same effect on the economy as those of the late 70`s and 80`s (Figure 2) indicating that the correlation between crude oil price increases and economic downturn is not perfect.

Figure 2: Real oil price and periods of economic downturn (grey shading)




Source: Haver Analytics (2008)

From the start of the millennium, the open interest for trading in the futures market has grown significantly (Figure 3). As most commodities today can be traded as derivatives on futures markets by speculators, the futuristic view regarding supply and demand does, to a larger extent, decide the prices both for futures contracts as well as for the spot trading. This increase in trading of futures contracts also coincided with an increase in price volatility in the commodity market and has often been blamed for these volatile prices. However, this high trade frequency should in theory create a more liquid market, as it is easy for investors to buy and sell shares hence the prices should stay somewhat stable.

Nevertheless, alongside this increased interest in futures trading in the commodity market the correlation between crude oil and other commodities has increased significantly. A research conducted by the U.S. Energy Information administration (EIA, 2012) found that there was an increase in the correlation between commodities both before and after the financial crisis. One of the reasons for this could be the rise in interest in general commodity exposure, which were gained by investing in the index funds-market. The index funds-market lets you invest in a fund that traces a basket of commodities, providing exposure for all the included commodities. Buyuksahin & Robe (2011) on the other hand, claims that hedge funds, and not index trading have affected these correlations. As the hedge funds are managed more aggressively than index funds, entering/exiting markets more frequently as well as being traded across markets to exploit perceived mispricing opportunities.

However, economists argue that index trading and/or hedge funds are not the only cause for increased correlation in price movements of commodities. Since the 1990`s we have seen the rise of the internet, the proliferation of electronic trading, a global financial crisis and interventions in markets by central banks around the world, which have resulted in investors being equipped with the itchiest trigger fingers ever in one of the touchiest periods in history (Zweig, 2012).

### Scope of the thesis

This thesis will try to identify if there is a causation relationship between the price of crude oil and the price of other commodities by using a Vector Autoregressive analysis (VAR). We will use the 2008 financial crisis to see if there was some causation relationship before or if these might have occurred during or after the financial crisis. In addition, we will see how the correlations have changed through the financial crisis. Even though correlation is not the same as causation, correlation is a hint that there might be a causation relationship.

The rest of the thesis proceeds as follows. We first end this section by reviewing our motivation and former research on the topic. The next section seeks to define the various markets and explain what influences the price of crude oil; the data section describes the data obtained and where we found it; the statistical theory, validation of data and model explains the statistical theory which we base our model upon as well as describes the methodological framework of our model and the validity of the time series; the result section presents the empirical results obtained from the model and discusses the results; and the last section concludes.

## 1.2 Motivation

To see how the price of oil affects the price of other commodities can benefit both commodity producers as well as speculators. As the crude oil price is such an important substance both in the financial sector as a traded commodity and as a direct or indirect input in the industrial and agricultural sector, several of the participants would be able to hedge or diversify their investments because of the impact from the change in the price of oil.

Most commodity prices are eventually decided by the relationship between supply and demand. However, these increased correlations to the oil price in periods of economic stress etc. might indicate that the oil price should be considered as an influencing factor, especially in periods of economic stress. Oil production companies can use this to diversify their investments. If i.e. lower oil prices would cause an increase in income from another commodity, the oil production company could invest in futures contracts for that commodity to make a profit. The opportunity for producers as well as retail sellers to see the effect of crude oil prices on their product line would make them able to take measures in time to hedge against future changes in crude oil prices. Index- and hedge fund speculators could be able to see what commodity futures contracts to include in their fund to diversify their investment or to gain more exposure.

Moreover, due to its importance to Norway and Norway`s economy we find it particularly interesting to learn more about crude oil and how it interacts with both national and global economies as well as how it affects various industries, and through which channels this occurs.

## 1.3 Former research

Ever since the 80`s a vast number of research surrounding the crude oil prices have emerged[1]. High volatility in the crude oil prices has historically lead out into subsequent recessions, as illustrated in Figure 2. This has caused for an investigation surrounding what causes these shocks to the crude oil prices, as well as which has the most significant and durable impact. There has also been conducted some research on how the price of oil has affected both global and national economies and vice versa. Given that crude oil is a substance of high importance to many industries as well as an important source of income to oil exporting countries its price will affect economic growth in most countries. Most researches emphasize how crude oil prices affect the macro economy, and in particular looks at the effects of oil price shocks (Hamilton, 2009 and Kilian, 2009).

One research paper that have investigated the relationship between oil price and commodities is the World Bank`s “Oil Spills On Other Commodities” (Baffes, 2007). This paper seeks to estimate the degree of pass-through of crude oil price changes to the price of most other primary commodities. They use a yearly time interval from the period 1971 until 2005 and utilize an OLS regression of the individual commodity price on the crude oil price by explicitly taking into account inflation and technological change. What they find is that the fertilizer index exhibits the largest pass through, followed by the index for food commodities. Further, precious metals had a very high pass through, while beverages, raw materials, and metals gave a mixed picture.

The U.S. Energy Information Administration (EIA, 2012) conducted a quite similar research paper, trying to identify time-periods when crude oil prices are responding more to either supply or demand, relative to the other, by examining the magnitude and sign of the correlation of crude oil prices against other commodity and asset classes. The correlations was calculated on a quarterly basis between the prices of WTI crude oil and other commodities, asset classes, and the implied volatility

[1] Hamilton (1983), Skeet (1988) and Mork (1992). See Barsky and Kilian (2004) and Hamilton (2009) for a review.

derived from the prices of options traded on WTI crude oil contracts. They found that the correlations were all positive and generally increased in magnitude from 2006 through 2009 and that the magnitudes of the correlations from 2009 to present have not been as strong as in 2009, but they remain above pre-2006 levels.

In DePratto, de Resende, and Maier (2009), they seek to investigate how changes in the crude oil prices affect the macro economy using a New Keynesian general-equilibrium open economy model. Their approach indicates that higher oil prices affect the macro economy primarily through the supply side, not the demand side. Supporting the notion that higher oil prices have affects similar to negative technology shocks, in that higher oil prices lower firm output in terms of value-added for a given input of capital and labor. In addition, that all countries respond to high oil prices by increasing interest rates, but real interest rates become negative, as the rise in inflation more than offsets the increase in interest rates.

Park and Ratti (2008), estimates the effects of oil price shocks and oil price volatility on the real stock returns of the U.S. and 13 European countries over the period 1986-2005 using a multivariate VAR analysis. They find that oil price shocks have a statistically significant impact on real stock returns in the same month or within one month, using real oil prices and real stock return. They also find that world real oil price, rather than national real oil price, has a statistically significant impact on real stock returns across all countries. Implying that markets anticipate significant and pervasive effects of oil price shocks in most countries and markets that will have implications for own firm circumstances reflected in stock price movements.

# 2.0 Market analysis

## 2.1 The Oil Market

Crude oil has been known and used ever since ancient times, and can be read about in old historical and biblical texts. However, the modern oil era is said to have started in Titusville, Pennsylvania, back in 1859 when Colonel Edwin Drake found oil at 69 feet underground. At first, they managed to extract 15 barrels a day (b/d) and within two years, they were producing over 3million b/d[2].

Today oil is the world's most important source of energy, meeting about 33% of the global energy needs with natural gas (24%) and coal (30%) as its closest rivals[3]. This has resulted in oil becoming the world's largest traded commodity, whether measured by value or volume. The Deutsche Bank has estimated that the physical crude oil market alone to be worth USD 2.2 trillion per year based on a 5 year WTI average historical price (using an average price of 71,5 USD/bbl. and the 2009 global demand of approximately 85mb/d)[2].

### 2.1.1 The Oil Price

This thesis focuses on what effects the price of oil has had on other markets. To be able to draw parallels to other markets and to see correlations, we first need to study how the price of oil is determined.

When referring to the oil prices we are talking about the price of one barrel of crude oil, often abbreviated as bbl. Crude oil is the oil that is naturally occurring and extracted from reservoirs beneath the surface of the earth. It has various characteristics depending on where in the world, and from which reservoir it is extracted. The quality of the crude oil is measured in terms of density and sulfur content. These characteristics determine the usefulness of the crude oil for refining purposes, which again will influence the price for the specific crude oil. However, the characteristics of the crude are not the only thing that decides the crude oil price.

### 2.1.2 The History of the International Oil Pricing System

Back in the days when "the oil industry" was growing up to become the big financial industry that it is today, the oil prices was controlled by a group of multinational Oil companies called "the seven sisters[4]". They controlled about 90% of the crude oil exports to the world markets by controlling every important oil pipeline in the world. In addition, they had joint ownership in most of the major oil production companies

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[2] Herrmann, Dunphy, and Copus (2010)

[3] BP (2013)

[4] The group consisted of Anglo-Persian Oil Company (Now BP), Gulf Oil, Standard Oil of California, Texaco (now Chevron), Royal Dutch Shell, Standard Oil of New Jersey and Standard Oil Company of New York (now ExxonMobil).

throughout the Middle East. This enabled the multinational oil companies to control the bulk of crude oil export from the major oil producing countries and prevent large amounts of crude oil accumulating in the hands of the sellers. Thus preventing the prices being pushed down by sellers competing to dispose unwanted crude oil to independent buyers.

However, between the mid 60`s and the early 70`s the economic growth in post-war Europe and the US caused for a significant increase in the demand for crude oil. Most of this demand was met by an organization called the Organization of the Petroleum Exporting Countries[5] (OPEC). OPEC, which was formed in 1960 with the main objective to prevent the income of the member countries from declining, was able to meet this rapid increase of global oil demand because of their enormous oil reservoirs. These oil market conditions created a strong sellers' market, which shifted the power from the multinational oil companies towards OPEC. Some OPEC governments stopped granting new concessions, demanding equity participation and some of them even opted for full nationalization of the oil reservoirs (Fattouh, 2011). Moreover, the Arabian-Israeli war in 1973, which resulted with an oil embargo[6], properly demonstrated this shift in the balance towards OPEC.

After the oil crisis in the late 70`s and during the 80`s with the worldwide economic recession, OPEC found that they had to leave their way of pricing the oil. New big oil discoveries in non-OPEC countries[7] (i.e. the North Sea) meant that significant amounts of oil began to reach the market from outside the OPEC countries. This increase in supply also meant an increase in the number and diversity of crude oil producers who were setting their prices in line with market conditions (Fattouh, 2011). The new suppliers ended up having more oil than required by contract and priced their crude oil under the OPEC price to secure the sale of all their production.

With OPEC losing market share, disagreement within the organization began to surface in the mid 80`s. This resulted in the netback pricing system, a system which provided oil companies with a guaranteed refining margin even if oil prices were to collapse, being adopted, eventually leading to the collapse of the crude oil price in 1986 (Fattouh, 2011).

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[5] Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela. See chapter 2.1 for further information regarding OPEC.

[6] Embargo means partial or complete prohibition of trade with a specific country. This embargo was proclaimed by the Arab members of OPEC against Canada, Japan, the Netherlands, the United Kingdom, and the US due to their support of Israel during the Yum Kippur war.

[7] Key centers of non-OPEC countries include North America, regions from the former Soviet Union, and the North Sea.

It is also worth mentioning the Domestic policy of the Ronald Reagan administration introduced in 1988, removing all of the remaining domestic price controls on crude oil in the U.S. Up until that point, the U.S. crude grades such as West Texas Intermediate (WTI) and Louisiana Light Sweet crude (LLS) had been trading on prices posted by the large American oil companies (Bruce, 2009). This deregulation policy resulted in a more transparent market dissolving the power of the huge American oil companies.

The "collapse" of the OPEC administered pricing system and the Reagan domestic policy led to a spot price, where for the first time, the oil price were set transparently by the market forces of supply and demand (Bruce, 2009). This "*market-related pricing system*" has been the prevailing method for pricing crude oil in the international market since the end of the 80`s and is still the prevailing way of pricing crude oil today.

### 2.1.3 The Market-Related Pricing system

The market structure that emerged is a structure, which allows buyers and sellers a greater flexibility in establishing commercial relationship that to a higher degree are meeting their respective needs. Today the crude oil market can be divided into two different markets, the "spot market" and the "futures market". The spot market is where buyers and sellers trade physical volumes of crude oil and is because of that referred to as the "physical market". This market typically consists of refiners, traders, producers, and transporters that are transacting from the oil well to the refinery (Grant, Ownby, & Peterson, 2006). The futures market is where derivatives or futures contracts[8], which settle according to the spot price of crude oil, are traded. The participants in the futures market include companies that have an interest in the crude oil for their daily business as well as speculators, which trade oil according to how their view on the direction the price of oil will take. This are also referred to as the paper markets. There is an intricate web of financial instruments linking the physical market and the paper market together providing the global oil market[9] with competitively determined market signals on current and future supply and demand conditions, assuring that the global price of crude oil properly reflects its market value (Grant, Ownby, & Peterson, 2006).

These changes to the market structure have led to more participants introduced to the market and a higher competition causing a high volatility in the crude oil prices (Vansteenkiste, 2011). This, especially because of the entry of the financial participants to the oil market, which led to a severely increase in trading activity of futures contracts. This high volatility in the crude oil prices has caused for a higher

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[8] Read more about futures contracts in section 2.3.

[9] Typically consisting of producers, refiners, marketers, traders, consumers, investment banks, hedge funds, and so forth.

awareness amongst both producers and buyers (e.g. refinery) of crude oil regarding the future price. As the producer wants to sell at the highest price possible and the buyer wants to buy at the lowest price possible, the use of derivatives to hedge[10] a future deliverance of crude oil at a specified price has become a common mean.

### 2.1.4 Benchmark Crudes and Price Reporting Agencies

Because of the differences in the quality of crude oil, the crudes has, as mentioned above, different prices. Given the vast variety of crude oils, the prices of one particular crude oil is set at a discount or at a premium to the price of a benchmark crude[11]. The most commonly used benchmark crudes are the West Texas Intermediate (WTI) from the U.S. and the Brent crude from the North Sea. These benchmark crudes are a central feature of the oil pricing system and are used by oil companies and traders to price cargoes under long-term contracts or in spot market transactions; by futures exchanges for the settlement of their financial contracts; by banks and companies for the settlement of derivatives instruments such as swap contracts; and by governments for taxation purposes (Fattouh, 2011).

The benchmark prices are, unlike the prices at the futures market, not observable in real time. They are reported prices that are identified or assessed by oil pricing reporting agencies (PRAs). These PRAs assess their prices based on information on concluded deals which they observe, or bids and offers, and failing that on market talk, other private and public information gathered by reporters, and information from financial markets (Fattouh, 2011). These assessments are crucial as the benchmark prices assessed have a large impact on how the oil markets and related derivatives set prices. Thus, it is important for the trustworthiness of the PRAs that they are both independent and integrated.

However, in recent time it has been debated whether the PRAs actually provide the transparency in the oil market as intended. Rather that they are "adding" to the price transparency of the market by influencing the decision-making territory that can influence the market structure. The accuracy of the PRAs heavily depends on the information identified and gathered by the PRAs, as well as the internal procedures and the methodologies used in the price assessment. As stated in a report from the International Organization of Securities Commissions (IOSCO) *"There is a risk that a PRAs benchmark price can be manipulated by the submission of false prices or by over or understating the volume transacted"* (IOSCO, 2012). When trying to identify the price the PRA`s are influenced by the market while at the same time the decisions they make influence various trading strategies of the market participants.

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[10] Hedge meaning: to make an investment with the sole purpose of reducing the risk of adverse price movements in an asset.

[11] A benchmark price is a price set by the country or producers organization that persistently exports the most of a commodity.

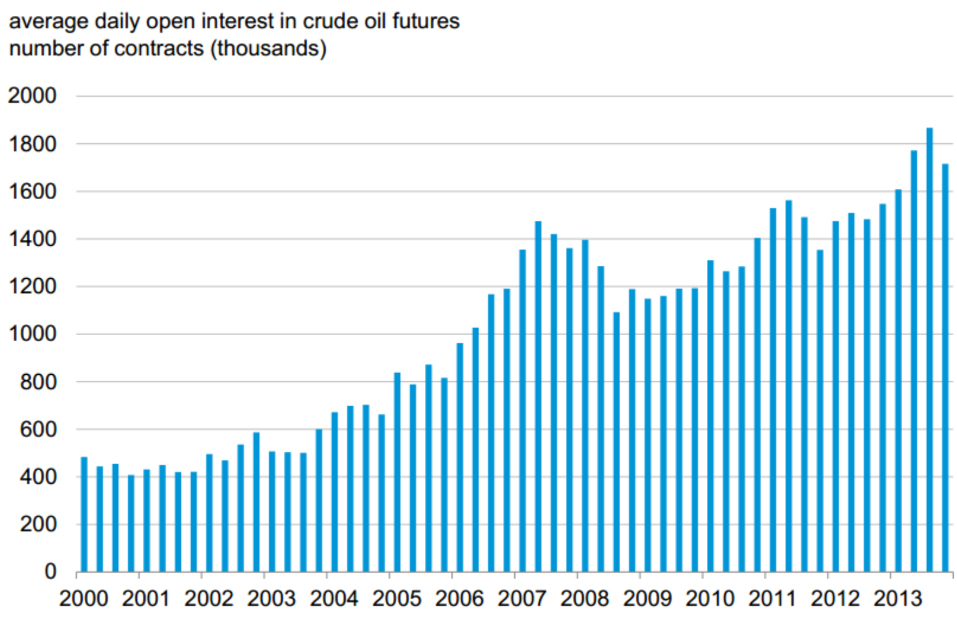
New markets and new risks may emerge because of these decisions, which will heavily influence the market.

### 2.1.5 Mercantile Exchanges

The benchmark crudes are underlying the futures contract being traded on the Mercantile Exchanges. The main international exchanges for trading oil and oil products are the New York Mercantile Exchange (NYMEX) and the Intercontinental Exchange (ICE) in London. These exchanges trade both spot contracts for immediate delivery as well as futures contracts for delivery at a later date. Given the large amount of crudes and the difficulty to follow them all, benchmark crudes are used. The two most commonly known benchmark crudes are, as mentioned above, WTI and Brent. Where the majority of Brent is being traded at the ICE and the majority of WTI is traded at NYMEX. In 2012, ICE Brent became the world's largest traded crude oil futures contract in terms of volume surpassing WTI (ICE, 2014).

With the introduction of the financial participants to the oil futures market, such as various investors, investment banks etc. and companies wanting to hedge some of their future income/spending the trading activity, as mentioned above, increased significantly (Vansteenkiste, 2011). According to Bruce (2009), the trade of crude oil derivatives in the futures market exceeds the trade of physical oil by the number of 14. How the interest for crude oil futures contracts have increased since the beginning of this millennium is illustrated in Figure 3. In addition, by comparing Figure 3 to Figure 4 one can see that the increase in numbers of participants to the crude oil futures market increases in quite the same trend as the crude oil prices during the same period.

Figure 3: Increase in participants in the crude oil futures market.




Source: www.bloomberg.com (2014)

### 2.1.6 Brent Crude

The Brent crude was originally produced from the Brent oilfield in the North Sea, which was discovered in the late 60s. However, the "original" Brent production quickly declined. In order to keep the physical market active and liquid, additional crudes produced from other fields in the North Sea was included into the Brent stream. Today Brent crude consists of four different crudes: Brent, Forties, Oseberg and Ekofisk, also referred to as the BFOE. It has an "API gravity" of 38.3 degrees, which makes it a "light" crude[12] and a sulfur content about 0.37%, which makes it a "sweet" crude[13].

Even though the production of Brent crude today, with these additional crudes, is declining, Brent crude is the largest underlying physical market of any comparable, traded and transparent benchmark (ICE, 2014). In fact, Brent crude assessments based on physical trade or the ICE Brent futures market are used directly or indirectly to price 70% of the world's oil (Fielden, 2013).

In the physical market for Brent Crude, vessel size parcels of 600 Mbbl. are being traded. The Brent physical market can be separated into two different but related physical markets: The 25-day BFOE and the "dated" Brent. When trading contracts that do not have a date attached to it, it is considered a "cash" contract and part of the "paper" market. As soon as the parcel gets a date attached to it, which occur at least 25 days forward, the cash contract becomes "wetted" and is considered a part of the "dated" Brent market. Platts, which is a PRA that assesses the physical Brent market, only consider Dated cargoes in its Dated assessment window that are for lifting dates[14] between 10 and 25 days forward of the assessment date (ICE, 2014). As the crudes included in the BFOE are slightly different grades of crude oil, the value of the BFOE quote is set by the most competitive grade at the margin. This, as well, is done by PRAs.

The ICE Brent futures contracts are based on the underlying physical BFOE market and the futures contracts are settled financially against the Brent Index. The Brent futures are traded in 1000 Bbl. contracts, which differs significantly from the physical Brent market. The Brent crude futures contracts are cash-settled contracts, meaning that there are no physical deliveries upon expiry. However, there is an exchange for physical (EFP) mechanism that allows the market participants to link their futures

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[12] API Gravity refers to American petroleum Gravity, which is a measure that compares how light or heavy a crude oil is in relations to water. An API value greater than 10 indicates that the crude is lighter than water, thus a light crude and an API value less than 10 indicates that the crude is heavier than water and therefor a heavy crude.

[13] A crude oil requires less than 0.5% to be considered a sweet crude.

[14] When a parcel is given a date it is typically a 3-day loading window for when buyers can collect their physical oil.

contracts to the physical market, allowing for the exchange of futures contracts at expiry for cash value equivalent to physical barrels.

### 2.1.7 West Texas Intermediate

The West Texas Intermediate (WTI) consists of several domestic U.S. streams of light sweet crude and is the North American benchmark for crude oil. Unlike the Brent crude, which is a waterborne[15] crude, WTI is a pipeline crude with deliveries made at the end of the pipeline system in Cushing, Oklahoma. WTI crude oil is similarly to Brent, a high quality crude. It has a sulfur content of only 0.24% and an API gravity of 39.6 degrees, making it both sweeter and lighter than the Brent crude.

In the U.S. market, physical crude oil is traded in increments of 1000 Bbls. As the WTI futures contracts also are traded at 1000 Bbls. per contract, it offers a nearly instantaneous price convergence between the physical and the futures market. Making the WTI contract the most liquid benchmark for the global price of oil (CME Group, 2013). WTI has in fact been the largest exchange-traded commodity for years, until 2012 when the traded volume of Brent exceeded that of WTI. As WTI is not exportable, due to political sanctions[16], it is not as flexible and responsive to trading conditions in the western hemisphere. The WTI futures contracts are, unlike Brent Futures, settled physically with deliverance in Cushing, Oklahoma. However, less than 1% of the NYMEX contracts are actually going to physical delivery (Herrmann, Dunphy, & Copus, 2010)

### 2.1.8 The Brent/WTI Spread

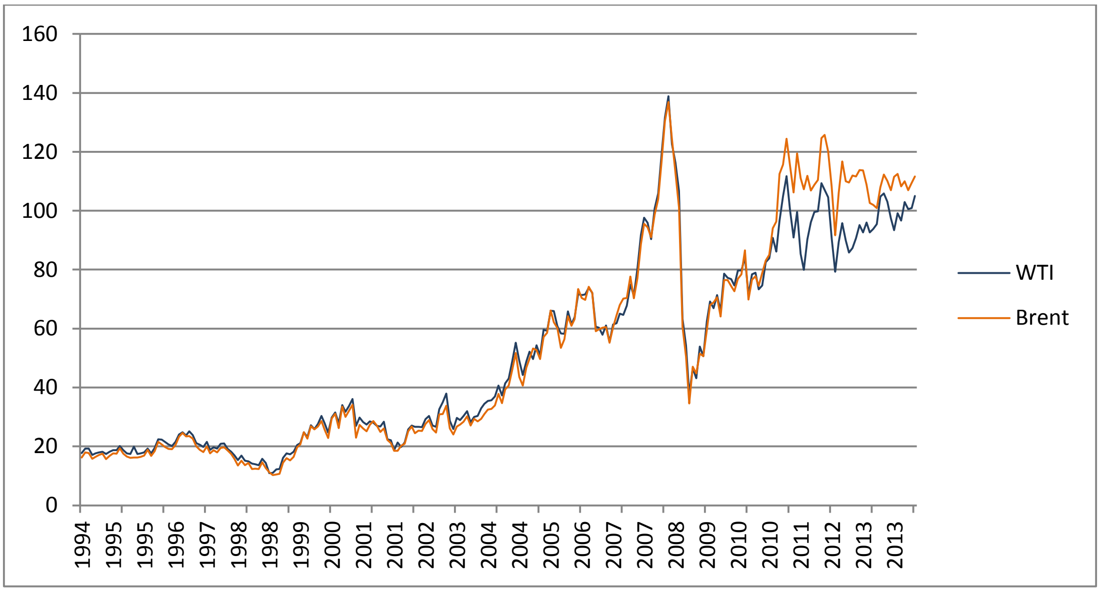
The spread between WTI and Brent crude represents the price difference between the two crude benchmarks. Where WTI is representing the price the U.S. oil producers receive and Brent is representing the prices received internationally (Pan, 2014). Both Brent and WTI are, as mentioned above, crudes of high quality and are both considered light sweet crudes. However, because WTI has a higher API gravity and less sulfur content than Brent, making it easier to refine, Brent has traditionally traded at a USD 1-2 discount to WTI. The reason for the close relationship between the prices of the two crudes is their similar physical characteristics. What differs them from each other are their logistical aspects as well as the fact that the Brent is exported worldwide while WTI is only exported in small amounts, primarily to Canada. Brent is a waterborne crude, which makes it easier to control the supply side, while WTI is transported through pipelines in and out of Cushing, Oklahoma, which have proven to be somewhat of a problem. At first, the problem was the

[15] Transported by ships.

[16] The primary laws prohibiting crude exports are the Mineral Leasing Act of 1920, the Energy Policy and Conservation Act of 1975, and the Export Administration Act of 1979. The so-called short supply controls in the Export Administration Regulations (EAR) of the Bureau of Industry and Security (BIS), an agency of the Department of Commerce, spell out these restrictions.

logistical bottleneck of getting enough oil into Cushing, which in many instances resulted in a rise in the WTI price compared to other international benchmarks such as Brent (Fattouh, 2011). However, recently the problem has been reversed. With the increase of Canadian exports to the U.S. the problem became to shift the oil out of Cushing, causing a larger than expected build-up of the crude inventories, resulting in lower WTI prices (see Figure 4) making Brent the new global benchmark.

Figure 4: Brent/WTI prices



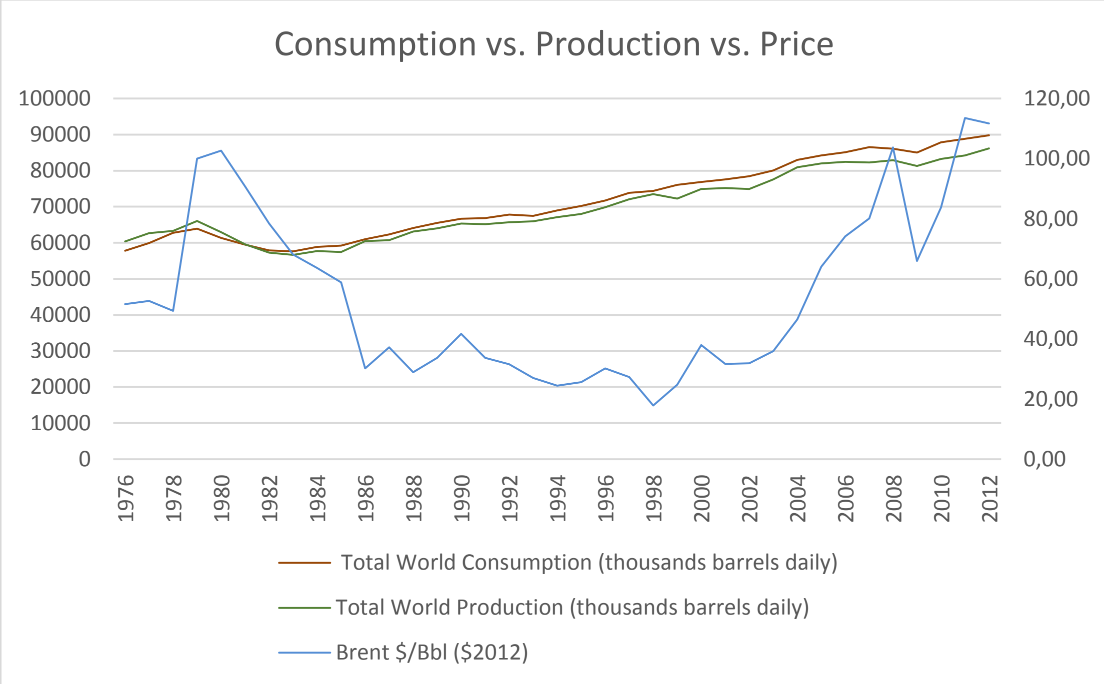

Source: DataStream (2014)

## 2.2 What drives the crude oil price?

The determination of the crude oil prices is a complex matter as it involves several different factors, the most important being the supply and demand fundamentals. However, there are disagreements regarding the relative importance of supply and demand in the oil prices determination. Hamilton (2009) underlines the effect of the global oil production failing to meet the increasing demand, which i.e. caused the record high price in the summer of 2008. On the other hand, Kilian (2009) uses the real price of oil to argue that shocks to the oil demand have driven the oil prices historically.

The global oil market mainly consists of producer, traders/hedgers/speculators, consumers, and policymakers. Given that it is the interaction between these "participants" that eventually determines the price of crude oil, based on the supply and demand fundamentals, we will go through the key drivers of supply and demand.

Figure 5: Consumption vs. Production vs. Price



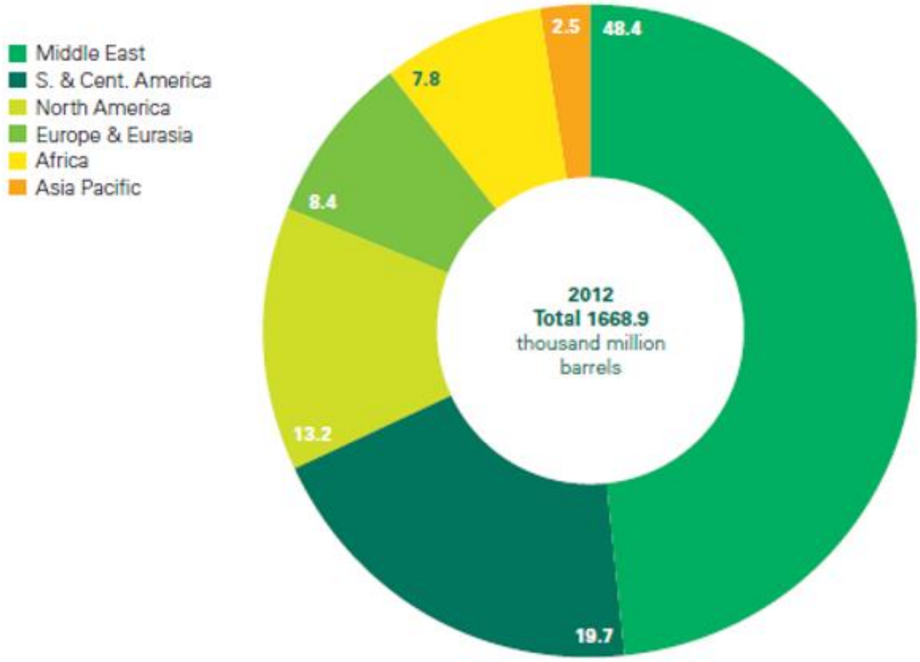

Source: BP (2013)

## Supply

The aggregate supply of crude oil has had a steady increase over the past decades (Figure 5). This is due to improvements in technology helping producers finding new oilfields as well as increasing the oil recovery rate. When talking about oil supply, the Organization of the Petroleum Exporting Countries (OPEC) is by far the most important contributor. At its simplest, OPEC effectively works as a supply-side swing; with the members seeking to co-ordinate their production through periodically agreed production targets, ensuring that the market remains roughly "in balance" at a particular price band (Herrmann, Dunphy, & Copus, 2010). The proved crude oil reserves was in 2012, by BP, found to be 1668.9 million barrels of which OPEC alone is accountable for 72.6%. Of the total world production, OPEC, with Saudi Arabia as its biggest producer (13.3%), is accountable for 43.4% of the world's crude oil production[17]. Because of this enormous share of the global crude oil market, it is obvious that their output decisions will have a significant impact on the aggregate oil supply.

[17] BP (2013)

Figure 6: Distribution of proved reserves in 2012 in percent.




Source: BP statistical report (2013)

By increasing or decreasing the production, OPEC may contribute to the decrease or increase of the price of oil. Even though Kilian (2009) states that OPEC`s efforts to coordinate production does not influence changes in the real price of oil to a large degree, Figure 37 in the Appendix shows how the prices of WTI has changed alongside OPECs production targets. From this figure one can see how the price of WTI seems to decrease or increase as OPEC`s production targets increase or decrease with a lag. However, OPEC will always try to keep the price at an "acceptable" level as too high prices in the long run may weaken oil's position as the world's primary energy source, which will not be beneficial for OPEC or any other crude oil companies and oil exporting countries.

How OPEC are utilizing their available production-capacity is, by many, used as an indicator of the current and future state of the oil market. OPECs spare capacity[18] provides an indicator of the tightness of the international oil market, and thus to what extent the oil market can respond to potential crisis that can disrupt and/or reduce oil supplies. With a low spare capacity, OPECs ability to respond to an increase in demand and in the crude oil price is rather limited. This has resulted in a risk premium being incorporated to the oil price when OPECs spare capacity is getting tight (See Figure 37).

[18] EIA defines spare capacity as the volume of production that can be brought on within 30 days and sustained for at least 90 days.

In non-OPEC countries, accessing the crude oil has become increasingly challenging over the years. From BPs statistical report (2013) we can see that the production from non-OPEC countries have decreased from almost 50% in 1996 to just above 40% of the world production in 2012. Because all the easy accessible oil fields already are in production many non-OPEC oil producers have turned to unconventional oil production such as deep water, oil sands and shale oil. These unconventional oils have higher production costs, which should imply that a decline in oil prices would reduce the production in these reservoirs. These "limitations" makes the non-OPEC producers price takers, as they are responding to the market prices rather than trying to influence the market price by altering the production. By comparing Figure 33 and Figure 36 in the Appendix, we can see how small the effects of changes in non-OPEC production have been compared to changes OPEC production on the crude oil price.

It is not only OPEC`s spare capacity and production targets that have an influence on the supply. Geopolitical events within and between OPEC countries have historically resulted in a reduction in the oil production. With the significant market share that OPEC has, a reduction in actual or future oil supplies can produce strong reactions to the international oil prices. As we can see from Figure 38 in the Appendix, historical events such as the Iranian revolution (1979) and the Iraqi invasion of Kuwait (1990) are both geopolitical events that led to a reduction in supply from OPEC countries pushing the price of crude oil upwards. Even today, the conflicts in Libya and Egypt as well as the sanctions against Iran has reduced OPECs total potential oil supply, resulting in an increase in the crude oil prices. There have also been problems with member countries not complying with the production targets set by OPEC, which in theory would affect the oil prices due to more or less oil in the market than planned. However, this is usually equalized by some of the countries producing more and others producing less than the agreed upon production targets.

Wars, natural disasters and/or geopolitical events in non-OPEC countries would also have an effect on the oil price. The conflict between Russia and Ukraine has caused for a tense situation between Russia and the rest of the world resulting in sanctions being put on Russia's financial sectors as well as the oil and gas sector. Given that Russia, in 2012, was the second largest oil producer in the world (12.8%), this situation and these sanctions have put an upward pressure on the prices of crude oil. However, apart from the tense situation between Russia and Ukraine and the rest of the world, such events have been less frequent in oil producing non-OPEC countries, if ever occurred, in recent times.

## Demand

In recent years, many of the countries that are not a part of the Organization of Economic Cooperation and Development (OECD), referred to as non-OECD countries, have experienced both economic growth as well as growth in the population. As non-OECD countries tends to have a greater proportion of their economy in the manufacturing business, economic growth will increase the level of production hence increasing the demand for crude oil to fuel both the production as well as the transportation of the produced goods. The fast-paced growth in the non-OECD GDP[19] has, in addition, raised the living standards and thus increased the demand for personal travel and freight transport, giving an additional input to the demand for crude oil. The correlation between the economic growth in the non-OECD countries (measured in GDP) and the oil consumption is evident in Figure 34 in the Appendix. The oil consumption of non-OECD countries has according to BP`s statistical review (2013) increased by 51.5% from 2000 to 2012, which is in contrast to OECD countries where the consumption during this period actually declined by 6.8%. It is assumed that the non-OECD GPD will increase by an average of 4.7% per year causing the non-OPEC countries energy consumption to be 47% more than the OECD countries by 2020 (EIA, 2013). The high correlation between the increase/decrease in GDP and the oil consumption in the non-OECD countries makes the economic growth in these countries an important factor for the futuristic demand that again can have a significant effect on the oil prices.

A perfect example of how the non-OECD countries affects the demand for oil, and hence the price, are the Asian countries and then especially China as seen in Figure 7. China has had a rapid economic growth over the last couple of years, which has led China to become the largest energy consumer and the second largest oil consumer in the world (11.7%). This and the fact that the economic growth in developing countries and oil consumption is highly correlated, makes the futuristic expectations regarding Chinas economic conditions an important factor concerning the oil prices. This is quite evident today with the much lower than estimated manufacturing PMI[20] in China, which has resulted in a downward pressure on oil prices over the last couple of months.

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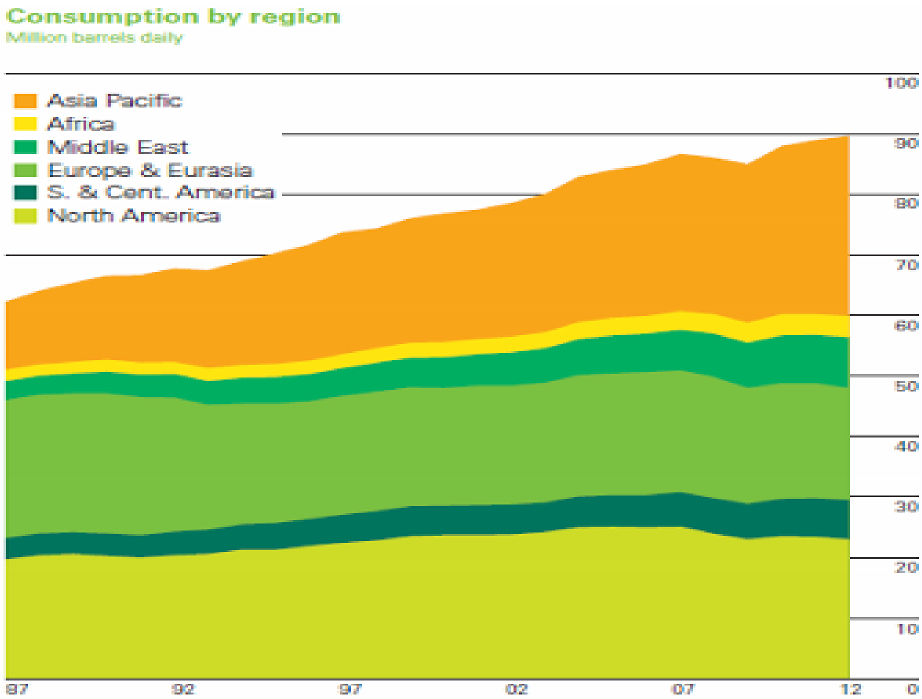
[19] Gross domestic product is the value of everything that is produced within a country during a period of time, commonly a year.

[20] Purchasing Managers Index. It is the headline indicator in the monthly Institute for supply Management (ISM) report on business.

Figure 7: Consumption by region in million barrels daily.




Source: BP statistical report (2013)

Even though OECD, in 2012, was accountable for about 50% of the world's oil consumption, the oil consumption in OECD countries has, as mentioned above, declined between 2000 and 2012. There are some different reasons for this. The economies in OECD countries have a larger service sector compared to the manufacturing sector, which in fact is, in most cases, outsourced to non-OECD countries. Because of the much larger service sector and a more mature economy, a growth in the OECD economies will not have such a high impact on the consumption of oil as for the non-OECD countries. It is also worth mentioning the increasing environmental awareness, which has become more and more important and an integrated part of the politics in the OECD countries (among others). The governments are constantly working towards lowering the emissions of carbon gasses by i.e. imposing fuel-efficiency standards on vehicles and putting high taxes on liquid fuels.

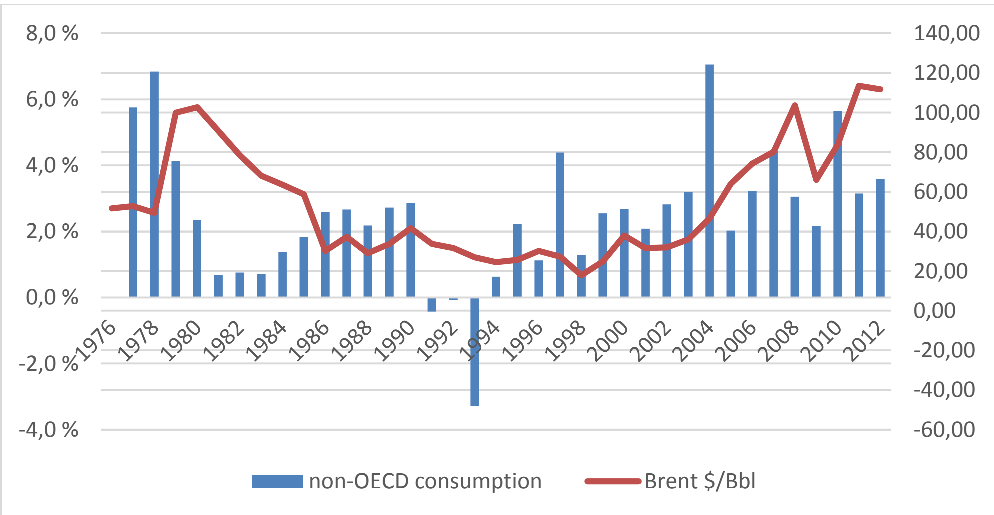
In the transportation sector crude oil is by far the most important source of energy (94.9%) accounting for almost 52% of the total oil consumption in 2012[21] and according to Herrmann, Dunphy, and Copus (2010), the transportation fuels will account for the majority of the growth in world oil demand in the years to come. Given the high vehicle ownership per capita in OECD countries one should believe that an increase in the price of oil, which is highly correlated with the price of gasoline, would decrease the demand for oil. However, historically the crude oil

[21] BP (2013)

prices have not had such an effect on the gasoline consumption as most people in OECD countries use their car no matter what the price of gasoline is. The only thing that has changed is the popularity of more fuel-efficient and “green cars”, using electricity or biofuels as energy sources, reducing the demand for gasoline and hence the demand for oil. Whether this is because the record high gasoline prices or if it is because of the environmental awareness, is a subject of its own and will not be answered in this thesis.

Aastveit, Bjørnland, and Thorsrud (2012) finds that as a country becomes more developed the income elasticity declines, consistent with Hamilton (2009), stating that the average income elasticity across developed countries is approximately 0.5 while the income elasticity for non-OECD countries may still be closer to unity. In the non-OECD countries, the liquid consumption has been stable or in fact increased in times of high oil prices. Which is because of, as mentioned above, the increased level of production and the raised living standards in these countries during the recent increases in the price of oil (see Figure 8). However, one interesting fact is that the governments in some non-OECD countries have been underpricing energy resources, facilitating for a constant economic growth in these countries (International Energy Agency, 1999).

Figure 8: Non-OECD liquid consumption and WTI crude oil prices.




Source: DataStream (2014)

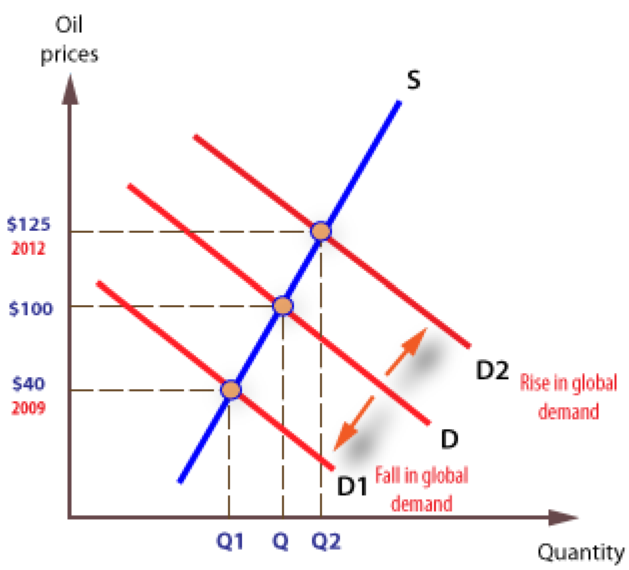
Some OECD countries and especially the U.S. hold large strategic petroleum reserves as a safe precaution for lack of future supply. The amount of crude oil or refined crude oil products held in these inventories serves as an indicator for the demand for crude oil and/or refined products. Which, in addition, will have a significant effect regarding speculations of future prices.

## Market Equilibrium

In most markets, the prices for commodities are decided by the interaction between supply and demand. The interaction between supply and demand is referred to as the market equilibrium, where the demand is equal to supply. A shift to either demand or supply will cause the equilibrium price to either increase or decrease for a period, before returning to the market equilibrium. However, the oil market is quite different from other markets as it has a fragile equilibrium with constantly fluctuating prices.

From Figure 5 it is easy to see that the supply has gradually increased alongside with the demand for crude oil. However, even though the supply and demand, from the graph in Figure 5 appears to be highly correlated, the price of oil seems to be fluctuating significantly. Unforeseen events such as natural disasters, wars, geopolitical events and rapid economic growth are all events that can cause sudden changes in both the supply and demand shifting the equilibrium price up or down. As the effect of the financial crisis spread throughout the world, the demand for crude oil dropped (See Figure 38 in the Appendix) shifting the price of oil down from its record high in the middle of 2008 to below 40 USD/Bbl. at the end of 2008. As the global economy started to recover, the demand soon shifted upwards (especially due to high production levels in China and India) putting an upward pressure on the oil prices (See Figure 9). In addition, a disruption in the oil production may as well cause for increase in the price for crude oil, as there would be less oil in the market than demanded.

Figure 9: Supply vs. Demand




All these events that causes the price to fluctuate this significantly are referred to as Oil Price shocks and there exists a large body of literature that are trying to identify these shocks and their subsequent effects. As mentioned above, Hamilton (2009) concludes that a combination of a low price elasticity of demand, the strong growth in demand from China, the Middle East, and other newly industrialized economies, and the failure of global production to increase is what caused the record high prices in the summer of 2008. Kilian (2009), On the other hand, argues that oil price shocks are driven mainly by a combination of aggregate demand shocks and precautionary demand shocks, rather than oil supply shocks. Kilian (2009) Further states that the oil price increase may have very different effects on the real price of oil, depending on the underlying cause of the price increase. For example, an increase in precautionary demand for crude oil causes an immediate, persistent and large increase in the real price of oil, an increase in aggregate demand for all industrial commodities causes a delayed, but sustained increase in the real price of oil that is also substantial; crude oil production disruption cause a small and transitory increase in the real price of oil within the first year (Kilian, 2009). In other words, Hamilton (2009) argues that it is the supply that drives the prices, while Kilian (2009) argues that it is mainly shocks to the aggregate and the precautionary demand that historically has driven the crude oil prices. In addition, Aastveit, Bjørnland, and Thorsrud (2012) finds that it is not only the underlying cause of the crude oil price increase, but also from where it originates that will decide the magnitude and the duration of the price increase. That demand shocks to emerging markets, and Asia in particular are far more important than demand shocks in developed economies in explaining fluctuations in the real price of oil and in global oil production.

Natural disasters, geopolitical events and wars are examples of unexpected events that will increase the aggregate and the precautionary demand as well as cause for a disruption in the crude oil production. The civil unrest and civil wars in the Middle East that have occurred during the last couple of years combined with sanctions on Iran are all examples of events that have caused an increase in the precautionary demand for crude oil, causing the oil prices to increase significantly. On the other hand, in the U.S. where the market has been flooded with oil from the large shale oil reservoirs as well as from Canada has caused for a downward pressure on price for WTI, increasing the WTI/Brent spread. The hurricanes Katrina and Rita disrupted the entire production in the Gulf of Mexico as well as caused severe damages to U.S. refineries. While the reduction of crude oil production in the Gulf of Mexico caused by these hurricanes was, comparatively, minor measured on a global scale, the loss in refinery capacity caused the U.S. demand for crude oil to fall and the world price of crude oil dropped (Kilian, 2009).

To be able to balance the supply and demand and account for unexpected events, inventories are used to store the “surplus” for future use or to supplement the supply in times when consumption levels exceeds the current production. Refineries and storage terminals can store crude oil and/or refined crude oil products to satisfy current or future demand. The inventory levels are sensitive to the current price of oil as well as the future prices. Should the market expectations about the future be that demand will increase or that there will be a shortage in supply, the price for future contracts tends to increase. This again, incentivizes the e.g. refineries to increase its inventory to be able to satisfy the tightening future balance and be able to sell at the higher expected price. On the contrary, a sudden drop in the oil production or an unexpected increase in consumption will tend to push the spot price of crude oil up relative to the futures prices incentivizing the e.g. the refineries to push out their inventory, meeting the current demand at the relative high spot price.

Figure 39 in the Appendix shows how the increase or decrease in inventory affects the WTI futures spread. The inventory presented in this figure is only OECD inventory data. This is because inventory data from other non-OECD countries are available on a less timely basis, if available at all. This lack of information about the global inventories creates an additional uncertainty in the oil market, which can influence the crude oil price (EIA, 2011).

As it would take some time for the oil producing companies to adjust their production levels for an increase to the aggregate or precautionary demand these inventories serves as a balancing point between supply and demand. By pushing oil out into the market in times of higher demand than supply, it would help reducing the otherwise large increase in the oil prices. At least until, for example, OPEC manages to increase its production targets to meet the aggregate demand.

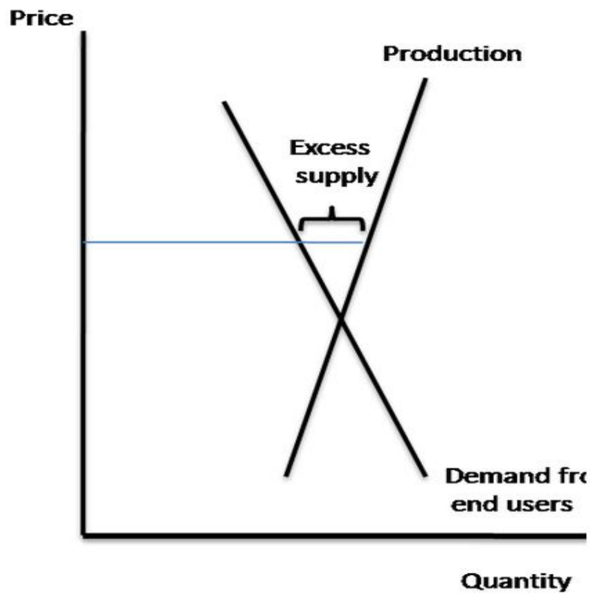
### Other influencing factors

Being that the demand and supply fundamentals are regarded, as the most important factors affecting the prices of oil there are also several other factors that will affect the oil prices. Calvo (2008) argues that excess liquidity and low interest rates have been contributing to the price increase, for both oil and other commodities. Vansteenkiste (2011) points out that in addition to the more fundamental based explanation, some studies have noted that speculation may also be behind the upward movement in commodity prices. There are disagreements regarding whether the increased number of participants from the financial sector, speculating on the future prices of certain commodities in order to make a profit, have caused for the large fluctuations in the commodity prices. Lombardi and Robays (2011) finds that speculative trading in futures market may affect spot oil prices significantly, but that their overall importance is limited over time. This view is however challenged by the work of De Long et al. (1990) showing that noise traders[22] might have an impact on prices if they hold large share of assets regardless of their survival in the long run. Such views have gained increasing prominence. As

[22] Irrational traders who trade on the basis of irrelevant information.

mentioned earlier in this thesis, the increase in the number of financial participants in the crude oil futures market has coincided with the rise in crude oil prices since 2000 (see Figure 3). However, Vansteenkiste (2011) states that one of the counterarguments that recently prices reflect fundamentals rather than speculations is the question "*Where are the stocks?"*[23] That if speculators were the main force pushing oil prices far above the level justified by fundamentals, excess supply should be observed (See Figure 10).

Figure 10: Excess supply




## 2.3 Natural resources

In this thesis, we will consider other natural resource markets compared to the crude oil market. We identify certain characteristics for each commodity, which influence the pricing of commodities. Debreu (1959), argues that a buyer and a seller agree on the price of a commodity according to its physical properties, location and date of delivery. In addition, when agreeing on a contract the degree of uncertainty to these characteristics will affect the price. E.g., a heterogeneous product where the standard is difficult to agree upon, it is more difficult to set a price than for a homogenous product where standards and quality easily can be agreed upon. Moreover, seasonal and fresh products have a higher production risk than an easily transported and continuously produced product. In addition to Debreu`s (1959) characteristics we will also utilize Dahl (2012) factors of commodity pricing and how they are traded in order to give the reader an overview of the different commodities researched in this thesis.

[23] See Krugman (2008)

Among producers, inventories, as with crude oil, are hold in order to be able to respond quickly to a sudden change in demand, and thus the amount of inventory hold will affect the price accordingly.

What all commodities have in common is that they, in the production and transportation process, rely both directly and indirectly on crude oil. Thus, it will be interesting to examine the relationship between oil and the commodities as we may see how a change in the oil price will affect the price of the commodities examined in this thesis. For a more thorough explanation on the motivation behind this thesis see Chapter 1.

In this chapter we will cover the supply and demand for each commodity and the terms suggested by Debreu (1959) and Dahl (2012) on how the price of each commodity are set. The chapter ends with a summary of all the commodities summarized in a table so that they are easily comparable. The resources are divided into more specified groups depending on type and abilities.

### 2.3.1 Agriculture

#### Soybeans

The use of the soy plant as food dates back to the 11th century BC. Due to the Chinese being very protective about the plant, it took several centuries before it became popular in other parts of the world and it was first in the 20th century it became popular in America and Europe. From the seeds are planted it takes about 6 months to become ready for harvesting. When harvested they are commonly made into either soy oil or soy meal, where the oil is mostly used in food production and in the biofuel production, while the meal is mostly used for animal feed due to its high protein content.

#### Supply vs. Demand

In 2011, the top three producers of soybeans were the U.S., Brazil and Argentina producing 83.2, 65.5 and 41 million tonnes respectively[24], while the growth in soybean production in the U.S. has slowed, there has been a rapid growth in Brazil, and it is expected to continue as they have the land and water necessary. The supply of soybeans are closely related to other agricultural commodities as farmers divides their lands so they can produce both, and thus a higher margin in the other commodity will decrease the supply of soybeans and thus drive the price higher.

Soybean rust is a common disease within the soybean production. As the soybeans lack of resistance it can ruin huge parts of the crops and thus reducing supply.

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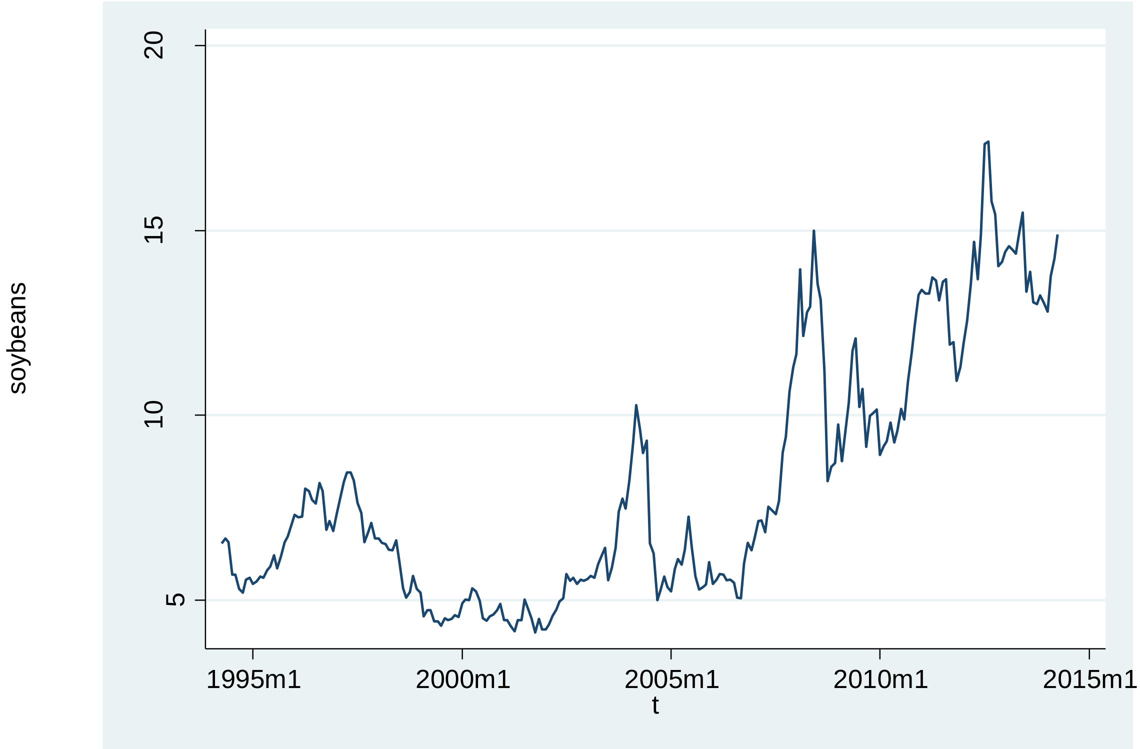
[24] USDA (2014)

The top three consumers in 2011 were China, U.S. and Brazil consuming 70.8, 48.8 and 39.5 million tonnes respectively[24]. As the living standard increases in the emerging economies people tend to eat more meat and soybeans, being widely used as animal feed, the demand is expected to increase. The demand will also see an increase as the use of biofuels become more and more common.

## Historic prices

Figure 11: Monthly soybean price in USD/Bsh.




Source: DataStream (2014)

With a few exceptions of some ups and downs, the price of soybeans has steadily increased over the past 20 years as seen in Figure 11. The graph shows the USD/Bsh.[25] for yellow soybean No. 1.

## Corn

Corn is native to the American continent and was first utilized in Mexico by indigenous people several thousand years ago. In Europe, it was first introduced during the discoveries of America, when explorers brought it back to Europe and introduced it to other countries. Now corn is widely used throughout the world, where more than half of the crops are used as animal feed. It is also commonly used as food and as a major substance in the ethanol production.

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[25] Bushel

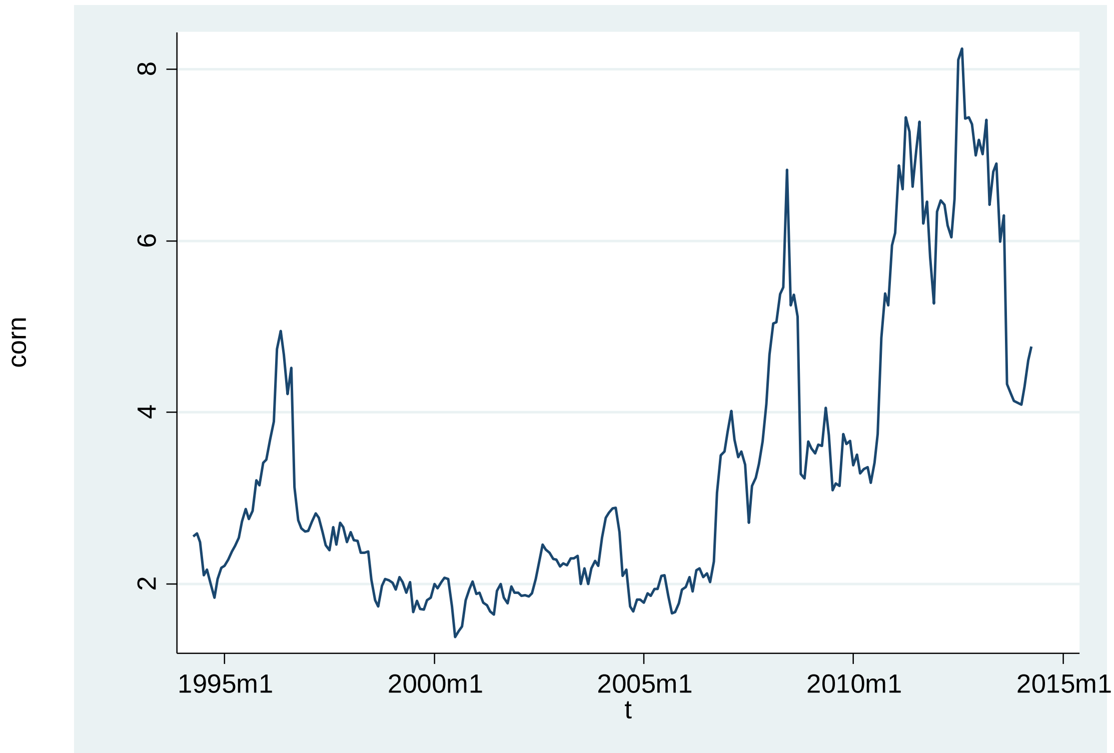
### Supply vs. Demand

The largest producer of corn in 2011 was the U.S. producing 314 million tonnes, the second and third were China and Brazil producing 193 and 70 million tonnes respectively[26]. Corn being farmed in the same fields as soybeans, the supply of corn is affected by the demand of soybeans; if the price of soybeans is high, the farmers will devote more acreage to soybeans and thus decrease the supply of corn.

On the consumption side it is the same three countries in the same order that are responsible for the greatest consumption, with 280, 188 and 54 million tons in 2011 respectively[26]. As with soybeans, the increase in wealth in the emerging economies drives up the demand for meat, and since corn is a major substance in the livestock feed, the demand for corn will increase. Ethanol is becoming more and more popular as a biofuel due to its abilities to reduce air pollution and conserve gasoline. Some states in U.S requires that the gasoline contains up to 10% ethanol in fuel the blend, several states have this requirement pending, and if introduced or the percentage ethanol is increased, the demand for corn is expected to increase.

### Historic prices

Figure 12: Monthly corn price in USD/Bsh.




Source: DataStream (2014)

[26] Earth Policy (2012)

After reaching about 5 USD/Bsh. in 1996 the price dropped severely and stayed at that level for a couple of years before the price started to incline and reach almost 7 USD/BSH before the financial crisis where it dropped to about 3.5 USD/Bsh. Since then the price recovered relatively fast and it reached its highest level in the period in about mid 2012 before it dropped and nearly halved in 2014. The prices are given in USD/Bsh. for Corn U.S. No.2.

### Wheat

There has been found traces of wheat in populations dating back to year 8000 B.C. Going from being a simple grain and food for people thru centuries, wheat is now responsible for about a fifth of the world calorie intake. People are researching the properties of wheat and try to make it adaptable to unusual breeding conditions, and thus make it possible to have crops year around. In addition to being used in a variety of human foods, it is also used as livestock feed. Wheat is produced in temperate climates, being dependent on some rainfall and as long as these requirements are met, the more sun the better as wheat uses sun to create growth energy. Worldwide there are 74 countries with a significant wheat production[27].

### Supply vs. Demand

The biggest producers of wheat consist of the EU, China, India, the U.S. and Russia being responsible for 143118, 121000, 92460, 57961 and 51500 (1000MT) respectively, estimated for 2013[27]. The main consumers of wheat are by far the EU being responsible for 48% of wheat consumption; by comparison, China is responsible for 8% and the U.S. for 4% on average from 2008/09 to 2010/11[28]. When supply exceeds demand, the excess amount will go into storage spared for later supply/demand shifts. The main factor affecting supply is climatically conditions, if poor weather crops can be ruined and supply decreases. The main drivers of demand are population growth, economic growth and eating habits. People living in rural areas have a tendency to eat more grain than people living in major cities. The reasons for this may be as simple as people living in rural areas do not have the same access to refrigerators as people living in urban areas. Wheat has been traded for centuries, but in 1865 wheat contracts and futures were standardized and is mainly being traded on the Chicago Board of Trade (CBOT). This have reduced the risk for farmers as they could plant and cultivate a crop without having the risk of a price drop. Prices are in dollars and cents, and the wheat is sold in lot sizes of 5000 Bushels where one bushel is 60 pounds[29].

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[27] IndexMundi (2014)

[28] O`Brien (2011)

[29] Wheat Futures Trading Basics (2009)

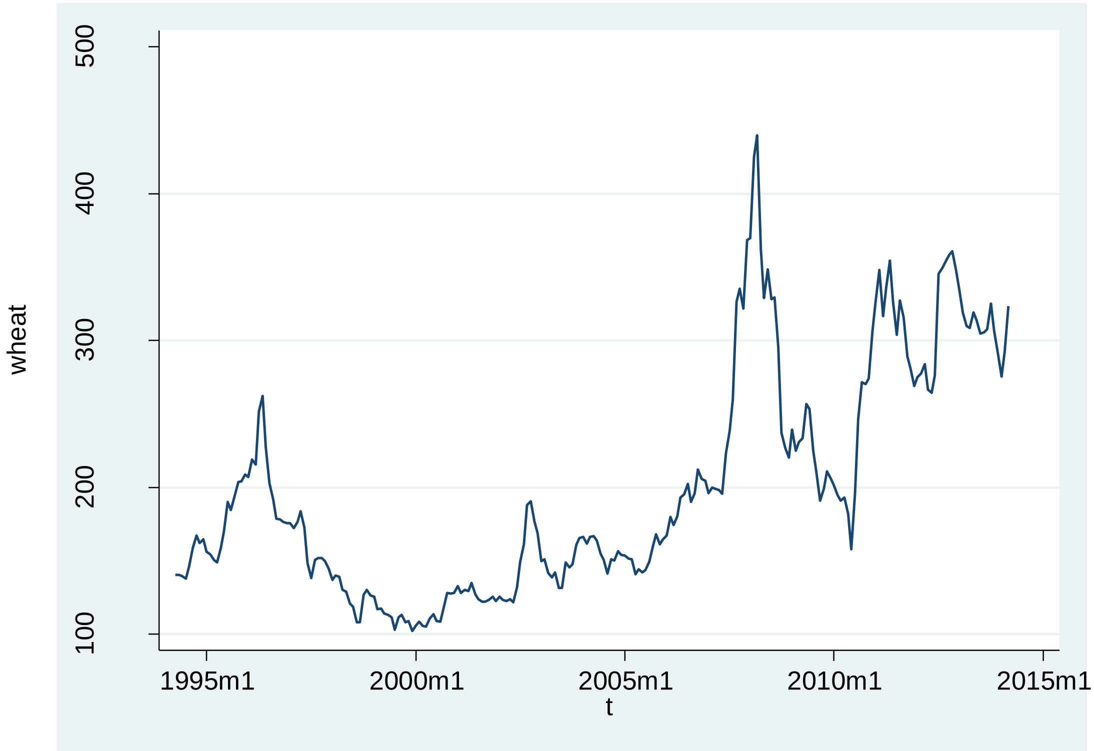
When storing wheat there are a lot of factors coming into play. If stored properly wheat can be stored for about a year, but this requires the right conditions. This makes it easier for producers to be flexible when selling their stock. Wheat is usually stored on site, taken to a storage facility or sent straight to port for export. Storing on site is becoming more and more popular as producers can harvest the whole crop before transporting the goods further on.

Regarding transportation of wheat there are a lot of uncertain variables, one do not know how large crops will be, transfer times are uncertain and demand and timing of future sales are uncertain.

Another factor affecting the wheat price is the price of fertilizer, if this increases the price of wheat will increase or less fertilizer will be used and thus the bushel per acre will decrease[30].

## Historic prices

Figure 13: Monthly wheat price in USD/Bsh.




Source: DataStream (2014)

Wheat saw an increase in its price through a few years before the price dropped in 96; from then on, it slowly increased until the financial crisis struck in 2008. In the end of 2010, the price started recovering from the crisis and has remained relatively

[30] Anderson (2005)

stable at around USD 300/Bsh. The price is single commin spot price from Chicago Board of Trade.

### Timber

Timber has been an important resource to humans for several millennia's, mainly as a fuel and as a construction material for everything from weapons to paper. Now it is most commonly used in construction of houses, making paper products. In addition to these uses, recent research has allowed timber to be used in ethanol production. However, the timber industry is rather special as there are hundreds of species, which are grown around the world, and they all have different abilities and is used according to their abilities.

### Supply vs. Demand

We were not able to find precise numbers on total world production and consumption, thus these will not be listed here. However, we will cover some factors affecting the supply and demand. A special feature when it comes to production of timber is its long shelf life. If demand sees a sudden decline suppliers can simply postpone harvesting and wait until demand increases.

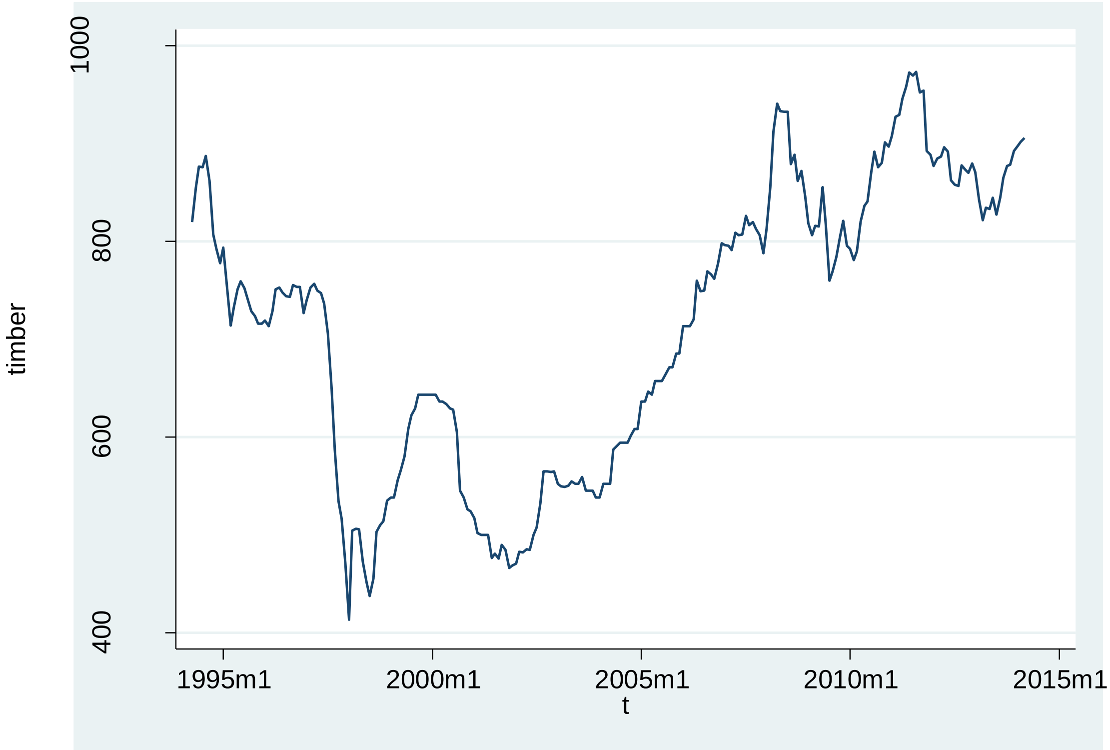
Lumber being produced all over the world makes it vulnerable to natural disasters. Especially forest fires and hurricanes in the U.S. and Canada being some of the largest producers of timber, can affect both demand and supply. Not only will supply decrease but the need for lumber to replace or repair damaged property will increase the demand.

As China is experiencing a rapid economic growth, so is its demand for housing. In 2009 softwood lumber imports increased with 81%, and thus demand for lumber saw an increase[31].

[31] Lumber (2012)

### Historic prices

Figure 14: Monthly timber price in USD/m^3.




Source: DataStream (2014)

The price of timber was relatively high in the beginning of the period before it saw a major drop in 1997 when it reached the lowest price of the period. Since then it has more or less experienced a stable increase with a few ups and downs since the financial crisis. The prices in Figure 14 are for Hard Sawnwood.

## 2.3.2 Metals

### Aluminum

Often referred to as the "miracle metal" aluminum is lightweight, durable and has a high recyclability. It is widely used around the world in everyday products such as metal cans, car parts, in the power grids, within the construction industry and etc. 75% of all the aluminum ever produced are still in use, the main reason for this is that it only takes about 5% of the energy required to produce compared to producing raw aluminum. The Danish chemist Hans-Christian Ørsted first extracted aluminum successfully in 1825, 72 years later Carl joseph Bayer invented the chemical process that refines alumina from bauxite, and thus created the basis for the modern aluminum industry. The extraction of aluminums raw material bauxite is spread around the world within certain areas, whereas consumption is worldwide. The process of extracting the aluminum from the Bauxite is a highly energy intensive process.

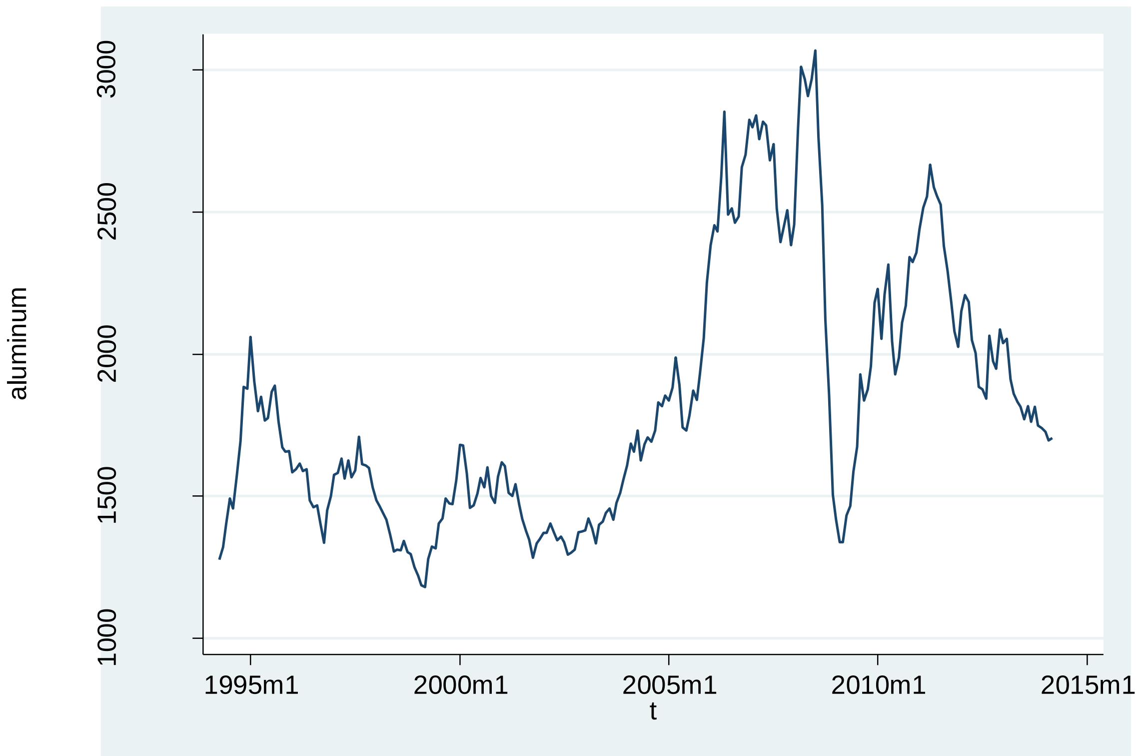
## Supply vs. Demand

The largest producer of primary aluminum[32] is by far China. Producing 12900 thousand metric tonnes in 2012, in comparison, Russia is the second largest producer in the world with 3815 thousand metric tonnes. On the demand side China is by far the largest consumer being responsible for 22200 thousand tonnes and the EU being the second largest consumer with a consumption of 6600 thousand tonnes (Aluminumchina, 2012). Both the construction industry and the transportation industry were responsible for 27% of the consumption (Hydro, 2013). Stricter demands for fuel consumption and lower $CO_2$ emissions are both responsible for the demand in the transportation industry. The lightweight and its anti-corrosion abilities of aluminum compared to other metals are also some of the reasons for the large demand within these two industries.

Bauxite being extracted in rather specific and rural areas all over the world, often requiring transportation through areas with a poor infrastructure for further processing, a process which can be both time consuming and expensive and thus affect the price.

## Historic prices

Figure 15: Monthly aluminum price in USD/MT.




Source: DataStream (2014)

[32] Primary aluminum being defined as liquid aluminum excluding any other alloying metals and metal produced from either returned scrap of remelted metal.

The aluminum price had its ups and downs before a major top before the financial crisis, where it more than halved its priced. It started to recover but has in recent years been decreasing. The prices in Figure 15 are spot prices for aluminum with at least 99.5% purity at the London Metal exchange.

### Iron Ore

Iron ore has been used by civilizations for thousands of years; in the early years one would heat the iron ore and hammer it to remove its impurities, and to extract the iron from the iron ore. Over the years, the methods became more advanced and blacksmiths developed blast furnaces allowing them to melt the iron ore and creating pig iron from where it is processed to, wrought iron, cast iron or steel. For Iron ore to be economically viable, it has to contain between 25-60% iron. The most common use of iron ore is to make steel; about 98%[33] of world iron ore production is used in steel production. Iron ore is located throughout the world where Australia, Brazil and Russia having the largest reserves according to USGS (2014) and World Coal Association (2014).

### Supply vs. Demand

As with coal, China is the largest producer of Iron Ore, producing 880 million metric tonnes in 2009. By comparison, the second and third largest producers Australia and Brazil produced 394 and 300 million metric tonnes respectively[34]. As mentioned above about 98% of the iron ore extracted is used for steel production, and thus by looking at which countries that have the highest steel production we will get a certain impression of where most iron ore are consumed. The top three producers of steel and thus most likely top three consumers of iron ore are China, EU and Japan.

As an iron ore mine has relatively high demands regarding infrastructure, its proximity to the market is an important factor when a new mine is to be opened. The ore is commonly transported by train to a port where it is loaded on to a freighter transporting it to a procession plant. Thus, the cost of this infrastructure and the cost of transportation influence the iron ore prices.

As most iron ore are being used for steel production, the demand for iron ore is heavily affected by the demand for steel, which again is driven by economic growth. Economic growth causes for an increase in the construction sector as well as higher living standards, causing for more steel being demanded for the constructions as well as for industries such as i.e. the automobile industry, which is highly dependable of steel.

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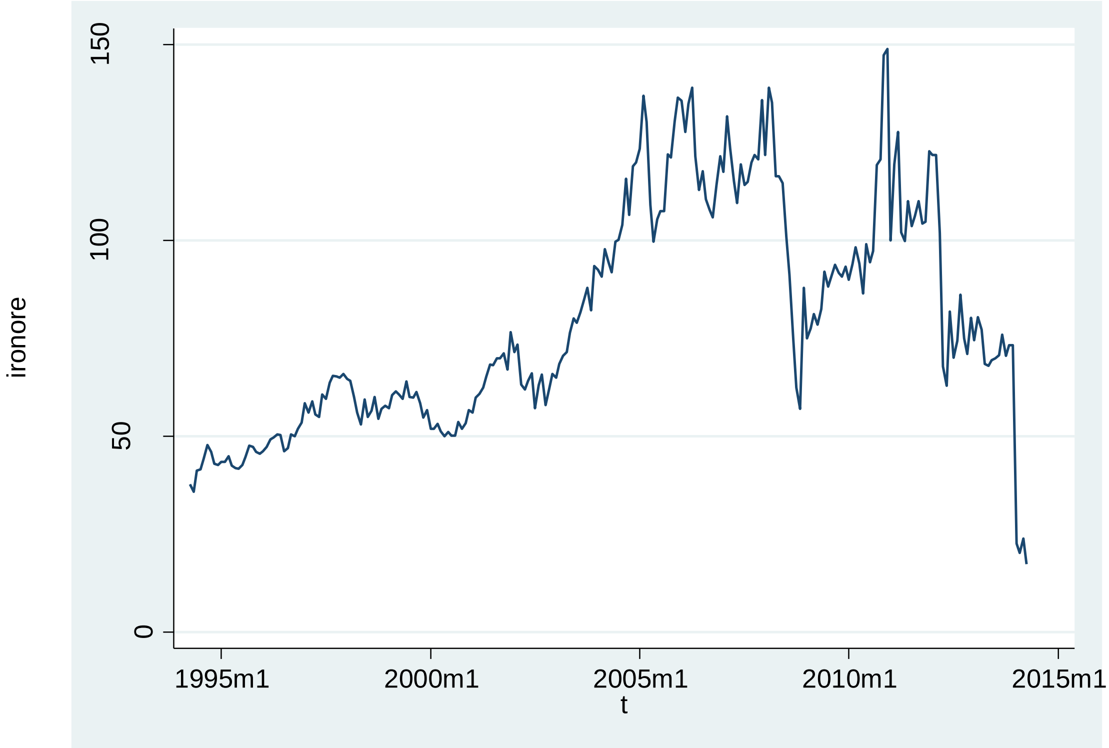
[33] Geoscience Australia (2012)

[34] IndexMundi (2014)

### Historic prices

Figure 16: Monthly iron ore prices in USD/DryMT




Source: DataStream (2014)

As Figure 16 shows, the price of iron ore saw a stable increase until the financial crisis, with a few ups and downs the years before the crisis. It recovered well from the crisis before it started declining in 2011 and has ever since. The prices in the graph are for great northern iron ore in USD/DryMT[35].

## 2.3.3 Energy sector

### Coal

Along with oil and natural gas, coal is a fossil fuel, meaning it originates from the remains of vegetation being buried by shifts in the earths crust and being exposed to high temperatures and high pressure over hundreds of million years. Coal is found worldwide, where around 70 countries have recoverable reserves, and the largest reserves being located in the U.S., Russia, China and India (World Coal Association, 2014). Coal is extracted from the ground and how it is mined depends on the geology of the deposit. From the excavation site it is either transported to a coal preparation plant or straight to where it will be used. Some people use coal for direct heating, however this usage only covers a small fraction of the total coal consumption, where electricity generation, steel production, cement production and liquid fuel are the most significant areas of consumption.

[35] Mega tonnes

## Supply vs. Demand

The largest producer of coal is China, being responsible 47.5% of total coal production in 2012. By comparison, the second largest producer, the U.S., were only responsible for 13.4% of the total production in 2012. The same two countries are also responsible for the largest consumption with 50.2% and 11.7% respectively[36]. What separates coal from other commodities is that merely 15% of the amount extracted is exported; meaning that most coal stays within the country it is produced. About 2/3[37] of the coal produced worldwide is used for electricity generation. This is mainly because coal is a very cheap source of energy compared to natural gas and renewable energy sources, even when carbon taxes are included.

Trading coal is not as common as trading other commodities, however there are several exchanges where both futures and spot trading are available. Being a fossil fuel the supply will eventually be depleted and as demand outgrows supply prices will increase.

Even though merely 15% of the coal produced is exported, the coal price is relatively dependent on the transportation costs due to most mines being located in rural areas. It is also dependent upon the price of other fuels, being very non-environmental friendly users of coal will prefer other sources of fuel if the price justifies it and thus decrease the demand for coal and its price.

[36] BP (2013)

[37] Jancovici (2013)

## Historic prices

Figure 17: Monthly coal price in USD/MT.


Source: DataStream (2014)

The coal price as seen in the graph above enjoyed a relatively steady incline until the financial crisis where the price saw a major decrease. It started recovering but since late 2011, it started declining and has been ever since. The prices shown above are for Australian thermal coal in USD/MT.

## Natural gas

Along with coal and oil, natural gas is a fossil fuel and originates from plants and vegetation several million years old. The gas is typically found together with oil or in separate reservoirs. Up until recent years, it was actually considered a byproduct of oil and usually burned at site. Today it is most commonly used in electricity generation, in fuels and in homes for heating and cooking. It is often preferred to other fossil fuels, as it is more environmental friendly and because of its relative cheaper price to that of the gasoline. Gas reserves are spread throughout the world with Iran and Russia having the largest proved reserves of 33.6 and 32.9 trillion cubic meters respectively[38].

## Supply vs. Demand

The three largest producers of natural gas are the U.S., Russia and Iran producing 681, 592 and 161 billion cubic meters respectively and the same three being the

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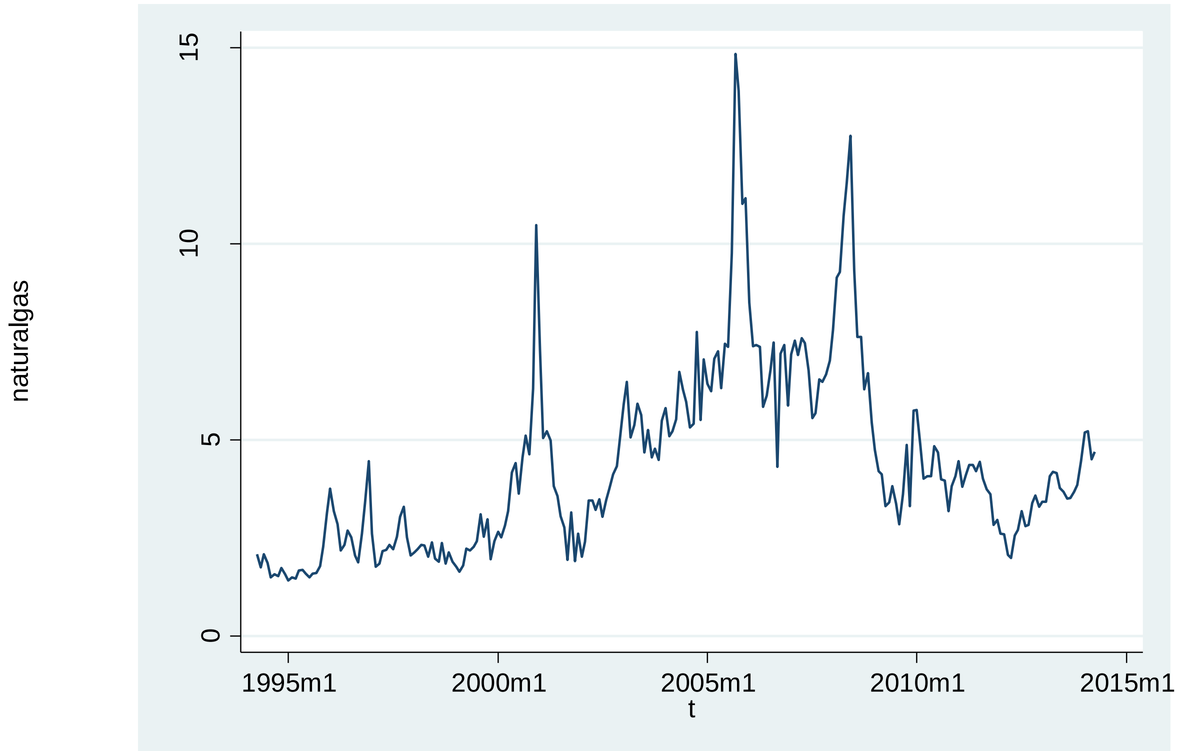
[38] BP (2013)

largest consumers as well with consumptions of 722, 416 and 156 billion cubic meters respectively[38]. Since natural gas is commonly used for heating, the weather is an important factor for the demand. During a period of cold weather the demand for natural gas usually increases, however as gas is fairly easy to store a short-term change in the demand, such as the aforementioned, will only have a limited effect on the gas price.

Natural gas is either transported through pipelines or by sea, when transported by sea the gas has to be cooled down to about -162 degrees Celsius where it under normal pressure becomes liquid, also known as Liquefies natural gas (LNG). This transformation is relatively expensive but it is easy to transport and lets you reach markets where building a pipeline is not economically viable. With an extensive use of pipelines in between countries, the price of natural gas is exposed to political unrest, where a supplying country has the possibility to shut down the pipeline.

### Historic prices

Figure 18: Monthly natural gas price in USD/MMBTU.




Source: DataStream (2014)

Figure 18 shows the price development to natural gas over the past 20 years. Since its all-time high around 2006 and another high in 2008 before the financial crisis, it took a big hit during the financial crisis and it is starting to recover with a steady increase since 2012. The recent low in 2012 was caused by major gas findings in the

U.S. The prices given above is for natural gas at the henry hub Louisiana in USD/MMBTU[39]

### 2.2.4 Beverages

#### Coffee

The first traces of coffee as a beverage dates back to the fifteenth century in Yemen. From Yemen, it slowly spread to the rest of the world. Now it is a well-known beverage highly popular throughout the world. Coffee production sets high demands to climate conditions and is mostly produced within subtropical- and areas close to equator, depending on what types of beans that is grown. The two most common types of coffee are Arabica, which accounts for more than 60% of world production, and are of a higher quality than the second most common type Robusta. Producing coffee is time consuming and an extensive process, when the plants are ready to be harvest due to that the plants often grow in difficult terrain they are most commonly harvested by hand but in some places machines can be used. Obviously using a machine is more effective than handpicking, but the machines cannot make a distinction whether the beans are fully ripe or not and thus the quality are affected.

#### Supply vs. Demand

The top three producers of coffee in 2011 were Brazil, Vietnam and Indonesia producing 43484, 20000 and 8250 thousand-60kg bags of coffee beans. On the consumer side, the U.S tops the list with 22043 thousand-60kg bags, with Brazil and Germany with 19573 and 9460 thousand-60kg bags respectively in 2011[40].

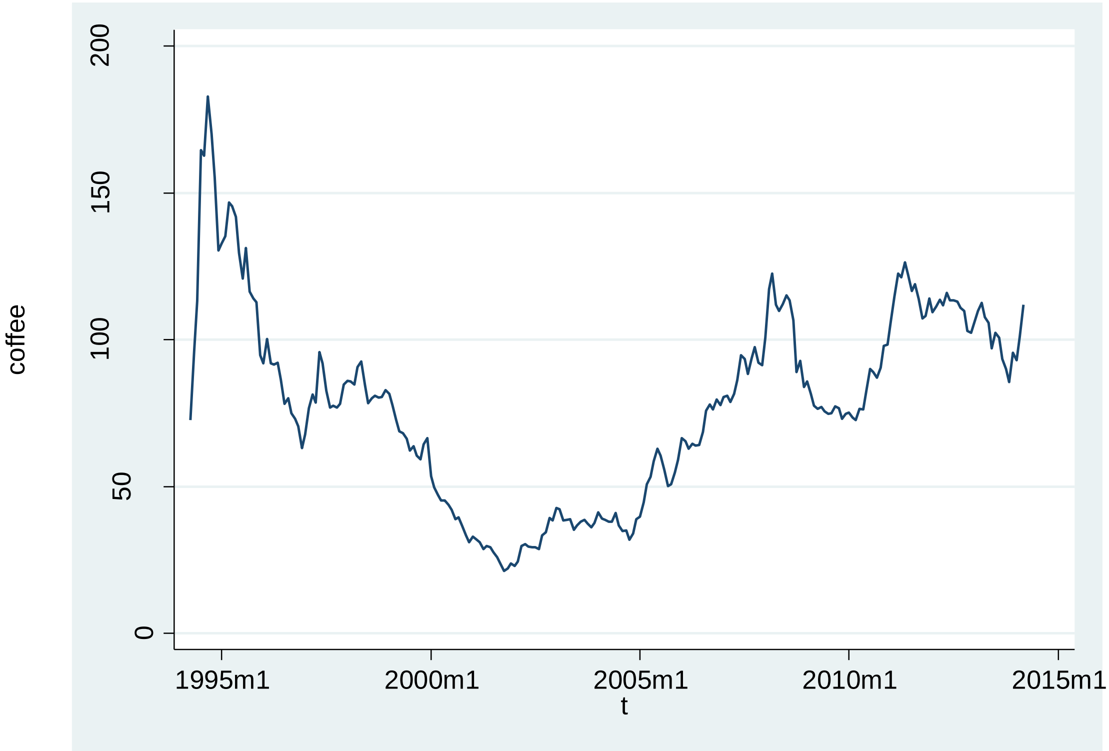
There is only a limited number of significant coffee producing countries, and thus any political instability in either one of these can affect the global supply of coffee and thus the prices. Also, the two different kinds of beans have a great effect on the supply and demand, as an increasing demand in either one will affect the demand for the other, and thus the price. A high percentage of the coffee beans produced are exported to Europe or North America, the beans aging rapidly and absorbing other odors requires a relative rapid transportation from where it is grown to the process facility. In addition, as with the other commodities the price of crude oil can affect the price of coffee.

[39] Million British thermal units.

[40] ICO (2012)

### Historic prices

Figure 19: Monthly coffee price in cents/lb.




Source: Indexmundi (2014)

The coffee price was at its highest in the beginning of the period. It had a relatively rapid decline until around end 2002 when it increased up until the financial crisis, where it had a small decrease to which it recovered relatively fast. Since its recovery, it has more or less remained stable around 100 Cents/lb. The prices above are in U.S. cents per pound Robusta coffee.

### Cocoa

Cocoa is grown in tropical areas and the production process is quite extensive as the entire production cycle is done by hand. Cocoa is most commonly used in chocolate and confectionary production where the beans are grounded into powder and the oil is extracted and made into cocoa butter, which are the base ingredients in to various types of sweets a process referred to as grinding. Throughout the years, this process has typically taken place close to the chocolate production facilities in Western Europe and North America, but a growing demand in emerging economies has caused an increase of grinding facilities closer to the production facilities[41].

### Supply vs. Demand

The three largest producers of cocoa are Cote d'Ivoire, Ghana and Indonesia producing 1486, 879, 440 thousand metric tonnes respectively. To compare with

[41] Sucden (ND)

production with consumption we use the amount grinded per country, where the largest consumers or grinders are Netherlands, Cote d'Ivoire and Germany grinding 500, 431 and 407 thousand metric tonnes respectively[42]. Due to increasing demand in emerging economies there have been concerns that the increase in production is not increasing sufficiently, this is mainly caused by increased prices in competing products and the fact that the cocoa plants in western Africa are old thus making them vulnerable to pests and diseases. The major countries producing cocoa are countries where political unrest is not uncommon, and can affect supply and hence the prices. Increased inspections to stop child labor and underpaid workers have also had a significant effect on the price.

## Historic prices

Figure 20: Monthly cocoa price in USD/MT.


Source: DataStream (2014)

Straight into the new millennia, the price of cocoa was at its lowest during this sample period. After the financial crisis, the price recovered and raised to its highest in late 2009/early 2010. Since then it dropped close to reaching its lows after the financial crisis from where it has increased to just pass 3000 USD/MT. The prices are from the international cocoa organization in USD/MT.

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[42] ICCO (2012)

### 2.2.5 Others

#### Gold

Gold has been around for centuries as a symbol of wealth and trade. Gold is traded worldwide, with the London gold price fix serving as the daily benchmark price. It is done by telephone of five bullion-trading firms of the London bullion market and is measured in USD per troy ounce. According to the World Gold Council 174 100 metric tonnes of gold were above ground; put together they will make a cube only measuring 20x20x20 meter[43]. By comparison, the world produced 2940 metric tonnes of iron ore, only in 2011 according to the U.S geological survey.

#### Supply vs. Demand

The supply of gold from mine production is situated throughout the world with mines on every continent. Over the last five years the average mine production of gold was approximately 2690 tonnes per year[43]. The reason that the production is so stable is because new mines usually replaces drained mines, and thus does not create extra supply. When a new mine is opened it can take as long as ten years for it to come on stream, which makes gold an inelastic commodity and unable to respond quickly to a change in price outlook. Given that the mining production has been relatively constant throughout the years, events of excess demand has been met by the supply of recycled gold.

In addition to mining, a second option for gold supplies is recycled gold. From 2008-2012 the use of recycled gold was responsible of an annual supply of 39%[43]. And, while mining provides a stable output, recycling tends to experience an increase in its supply when prices increase, which helps keeping the price relatively stable.

The demand for gold is spread all over the world, with East Asia, the Indian subcontinent and the Middle East was responsible for approximately 2/3 of the consumer demand. Each market is driven by different sets of socio-economic and cultural incentives, which creates multiple factors affecting the demand for gold. Rapid changes in these factors in the most consuming countries can create new types of demand in the future. The demand for gold can be divided into four subgroups: Investment, technology, jewelry and central bank net purchases.

As of 2013, investment has seen the largest growth regarding demand of gold. According to the World Gold Council investment, demand has increased around 435% the last five years to the end of 2012, in which year the net inflows were approximately USD 82.3bn. The main motivator for investors to invest in gold is its abilities to insure against economic instability and reduce risk[43].

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[43] World Gold Council (2014)

One can invest directly in gold buying coins or bullions or gold linked products that do not include direct ownership of gold, but that is directly related to the gold price. Exchanged-traded funds is another way of investing, where the funds track movements in the price of gold. They are listed on a stock exchange and traded in forms of shares. One can also choose to invest in companies involved with gold, such as mining companies and thus not have any ownership in physical gold. This option includes the risk of poor management; sudden changes in mining costs and does not necessarily track the gold price.

Within the technology sector, such as electronic, industrial, medical and the dentist industry the demand accounts for around 11% of the global demand, which is an annual average of 440 tonnes from 2008 to 2012[44]. Newer research suggests the use of gold to function as a catalyst in fuel cells and pollution control. Nano particles of gold can be used in advanced electronics, glazing coatings and cancer treatments, but this requires further research in new areas.

Over the years, jewelry has steadily been responsible for the largest demand of gold. In 2012 the jewelry demand were around USD 101.8bn, where India being the biggest consumer in volume terms being responsible for around 28% of the global demand in 2012[44]. What drives the jewelry demand is a combination of whether or not the consumer wants it, and whether or not they can afford it or not. During stable periods or gradually rising prices, the demand tends to increase while as in periods of high price volatility it tends to decrease.

The amount of gold governments holds as a reserve varies from country to country, but it usually averages around 15%. Larger economies such as North America and Western Europe typically hold around 40% of their total external reserves in gold, mainly due to historical traditions of the gold standard. On the opposite end, developing countries do not have that tradition and typically holds around 5% of their total external reserves in gold. In total, around 20% of above ground gold is held as reserve assets by central banks and multinational organizations[44].

It has been a major change in official sector within its attitudes towards gold.
The official sector was a major seller of gold for over two decades, 2010 was the first year where the official sector were buying and not selling gold for over 21 years. It is a way of diversifying their external reserves. In addition to this, central banks across Europe has decreased their willingness to sell, mainly due to the financial crisis and issues in the Euro area. Because of these changes, central banks has gone from being a significant supplier of gold, to become buyers and have since 2010 significantly increased the amount bought. All factors mentioned here, will also be important

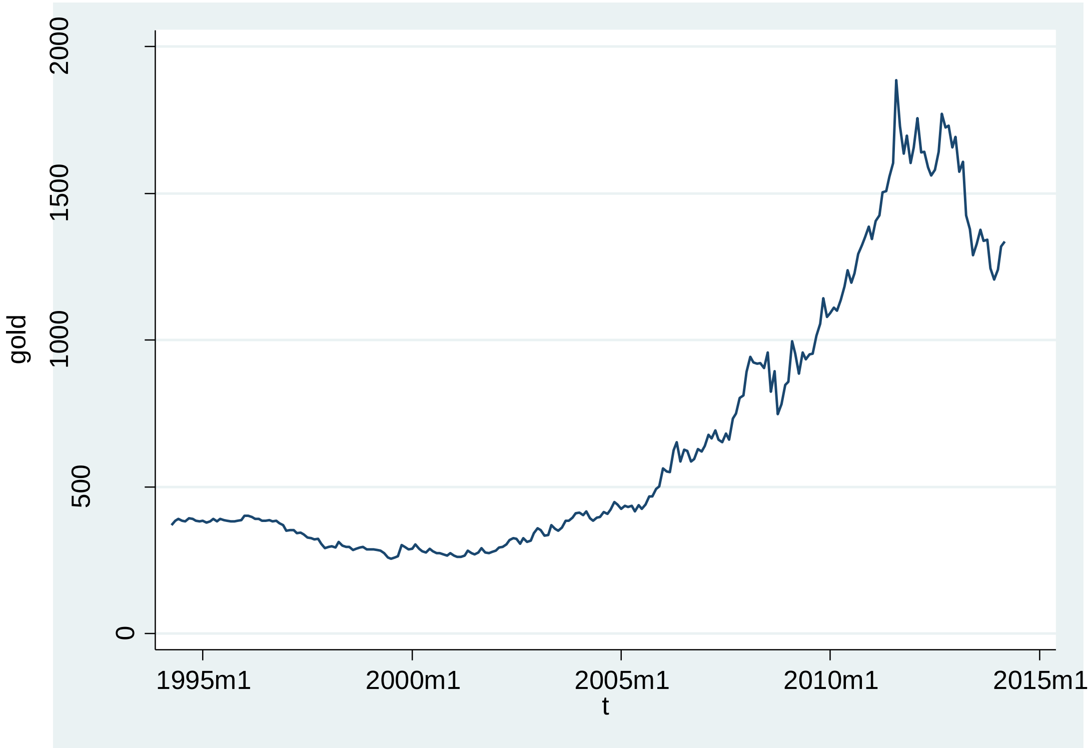
[44] World Gold Council (2014)

when it comes to the future of gold sales, and thus it is unlikely that the official sector will sell gold in near future.

Gold mines are often situated in rural and remote areas usually with a non-satisfying infrastructure; this is a concern especially in developing countries in Africa and Latin America, where the government does not invest in improving the infrastructure. It is common for large-scale mining companies to finance either parts of or the whole infrastructure close to the mine, as this is necessary in order to be able to transport heavy machinery as well as the gold itself[45].

## Historic prices

Figure 21: Monthly gold price in USD/troy ounce.




Source: DataStream (2014)

From the chart above one can see the gold price remained relatively stable up until 2001 where the price exploded and with the exception of a small dip during the financial crisis, it remained inclining until approximately 2011 where it started declining. During the financial crisis, volume of gold jewelry sales dropped and especially in western markets and the U.S. affected the most. Since then the demand in India and Asia is recovering while the Chinese market has seen a continuous consumption in jewelry demand. The prices above are USD/per troy ounce.

[45] Easing the journey: road schemes boost economies (2014)

## Natural Rubber

The first use of natural rubber is traced back to South-America to the 11th century. The indigenous people had used rubber to create balls for various types of games. In Europe, it first became popular by the French who discovered its potential and developed methods to effectively produce rubber. This was soon noticed by other nations who adopted their methods and implemented them in their colonies around the world. However, in our thesis we have used the price of RSS3 rubber that is made from natural rubber. Natural rubber is tapped from the Havea Brasiliensis tree that only grows in tropical regions, from where its liquid content is removed and it is shaped into a mold before it is dried for a week and then sold. Its most common uses are within the car industry as tires, tubes and other parts, and within the clothing industry where it is highly sought after due to its ability of being water resistant as well as its toughness and durability.

## Supply vs. Demand

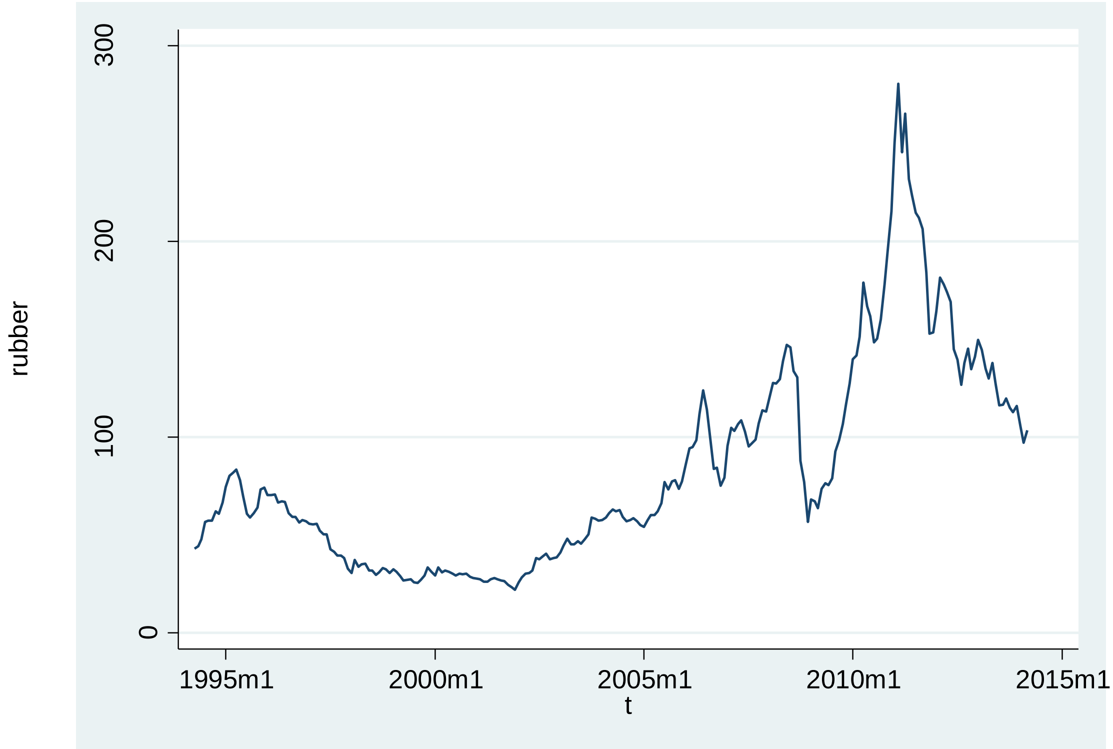
The largest producer of natural rubber in 2011 was Thailand producing 3394 thousand tonnes with Indonesia and Malaysia being second and third producing 2982 and 996 thousand tonnes respectively[46]. As the natural rubber trees can only grow in certain climates changes in weather conditions can affect the production process greatly and thus decrease supply.

The top consumer of natural rubber is China with 3603 thousand tonnes, with the U.S. and India being second and third largest consumer in 2011 with a consumption of 1029 and 958[46]. Economic growth will in most cases increase the demand for rubber, as the demand for products highly dependent on natural rubber, such as the car industry, usually increases when the economy is growing

[46] NMCE (2012-13)

## Historic prices

Figure 22: Monthly rubber price in cents/lb.




Source: Indexmundi (2014)

As Figure 22 shows after a low in 2002 the price of rubber steadily increased until the financial crisis when it dropped dramatically. It recovered fast and almost reached 300 cents/lb. 2011. Since then it has declined to below 100 cents/lb.

## Salmon

Salmon is a widely popular fish consumed all over the world, where Norway is the largest producer of the most common specie, the Atlantic salmon. The salmon are produced in cages located within fjords where they are shielded from rough weather. Until the salmon reaches juvenile age they are breed in freshwater for twelve to eighteen months before they are moved to a salt water cage where they reach the desirable size within 14-16 months. From there they are slaughtered and processed and transported to its end market.

## Supply vs. Demand

In 2013 Norway produced the most salmon with a production of 1029 thousand tonnes, with Chile and Scotland being the second and third largest producer with 421 and 142 thousand tonnes produced. On the consumption side, the EU was by far the largest consumer with a consumption of 817 thousand tonnes with the U.S. and

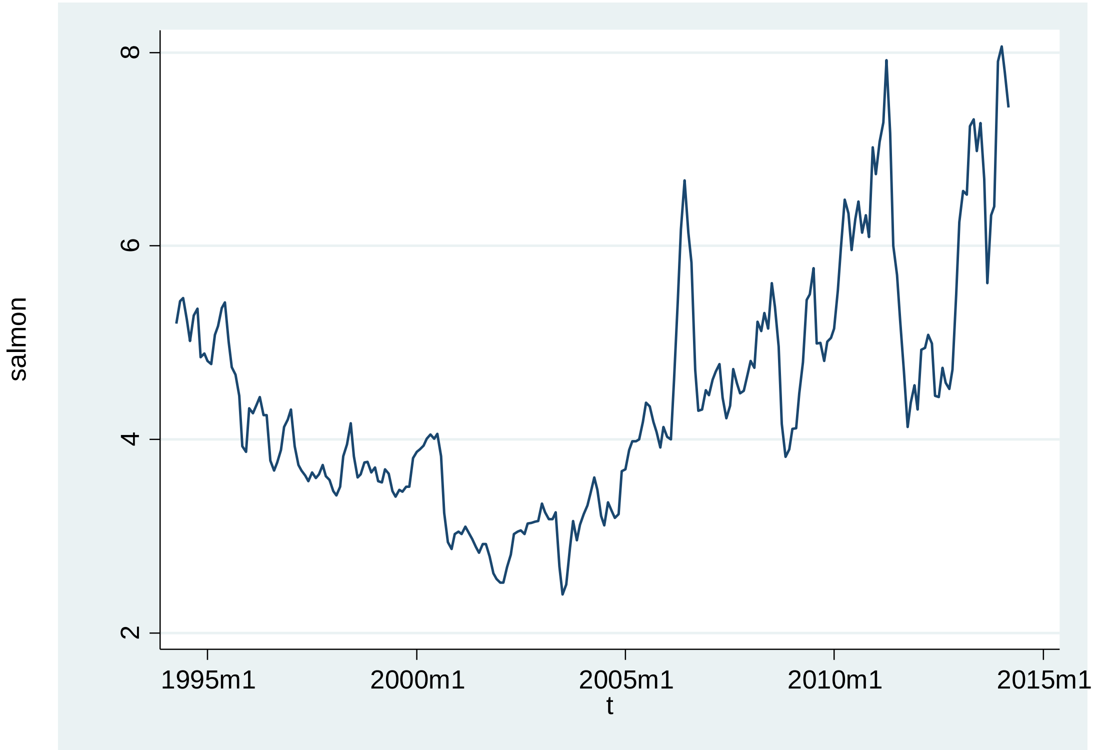
Russia being second and third with a total consumption of 333 and 143 thousand tonnes respectively[47].

There are discussions around whether or not it is environmentally responsible to breed salmon, this concerns is mainly about diseases and the fact that during storms the salmon may escape and breed with wild salmon and thus affect the natural breed of salmon. New research regarding this matter may affect the demand both positively and negatively.

The feed is a major part of the costs of a breeder and thus increases in these prices may affect the price of salmon.

### Historic prices

Figure 23: Monthly Atlantic salmon price in USD/kg.




Source: DataStream (2014)

Since 1994, the price of Atlantic salmon decreased until 2004, since then the price has been steadily increasing with some major fluctuations. The prices in the graph are in USD/kg Atlantic salmon.

[47] Marine Harvest (2013)

### 2.2.6 Summary

Table 1: Summary of commodities.

| | Homo/heterogen | Seasonally dependent | Quality loss when stored | Price/unit |
|---|---|---|---|---|
| Oil | Homo | No | No | USD/Barrel |
| Wheat | Hetero | Yes | Yes | USD/BSH |
| Soy Beans | Hetero | Yes | Yes | USD/BSH |
| Corn | Hetero | Yes | Yes | USD/BSH |
| Timber | Hetero | Yes | No | USD/m^3 |
| Aluminum | Homo | No | No | USD/MT |
| Iron Ore | Homo | No | No | USD/DryMT |
| Natural gas | Homo | No | No | USD/MMBTU |
| Coal | Homo | No | No | USD/MT |
| Coffee | Hetero | Yes | Yes | Cents/lb |
| Cocoa | Hetero | Yes | Yes | USD/MT |
| Salmon | Hetero | Yes | Yes | USD/kg |
| Rubber | Hetero | Yes | No | Cents/lb |
| Gold | Homo | No | No | USD/troy ounce |

## 2.3 Types of trading

This section will cover the basics on various ways to trade commodities.

### Spot market

Spot trading is when you buy or sell a commodity and it is paid and delivered instantly or within a couple of days. The spot price is mostly decided depending on the supply and demand.

### Futures

A future contract is an agreement to buy or sell a specific amount of a commodity at some time in the future to an agreed upon price. Future contracts are traded on various exchanges around the world and are standardized contracts. Standardized contracts meaning that the volume, type of product, price, the time the commodity is to be bought or sold, and where it is to be delivered, is stated in the contract. Commonly the physical transaction never takes place as the contract usually is liquidated before expiry. The main reason for trading futures is to reduce the risk of financial loss due to a change in prices also referred to as hedging[10]. Futures contracts are also commonly being traded by investors, speculating in price changes hoping to make a profit. Unlike the spot market where the price mainly is decided by the current supply and demand, the futures price are rather decided by the futuristic view regarding the supply and demand as well as uncertainties regarding geopolitical events, weather etc.

### Forward contracts

A forward contract shares many of the same features as a future contract, as two parties agrees upon a specified commodity, quantity, quality and a time of delivery. However, these contracts are not standardized and traded on exchanges as oppose to future contracts. However, they share the same purposes as mostly being used to hedge against price fluctuations and by speculators who seek profit, but since they are not traded on exchanges they have a higher default risk.

### Exchange trade funds

In its simplest terms, Exchange Traded Funds (ETFs) are funds that track an index, a commodity or a basket of assets like an index fund, but are traded as a stock on an exchange. The ETFs allows the investor to be exposed to a single commodity or a range of commodities with the goal to provide the investor with a benchmark return at minimal cost.

## 3.0 Data

In this thesis, we use a data sample period of about 20 years, from 1994 to 2014 for all the commodities and for S&P 500. Due to lack of available data, we only managed to obtain 19 years of data from the Oslo Stock exchange and 18 years from the Shanghai index. Given the sharp increase in global commodity price leading up to the financial crisis, and the various outcomes for the different commodities after the financial crisis, we have also chosen to investigate if there was a relationship before the financial crisis and/or whether the financial crisis caused/removed this relationship. In this analysis, we will use monthly data from 1994 to the end of June 2008.

To gather the data we have made use of DataStream and indexmundi.com, as not all of the various commodities and indices of interest were available in one of the databases. Indexmundi only provides price history at a monthly basis, while DataStream can provide daily data for some of the commodities and indices. In general, when selecting time intervals one would choose the shortest interval possible as it provides us with the greatest number and more detailed information, providing a better foundation for the financial analysis. However, when choosing too short time-intervals one would have to account for small temporarily shocks and fluctuations that may even be more of a disturbance for the model rather than helping us obtain significant results. Because of this and due to the availability of monthly data, we decided to run all the tests with a monthly time interval. This will provide us with a sample size of about 240 observations for almost all of the time-series. The only exceptions are the Oslo stock exchange, missing data from 1994 and 1995, and the Shanghai index, missing data from 1994 through 1996. However, this will still provide us with more than 200 observations each, which we believe will be sufficient and will provide a solid foundation for the financial analysis of the results.

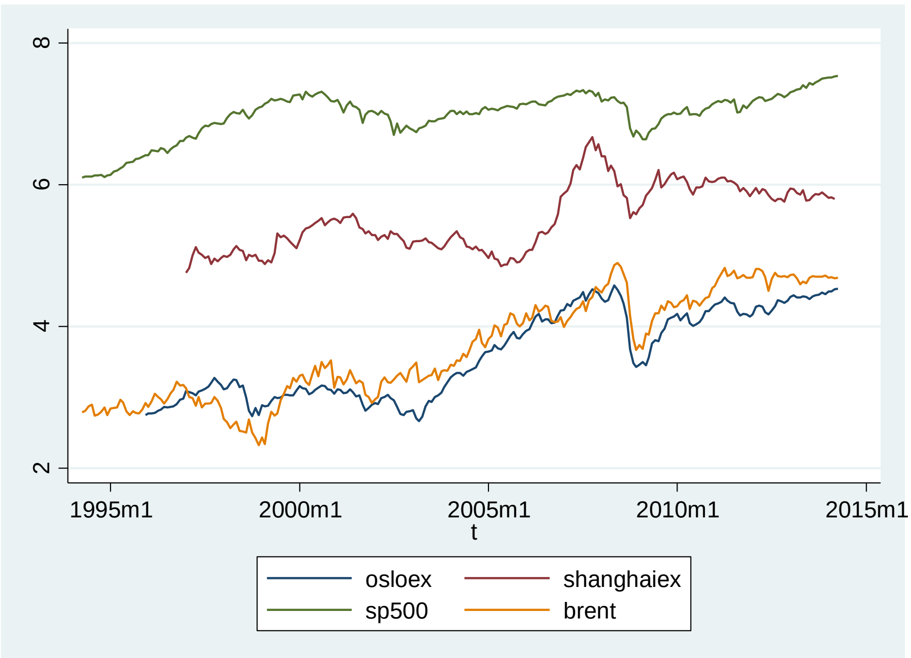
### Commodities

When deciding on what commodities to include in the analysis, we decided to primarily look into 4 different sectors or industries, in addition to some other specific commodities, not included in the specified sectors or industries, that are interesting to see if interacts with the crude oil price. The different commodities and their abilities are listed in Table 1.

### Indices

Because it is commonly known that the economic growth in various countries will have a certain influence on the price of crude oil and other commodities, we have included some indices to reflect economic growth. We have included the S&P500 index as a measurement for the global growth and the Shanghai index as a measurement for economic growth in China. The reason for including China is that China has had a significant impact on the global economy over the last decade, and hence has been a major contributor for driving the commodity prices. We have also chosen to include the Oslo stock exchange as a measurement for economic growth in Norway.

Figure 24: Indices and Brent development.




Source: datastream

### S&P500

Because the global economy can have a significant effect on the price of crude oil and vice versa, we have thought it appropriate to include an index reflecting the global economic growth. Because big economies often will affect the global economy and thus the economies in other countries, we have thought the U.S. economy as a sufficient indicator for the global economy. The U.S. is the world's largest economy and will hence be reflected in most other economies around the world. One example on the U.S. economical position is the 2008 financial crises, which had its origins in the U.S. economy and quickly spread out to all other economies in the world.

To reflect the U.S. economy we have chosen to use the S&P 500. S&P 500, or the Standards and Poor`s 500 is a stock index covering 500 of the leading American companies having common stocks listed on the NYSE[48] and NASDAQ[49]. The S&P 500 is widely regarded as the best single measure for large capitalized[50] U.S. equities, and captures approximately 80% coverage of available market capitalization. S&P 500 has over USD 5.14 trillion benchmarked to the index, with index assets comprising approximately USD 1.6 trillion of this total. Companies to be included in the S&P 500 are assessed by looking at the company's market capitalization, liquidity and monthly trading volume. Most people agree that the S&P 500 is the better representation of the U.S. market as well as the global market[51].

### Shanghai Index

During the last decade, the economic growth in Asia and China in particular has had a significant effect on the international market. As one of the biggest oil consumers in the world, Chinas economic growth has tended to drive the price of crude oil. Because of the, seemingly, tight relationship between the Chinese economy and the crude oil prices we wish to investigate this relationship and see how they interact. In addition, because of China's significant effect on the international market, we wish to further investigate if their economic growth has had any effect on the prices of the other commodities included in our sample.

To reflect the Chinese economy we have chosen to use the Shanghai Stock Exchange Composite Index (SHCOMP). SHCOMP is a capitalization-weighted index and is a stock market index of all stocks that are traded at the Shanghai Stock Exchange (SSE)[52]. Even though there are many large, state-run companies that have yet to go public, the SHCOMP will closely resemble the overall economy of China[53].

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[48] New York Stock exchange. The, by far, largest stock exchange in the world.

[49] Used to be National Association of Securities Dealers Automated Quotations, the second largest stock exchange in the world.

[50] A term used by the investment community to refer to companies with a market capitalization value of more than USD 10 billion.

[51] S&P 500® (2014)

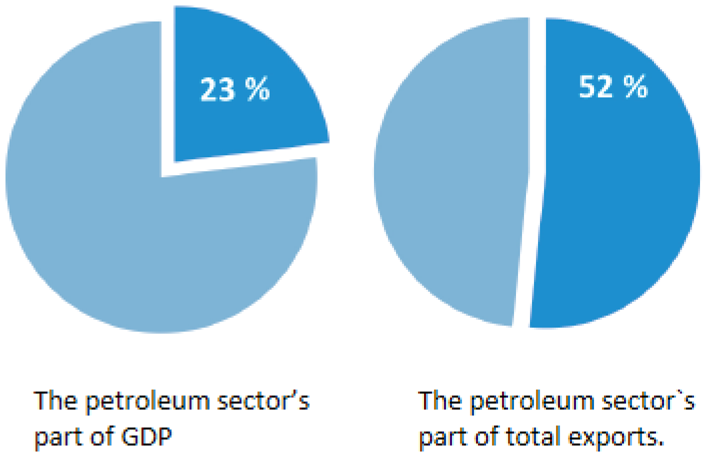
[52] Trading Economics (2014)

[53] Investopedia (2014)

### Oslo Stock exchange

The oil price has since the 80`s made up a big part of the Norwegian economy. Bjørnland and Thorsrud (2013) investigate how important the oil is to Norway, looking on how it affects GDP, employment and productivity. As the oil market is a major contributor to the Norwegian economy, we found it interesting to see how changes in the oil price will affect the economic growth in Norway.

Figure 25: Macroeconomic indicators for the petroleum sector 2012.




Source: Bjørnland and Thorsrud (2013)

As a reference to the Norwegian economy, we have used the Oslo Stock exchange Benchmark Index (OEBX). OSBX comprises a representative selection of all the shares listed on Oslo Stock exchange. Oslo Stock exchange was, in 2012, ranked as the 38th largest derivatives exchange by the (Acworth, 2013). Figure 24 illustrates how OSEBX and Brent closely have followed each other over the sample period.

### Oil

To serve as a benchmark for the oil price we have chosen to use Brent. This is because Brent, as of 2012, is the largest traded commodity and considered by most people as the world's benchmark for crude oil being used, directly or indirectly, to price 70% of the world's oil (Fielden, 2013). As all the commodities to be included in the analysis originates from different countries around the world and are being traded on various mercantile exchanges, it is more likely to see an effect from changes in Brent rather than other "national" benchmarks (Park & Ratti, 2008). One could consider using WTI, as WTI and Brent have been highly correlated over the years up until lately[54]. However, due to a large change in the market dynamics the price of WTI has declined relative to that of Brent (see Figure 4). Table 2 provides the descriptive statistics of the time series used in our model.

[54] See section 2.1.8 The Brent/WTI Spread.

Table 2: Descriptive statistics 1994-2014 and 1994-2008 respectively.

| Variable | Obs | Mean | Std. Dev. | Min | Max | Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Brent | 241 | 3,696 | 0,734 | 2,329 | 4,900 | Brent | 171 | 3,364 | 0,585 | 2,329 | 4,900 |
| SP500 | 241 | 6,986 | 0,325 | 6,104 | 7,539 | SP500 | 171 | 6,924 | 0,338 | 6,104 | 7,336 |
| Shanghaiex | 207 | 5,526 | 0,456 | 4,756 | 6,673 | Shanghaiex | 138 | 5,328 | 0,429 | 4,756 | 6,673 |
| Osloex | 221 | 3,609 | 0,614 | 2,666 | 4,583 | Osloex | 151 | 3,345 | 0,543 | 2,666 | 4,583 |
| Aluminum | 240 | 7,481 | 0,235 | 7,073 | 8,029 | Aluminum | 171 | 7,432 | 0,240 | 7,073 | 8,010 |
| Ironore | 241 | 4,316 | 0,416 | 2,857 | 6,817 | Ironore | 171 | 4,267 | 0,372 | 3,580 | 4,935 |
| Coal | 241 | 3,929 | 0,562 | 3,178 | 5,262 | Coal | 171 | 3,644 | 0,380 | 3,178 | 4,961 |
| Naturalgas | 241 | 1,337 | 0,519 | 0,344 | 2,697 | Naturalgas | 171 | 1,323 | 0,589 | 0,344 | 2,697 |
| Soybeans | 241 | 2,011 | 0,392 | 1,416 | 2,857 | Soybeans | 171 | 1,813 | 0,258 | 1,416 | 2,708 |
| Corn | 241 | 1,086 | 0,452 | 0,322 | 2,109 | Corn | 171 | 0,869 | 0,296 | 0,322 | 1,921 |
| Wheat | 240 | 5,224 | 0,364 | 4,627 | 6,086 | Wheat | 171 | 5,069 | 0,292 | 4,627 | 6,086 |
| Timber | 240 | 6,546 | 0,217 | 6,024 | 6,881 | Timber | 171 | 6,458 | 0,194 | 6,024 | 6,847 |
| Rubber | 240 | 4,216 | 0,626 | 3,096 | 5,638 | Rubber | 171 | 3,936 | 0,474 | 3,096 | 4,991 |
| Cocoa | 241 | 7,483 | 0,354 | 6,665 | 8,188 | Cocoa | 171 | 7,307 | 0,247 | 6,665 | 8,054 |
| Coffee | 240 | 4,250 | 0,480 | 3,057 | 5,209 | Coffee | 171 | 4,119 | 0,503 | 3,057 | 5,209 |
| Gold | 240 | 6,301 | 0,622 | 5,542 | 7,542 | Gold | 171 | 5,955 | 0,321 | 5,542 | 6,850 |
| Salmon | 240 | 1,452 | 0,266 | 0,875 | 2,087 | Salmon | 171 | 1,344 | 0,206 | 0,875 | 1,899 |

# 4.0 Statistical theory, validation of data and model

This part will cover the statistical theory that this thesis will be based upon. This theory is mainly based on Wooldridge (2003), Stock and Watson (2007) and Bjørnland and Thorsrud (2014) works. Firstly, we will cover the simple regression model using only one independent variable to explain the dependent variable, and further on explain a multiple regression and how we can interpret results from these analyses to draw conclusions, and further on different assumptions required for the analyses and results to be reliable.

## 4.1 Statistical theory

### 4.1.1 The simple regression model

The sole purpose of a regression model is to investigate changes in one variable looking at the changes in another variable. Both variables being populations or as in our case, time series looking at changes in different commodity prices and stock indices explained by changes in the oil price. The variable we want to explain is referred to as the dependent variable, and the explanatory variable referred to as the independent variable. These are also the terms that will be used in this thesis. The method explains the dependent variable $(Y)$ using the linear relationship between one or more dependent variables$(X_n)$. The equation below explains this relationship.

$$y = \beta_0 + \beta_1 x + u$$

Where $\beta_0$ is the intercept parameter, $\beta_1$ is the slope parameter, which means that a one-unit change in $\beta_1$ will cause a one-unit change in $y$. All other factors affecting $y$ other than the independent variable is captured in the error term$(u)$.

### 4.1.2 Ordinary least squares

Ordinary least squares is maybe the most common and most known method of linear regression. In an ordinary least squares regression the intercept- and slope-parameter is estimated by minimizing the sum of the squared residuals. The residuals are estimated from the difference in the observed values $(y)$ and the models estimated values $(\hat{y})$. For the results to have any meaningful interpretation there are a different set of assumptions that need to be fulfilled for the OLS to be unbiased and the best linear unbiased estimator (BLUE), a more thorough description of these terms will follow.

**Assumption 1**: States that the time series process follows a model that is linear in its parameters.

$$y_i = \beta_0 + \beta_1 x_i + u_i$$

Where $\{y_i, x_i, u_i: i = 1, 2, \ldots, n\}$ where $n$ is the number of observations.

**Assumption 2:** For each $i$ the mean value of the error $u_i$, given the independent variables for all time periods, is zero.

$$E(u_i|X_i) = 0, i = 1, 2, \ldots, n.$$

**Assumption 3:** The independent variables cannot be constant or a in a linear combination of the others. However, this does not rule out the fact that the independent variables can be correlated, they just cannot be in perfect correlation within the sample.

**W**hen these three assumptions holds, the OLS estimators are unbiased conditional on $X$, and therefore unconditionally as well. The estimators being unbiased means that the expected estimated parameters are equal to the parameters, as shown in the mathematical expression below.

$$E(\hat{\beta}_j) = \beta_j, j = 1,2, \ldots, k$$

**Assumption 4:** Homoscedasticity, the variance of the error term cannot depend on $X$. For this to hold $u_t$ and $X$have to be independent and the $Var(u_i)$ must be constant over time. When assumption 4 does not hold we say that the errors are heteroskedastic.

$$Var(u_i|X) = Var(u_i) = \sigma^2, i = 1,2, \ldots, n.$$

**Assumption 5:** No serial correlation meaning that conditional on $X$, errors in two different time periods are uncorrelated.

$$Corr(u_i, u_h|X) = 0 \; for \; all \; i \neq h$$

An easier way of thinking of this assumption is treating $X$as nonrandom, thus removing the conditioning on $X$, so the equation will look like this:

$$Corr(u_i, u_h) = 0 \; for \; all \; i \neq h$$

When this does not hold, the error terms suffer from serial correlation because they are correlated over time.

**Gauss Markov theorem:** States that when these assumptions hold the OLS is BLUE, as mentioned above this means that the estimators are unbiased, in addition to this the parameters have the smallest variances among all possible linear estimators, and thus gives the most precise estimation of these.

To be able to utilize the OLS standard errors, t statistics and F statistics we need one more assumption.

**Assumption 6:** The error term is independent of $X$and it is normal distributed.

$$u_i \sim norm(0, \sigma^2)$$

When all 6 assumptions hold the parameters will have the smallest variances among all possible estimators, whether they are linear or not. The 6$^{th}$ assumption is not necessary for the estimator to be BLUE.

### 4.1.3 Statistical inference

The estimated parameters derived from an OLS analysis gives us a certain idea on how a variable affects another and not necessarily the true parameters. We therefore have to control whether our estimated values holds a good explanation on the true parameter. To do so we use hypothesis testing.

The first step in a hypothesis test is to define the hypothesis. We define two different hypotheses, the null hypothesis and the alternative hypothesis. The null hypothesis is the one to be tested, and it is assumed true until the data proves otherwise, whereas the alternative hypothesis is the other outcomes of the tested variable. The null hypothesis can only take one value, an example is shown below:

$$H_0: \beta_j = 0$$

In this case when $\beta_j = 0$ tells us that the corresponding independent variable$(x_j)$ does not affect the expected value of the dependent variable$(y)$. The alternative hypothesis can be given in to forms, either as two sided or one sided as the examples below.

$$H_1: \beta_j \neq 0 \; or \; H_1: \beta_j < 0$$

The hypotheses are formulated such that if one is true then the other one has to be false. When conducting a hypothesis test there are two errors that we can do, either a type I or a type II error. A type I error is to reject $H_0$ when it in fact is true, type II error is not to reject $H_0$ when it is not true. After we have decided whether or not to reject the null hypothesis, we have either made an error or decided correctly. Exactly which one it is we will never know, but by defining a significance level which tells us the probability of a type I error has been committed usually denoted as $\alpha$ and is written on the following form:

$$\alpha = P(reject\ H_0|H_0)$$

Meaning what is the probability of rejecting $H_0$ given $H_0$ is true. Common values for $\alpha$ are 10%, 5% and 1%, meaning we are willing to reject $H_0$ wrongly either 10%, 5% or 1% of the time.

A relative simple method of testing hypotheses is using the t-test, a significance level is decided and the t-value computed using the equation below:

$$t = \frac{\hat{\beta}_j - \beta_j}{se(\hat{\beta}_j)}$$

Where $se(\hat{\beta}_j)$ is the standard error of the estimator. We then need the degrees of freedom, which the minimum amount of observations needed to estimate a line and calculated by: (number of observations – 2). The t-value is compared to the critical value $(c)$ which is obtained from a t-distribution with the given degrees of freedom and if $t > c$ we can reject the null hypothesis. This meaning we are willing to mistakenly reject the null hypothesis when it is true 5% of the times and that the parameter is statistically significant.

Another option on testing hypothesis is the p-value that tells you what the significance level is. A p-value of 0,034 indicates that the significance level is 3,4% and thus the probability of rejecting the null hypothesis even though it is correct. Computing the p-value is somewhat more difficult, so how to do this will not be covered in this thesis, as it will be obtained from the computer program we use.

R-squared is the ratio of the explained variation compared to the total variation, and can be interpreted as the fraction of the sample variation in $y$ that is explained by $x$, This makes it a great measure for how well the independent variable explains the dependent variable. The equation used for calculating $r^2$ is:

$$r^2 = 1 - \frac{\sum \hat{u}_i^2}{\sum (Y_i - \overline{Y})^2}$$

$r^2$ Can take a value between 0 and 1, where it being zero means that there is no relationship between the independent and dependent variables, and it being 1 means that there is a perfect fit. When adding new independent variables to the regression equation, $r^2$ will always increase in value due to that the sum of squared residuals will never increase in value as more independent variables are added. To avoid these kinds of issues, the adjusted R-squared are introduced. The adjusted R-squared will take into account the loss of degrees of freedom when a new independent variable is introduced. This “penalty” of adding a new variable is why the adjusted R-squared sometimes is preferred above the R-squared. It is fairly easy to think that the adjusted R-squared is a better estimate of the population, as one may think it corrects the bias in R-squared, but the ratio of two unbiased estimators is not an unbiased estimator.

### 4.1.4 Vector Autoregressive Model (VAR)

The VAR model was first introduced by Sims (1980) replacing methods where serious objections were making it unlikely to get reliable results, the VAR model takes these objections into account and thus improving the strategies for econometric analysis. The main reason for using a VAR model is its possibility to see how different variables will affect each other using their past/lagged values. In a VAR model all variables are treated endogenous, meaning there is a correlation between the variable and the error term. A VAR model by its simplest form consists of two variables and its general form are shown below:

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

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

However these expressions does not include the contemporaneous feedback terms, these terms needs to be included to capture how the present value of $y_{1,t}$ will affect the present value of $y_{2,t}$ and vice versa.

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

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

By putting the terms into vectors and matrices, and moving the contemporaneous term to the left side, we can rewrite the equations as follow:

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

Or

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

Where

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

$$y_{t-1} = \begin{pmatrix} y_{1,t-1} \\ y_{2,t-2} \end{pmatrix} \; and \; u_t = \begin{pmatrix} u_{1,t} \\ u_{2,t} \end{pmatrix}$$

By multiplying with the inverse matrix of $A(A^{-1})$, we end up with the general form of the VAR model.

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

By doing this we have ensured the VAR does not contain any contemporaneous feedback terms on the right hand side, only values known at time $t$, and thus can be estimated using OLS.

### Stationarity

When we are considering non-stationarity trends, we look at two types of trends; a deterministic trend, which is a nonrandom function of time, and a stochastic trend, which is random and varies over time. According to Stock and Watson (2007), it is more appropriate to model economic time series with stochastic trends rather than deterministic trends. This is due to the fact that the predictability of deterministic trends is hard to understand since they are commonly full of surprises and unpredictable movements.

When conducting time series analyses, stationarity is an important term that needs to be taken into consideration. The term stationarity means that the time series` mean, variance and autocorrelation are constant over time. A time series not meeting these requirements will usually have a mean differing at different times and the variance increasing. Economic time series rarely fulfill these requirements in their original unit of measurement, as they tend to follow a random walk, with unpredictable movements up and down. Examples of Random walk and stationarity in time series can be seen in Figure 27 and Figure 28.

A non-stationary time series can induce spurious regression, in other words, assuming there is a relationship between the variables when in fact there is not. Using standard analysis on non-stationary data may give results that appear to be relevant and useful but in fact, they are useless.

There are various ways of checking for stationarity, from plotting the time series and calculating the autocorrelation coefficients to more formal methods such as the Dickey-Fuller test, which will be utilized in this thesis. This test is the most common and is one of the most reliable. Since the Dickey-Fuller test only captures autoregressors with one lag, we will make use of the augmented Dickey-Fuller test.

The augmented Dickey-Fuller test for a unit autoregressive root, tests the null hypothesis $H_0: \delta = 0$ against the one-sided alternative $H_1: \delta < 0$ in the regression (Stock and Watson, 2007). The Dickey-Fuller regression is expressed as follows:

$$\Delta Y_t = \beta_0 + \alpha t + \delta Y_{t-1} + \gamma_1 \Delta Y_{t-1} + \gamma_2 \Delta Y_{t-2} + \cdots + \gamma_p \Delta Y_{t-p} + u_t$$

Where the null hypothesis stating that $Y_t$ has a stochastic trend and the alternative hypothesis stating that $Y_t$ is stationary around a deterministic linear time trend denoted as $t$ in the equation above. To be able to use the augmented Dickey-Fuller test we need to know how many lags that will be applied to the model, this will be covered in the next section.

### Lag selection

When conducting our research we need the optimal number of lags. If we use a to small amount of lags the accuracy of our forecast may be decreased, on the opposite, including to many lags will increase the estimation uncertainty. We therefore have to find the proper balance when deciding on how many lags to include in our models.

To decide on the amount of lags there are several information criterions we can rely on. The information criterions contains two factors, the sum of residual squares (SSR) which will not increase when a lag is added and a second term which is the number of estimated regression coefficients, which will increase when a lag is added. The purpose of using these criterions is to minimize these values and thus make sure at the appropriate number of lags are selected. Two highly relevant examples of criterions are:

The Akaike information criterion (AIC):

$$AIC(p) = \ln\left(\frac{SSR(p)}{N}\right) + (p+1)\frac{2}{N}$$

The Schwarz information criterion (SIC) or also known as Bayes information criterion:

$$SIC(p) = \ln\left(\frac{SSR(p)}{N}\right) + (p+1)\frac{\ln N}{N}$$

Where $N$ is the sample size, the $SSR(p)$ is the sum of squared residuals of the estimated in our model and the IC estimator of $p$, $\hat{p}$, is the value that minimizes the $IC(p)$ among the choices $p = 0, 1, \dots, p_{max}$ where $p_{max}$ is the largest value of $p$ considered.

In order to decide upon which criterion to utilize in our model we will rely on the findings of Ivanov and Kilian (2005). In their research paper they conclude that what criterion to use depends on the frequency of the time series, where SIC are the better criterion for quarterly data and the AIC for monthly data. Hence, we will be using the AIC.

### Cointegration

Two or more variables that share the same stochastic trend are typically cointegrated. Engle and Granger first developed the idea in 1987 and for their contribution to the understanding of non-stationary variables received the economic Nobel Prize. If two variables are integrated of order $I(1)$, and there exist a linear relationship they are stationary when integrated of order $I(0)$ and thus cointegrated. When this is the case, it will be more beneficial to rely on a Vector error correction model (VECM) rather than a VAR. Consider a VAR of order $p$ given by equation:

$$y_t = A_0 + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + +A_p y_{t-p} + u_t$$

When transformed into VECM form it becomes:

$$\Delta y_t = A_0 + \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \cdots + \Gamma_{p-1} \Delta y_{t-p-1} + u_t$$

Where $\Pi = \alpha\beta`$, $\alpha$ measures how fast the system error adjusts back to equilibrium, and $\beta$ is a matrix of cointegration parameters. By doing this transformation the Johansen approach for testing whether two variables are cointegrated or not can be applied and the number of non-zero eigenvalues in $\Pi$ will be determined. To decide which rank the $\Pi$ matrix will have, two test statistics can be used: the trace statistic and the max statistic.

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \; r = 0, 1, 2, \ldots n - 1$$

We start by testing $H_0: r = 0$, meaning no cointegrating vectors, if it is not rejected $\Pi$ has no rank. If rejected we test for one cointegrating vector ($H_0: r = 1$), and we will keep on testing until $H_0$ no longer can be rejected.

$$\lambda_{max} = -T \, ln\,(1 - \hat{\lambda}_{r+1}) \; r = 0, 1, 2, \ldots n - 1$$

Where the null hypothesis is that there are at most $r$ cointegration relationships ($H_0: r = 1$) and the alternative becomes $H_1: r = 1 + r$. The test is repeated until the null hypothesis no longer can be rejected.

## Autocorrelation (serial correlation)

In time series economics autocorrelation is a common problem, as it typically affects the error term, which means that the error term for $t_i$ is correlated with the error term $t_{i+1}$. A simple graphical analysis may reveal whether the error term is correlated or not. If the residual plot shows a distinct pattern the error terms exhibits autocorrelation, and on the opposite, if they do not have a distinct pattern they do not suffer from autocorrelation. Utilizing a graphical method to check whether the error terms suffer from autocorrelation can be somewhat difficult and we will therefore rely on the Lagrange multiplier test, which will provide us with a more accurate answer to whether they suffer from autocorrelation.

*Lagrange multiplier*

”The name of the test is motivated by the fact that it can be regarded as testing whether the Lagrange multipliers involved in enforcing the restrictions are significantly different from zero” (Arellano, 2002).

The Lagrange multiplier will let us examine the relationship between the estimated value of the residuals versus and its lagged values. We will run a test on the estimated residuals using hypothesis testing and use the critical value from Chi squared tables to decide whether or not to reject the null-hypothesis. We use the following expression:

$$u_t = p_1 u_{t-1} + p_2 u_{t-2} + \cdots + p_i u_{t-i} + \varepsilon_1 \; where \; \varepsilon \sim (0, \sigma_\varepsilon^2)$$

The hypothesis is set up:

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

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

The R-squared is multiplied with degrees of freedom, which is the amount of lags used, and compare with the relevant chi square critical value. If $TR^2$ exceeds the critical value, the null-hypothesis will be rejected. Where T represents the degrees of freedom.

## Stability

A VAR being stable means that the effects of shocks eventually die out, otherwise it may cause shocks to increase over time and lead to unrealistically extreme short rate projections and thus making the model invalid. Checking that the eigenvalues are within the unit circle, in other words, less than 1, easily controls this.

### Residual normality

As mentioned earlier in this chapter, there is assumed normality among the residuals. This is assumed necessary in order to make statistical inference about the observations. One common test used to test this assumption is the Jarque-Bera test, which tests whether the error terms have the skewness and excess kurtosis equal to a normal distribution. Skewness is a measure to what extent the distribution is symmetric about its mean, and kurtosis measures the thickness of its tail. Let $u$ be the errors and their variance $\sigma^2$. The kurtosis and skewness are then given by the two following equations:

$$S = \frac{1}{n}\frac{\sum_{i=1}^{n}(x_i - \bar{x})^3}{(\sigma^2)^{3/2}}$$

$$K = \frac{1}{n}\frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{(\sigma^2)^2}$$

The Jarque-Bera test is expressed as:

$$JB = \frac{N}{6}\left[S^2 + \frac{(K-3)^2}{4}\right]$$

N is the number of observations, and the test follows a chi square distribution with two degrees of freedom. The test result is compared to the respective chi square critical value where null-hypothesis is either rejected or not rejected, the null-hypothesis being that the distribution are normally distributed.

### Granger Causality

Using a VAR model containing many lags of the variables, we wish to see which ones that has a significant effect on each dependent variable and which ones that does not. A technique for determining whether one time series is useful in predicting the other is Granger Causality test. A simple definition of Granger Causality is "X is said to Granger-cause Y if Y can be better predicted using the histories of both X and Y than it can by using the history of Y alone" (Giles, 2011). Consider a VAR(2) model with two variables, the first equation would be:

$$y_{1,t} = \beta_{10} + \alpha_{11}y_{1,t-1} + \alpha_{12}y_{2,t-1} + \alpha_{13}y_{1,t-2} + \alpha_{14}y_{2,t-2} + u_{1,t}$$

The coefficients would be estimated using OLS, and it would be performed an F-test to check which variables that affects each other. For example if the causality of $y_{2,t}$ on $y_{1,t}$ were to be tested the null hypothesis would be $H_0$: $\alpha_{12} = \alpha_{14} = 0$. If $H_0$ is rejected it implies granger causality and in this example one would say $y_{2,t}$ granger causes $y_{1,t}$.

### Impulse response function

The Granger causality test tells us whether one time series is useful in forecasting another, but it does not tell us anything about the "cause" and "effects" between the variables. The Impulse Response Function (IRF) of a VAR analysis is an analysis of the dynamic effects of the system when the model receives an impulse, an impulse being a shock given to the variables. IRF trace out the response of current and future values of the variables to a one-unit increase in the current value of one of the VAR errors, assuming that this error returns to zero in subsequent periods and that all other errors are equal to zero (Boston College, ND). This will allow us to see if a positive shock to one variable causes a negative or a positive shock to the other variable in the analysis, and for how long this effect is significant.

### Fisher transformation

The fisher transformation is commonly used when it is desirable to test the relationship between two correlation coefficients within the same population. Firstly, the coefficients are transformed using either one of the following formulas:

$$\grave{\rho} = \operatorname{arctanh}(\rho)$$

Or

$$\grave{\rho} = \frac{1}{2}\log\left(\frac{1+\rho}{1-\rho}\right)$$

Then the corresponding z-value is calculated:

$$z = \frac{\grave{\rho}_1 - \grave{\rho}_2}{\sqrt{\frac{1}{n_1 - 3} + \frac{1}{n_2 - 3}}}$$

Since the population is assumed normally distributed we use z to obtain the respective p-value from a normal distribution.

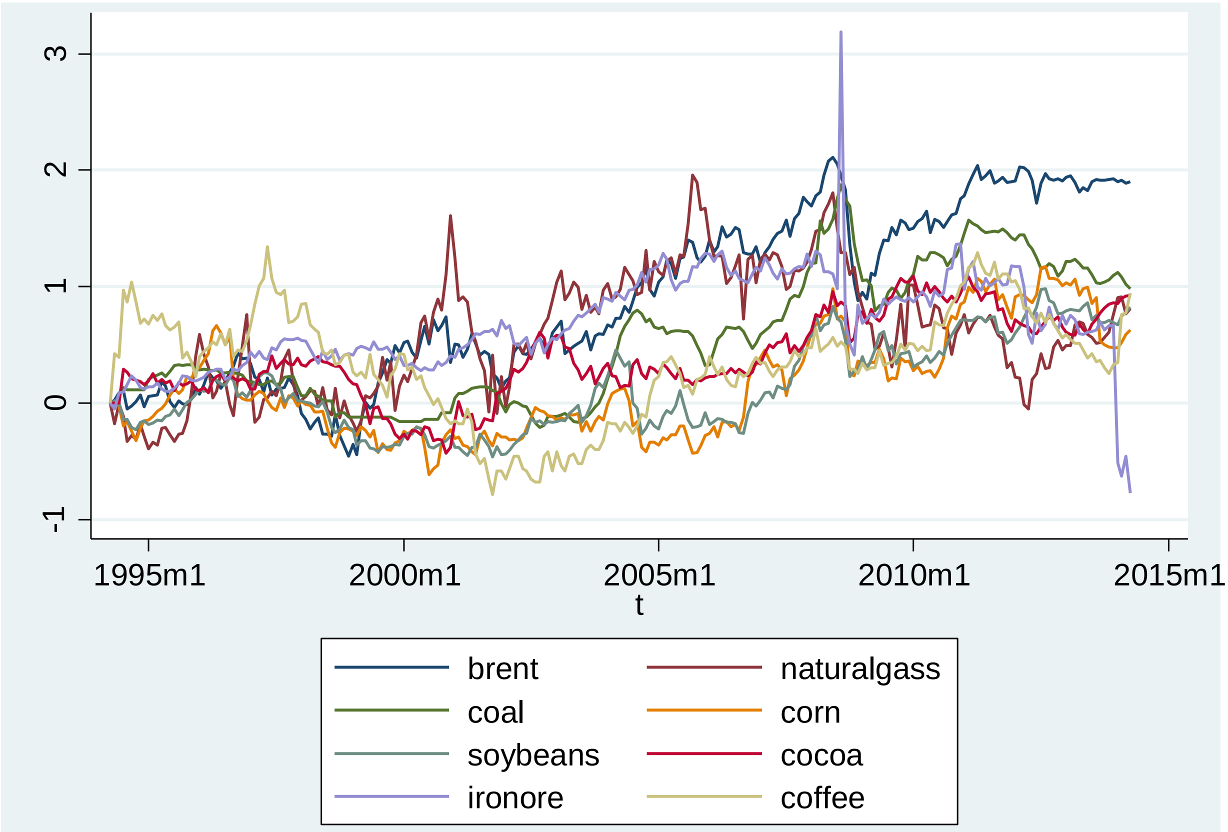
## 4.2 Validation of data

Before we can analyze the interaction between the oil price and other commodity prices, we have to examine the stochastic properties of the time series to be included in the VAR models. This is one of the most important steps in the model building, as an error or wrong assumptions in the stochastic properties can cause misleading results. Throughout these tests, we determine which model to use as well as to see if the dataset might need adjustments in order to provide valid results. In order to examine our model and find out whether it is statistically valid, we will make use of the different tests mentioned in the previous section.

### 4.2.1 Unit root tests

A graphical analysis of the data included in this study reveals how all the time series appear to be non-stationary. This is not unusual as most economic time series are likely to contain a unit root (non-stationary[55]). Throughout the entire sample period the various commodities as well as the indices experiences high levels of volatility, which is expected from commodity prices. From Figure 26 and Figure 24 we can see how the prices for the different commodities as well as indices changes throughout the sample period and it is quite clear that they all exhibits non-stationarity in the mean. However, a graphical analysis is not sufficient to tell whether the time series are stationary or not.

Figure 26: Logarithmic development in commodity markets.




Source: datastream

To be able to examine the stationarity properties of the time series we make use of the augmented Dickey-Fuller test (ADF). The test results from the ADF test for Brent vs. the commodities can be found in Table 3. While the ADF test results for the indices vs. the commodities and from Brent vs. the indices can be found in Table 12, Table 13 and Table 14 in the Appendix.

[55] See part 4.1.4 Vector Autoregressive Model (VAR).

Table 3: ADF unit root test results

| Delperioden | | | | |
|---|---|---|---|---|
| **ADF Unit Root Test** | | | | |
| | Log Level | | First log difference | |
| | #Lags | Test Statistics | #Lags | Test Statistics |
| **Brent** | 1 | 0.592 | 1 | -10.263*** |
| Aluminum | 1 | -0.490 | 0 | -11.339*** |
| Gold | 1 | 1.858 | 0 | -13.584*** |
| Wheat | 2 | -0.407 | 1 | -8.507*** |
| Natural gas | 1 | -1.467 | 3 | -10.605*** |
| coal | 2 | 0.939 | 1 | -6.768*** |
| corn | 2 | -1.020 | 1 | -7.607*** |
| soybeans | 1 | -0.371 | 0 | -11.993*** |
| cocoa | 2 | -0.554 | 0 | -13.686*** |
| iron ore | 2 | -1.064 | 1 | -10.852*** |
| cofee | 2 | -1.374 | 1 | -8.006*** |
| Rubber | 2 | -0.031 | 1 | -8.172*** |
| Timber | 2 | -1.419 | 1 | -7.558*** |
| Salmon | 2 | -2.325 | 1 | -8.762*** |

Optimal lag number varies when comparing Brent with the different commodities,
but as theese changes does not alter the ultimate conclution we will only present the
results from Brent with one lag.
Numbers in **bold** and *kursive* indicates lag adjustment to avoid autocorrelation

*** Significant at 1% ** Significant at 5% * Significant at 10%

| Hele perioden | | | | |
|---|---|---|---|---|
| **ADF Unit Root Test** | | | | |
| | Log Level | | First log difference | |
| | #Lags | Test Statistics | #Lags | Test Statistics |
| **Brent** | 1 | -1.021 | 1 | -10.296 *** |
| Aluminum | 2 | -2.429 | 2 | -8.614*** |
| Gold | 1 | 0.421 | 1 | -17.725*** |
| Wheat | 2 | -1.348 | 2 | -10.293*** |
| Natural gas | 1 | -2.586* | 1 | -17.848*** |
| coal | 2 | -1.426 | 2 | -7.840*** |
| corn | 1 | -1.602 | 1 | -14.547*** |
| soybeans | 1 | -1.058 | ***2*** | -14.688*** |
| cocoa | 1 | -1.367 | 1 | -16.574*** |
| iron ore | 4 | -1.073 | 3 | -7.386*** |
| cofee | 1 | -1.358 | 1 | -9.290*** |
| Rubber | 3 | -1.250 | 3 | -7.608*** |
| Timber | 2 | -1.418 | 2 | -9.164*** |
| Salmon | 2 | -2.113 | 2 | -9.550*** |

Optimal lag number varies when comparing Brent with the different commodities,
but as theese changes does not alter the ultimate conclution we will only present the
results from Brent with one lag.
Numbers in **bold** and *kursive* indicates lag adjustment to avoid autocorrelation

*** Significant at 1% ** Significant at 5% * Significant at 10%

Almost all of the commodity prices and indices were found to be non-stationary, which was according to our expectations from the graphical analysis. The only exception was natural gas, which proved to be statistically significant using at a 10% significant level. However, as we use a 5-percentile rejection region in this thesis the null hypothesis of stationarity was rejected here as well, confirming our suspicion of non-stationarity in all of the time series.

As all of the time series proved non-stationary, we had to do a rerun of the ADF test with differenced variables. The first difference of a time series is the series change from one period to the next, and is a common statistical method for making time series stationary. With differenced variables, we were able to reject the null hypothesis even at a 1% significance level, indicating that all of the time series are integrated of order $I(1)$ implying $I(0)$ by first difference. Figure 27 and

Figure 28 displays the relationship between the initial times series of the price of Wheat and Brent and their differenced values. From Figure 27 it is quite clear that both the Wheat and Brent time series mean, variance and autocorrelation not are constant over time. This is however evident for the first log differenced values, as these become stationary time series that fluctuate around the mean of zero (Figure 28).

Figure 27: Natural logarithm Wheat and Brent time series.

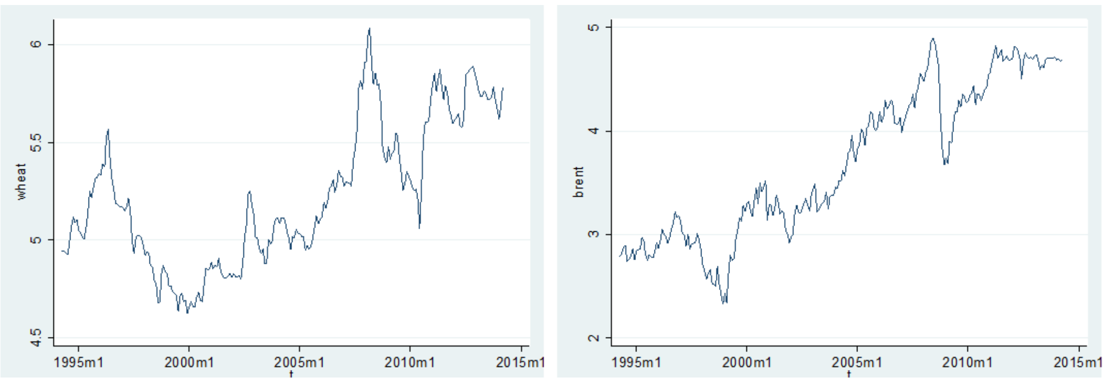
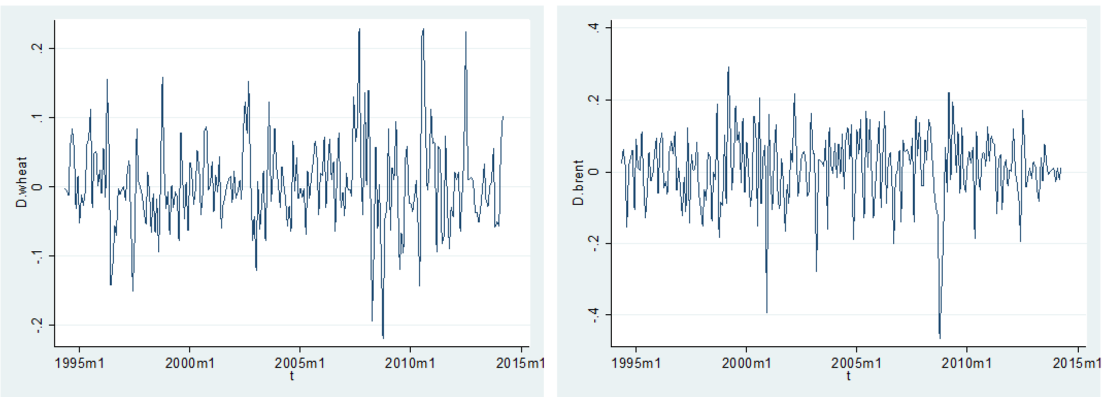



Figure 28: First log differenced Wheat and Brent time series.



### 4.2.2 Lag Selection & Cointegration

In order to decide the appropriate number of lags for the different tests we have made use of Akaikes information criterion (AIC), based on former research conducted by Ivanov and Kilian (2005) who claimed that AIC provides the best results when using monthly data, as mentioned earlier. The optimal lag levels for the different commodities and/or indices are listed in Table 4 below.

From the Johansen tests for cointegration[56], all the time series proved not to be cointegrated, indicating that we may proceed with the analysis using the VAR model without any adjustments.

Table 4: Number of lags

| | Optimal number of lags | | | Optimal number of lags | |
|---|---|---|---|---|---|
| | Brent | | | Brent | |
| Commodities | Log level | First log difference | Commodities | Log level | First log difference |
| Aluminum | 2 | 1 | Aluminum | 1 | 0 |
| Gold | 1 | 0 | Gold | 1 | 0 |
| Wheat | 2 | 1 | Wheat | 2 | 1 |
| Natural gas | 1 | 0 | Natural gas | 1 | 3 |
| Coal | 2 | 1 | Coal | 2 | 1 |
| Corn | 1 | 0 | Corn | 2 | 1 |
| Soybeans | 1 | 0 | Soybeans | 1 | 0 |
| Cocoa | 1 | 0 | Cocoa | 2 | 0 |
| Iron ore | 4 | 3 | Iron ore | 2 | 1 |
| Cofee | 1 | 1 | Cofee | 2 | 1 |
| Rubber | 3 | 2 | Rubber | 2 | 1 |
| Timber | 2 | 1 | Timber | 2 | 1 |
| Salmon | 2 | 1 | Salmon | 2 | 1 |

### 4.2.3 Autocorrelation (serial correlation)

Further, in order to ensure that our model is statistically valid, the error term cannot exhibit autocorrelation. As mentioned in the methodology chapter, we will use the Lagrange multiplier test to examine the relationship between the estimated values of the residuals versus its lagged values. Some of the tests proved, by the Lagrange multiplier test, occurrences of autocorrelation. In order to avoid this problem the number of lags was increased until the null hypothesis of no autocorrelation could not be rejected, so that the residuals would not exhibit autocorrelation. The lag lengths adjusted for autocorrelation are displayed in Table 5 below.

[56] See part 4.1.4 Vector Autoregressive Model (VAR).

Table 5: Number of lags adjusted for autocorrelation.

| | Optimal number of lags Brent | | | Optimal number of lags Brent | |
|---|---|---|---|---|---|
| Commodities | Log level | First log difference | Commodities | Log level | First log difference |
| Aluminum | 1 | 0 | Aluminum | 2 | 2 |
| Gold | 1 | 0 | Gold | 1 | 1 |
| Wheat | 2 | 1 | Wheat | 2 | 2 |
| Natural gas | 1 | 3 | Natural gas | 1 | 1 |
| Coal | 2 | 1 | Coal | 2 | 2 |
| Corn | 2 | 1 | Corn | 1 | 1 |
| Soybeans | 1 | 0 | Soybeans | 1 | ***2*** |
| Cocoa | 2 | 0 | Cocoa | 1 | 1 |
| Iron ore | 2 | 1 | Iron ore | 3 | ***3*** |
| Cofee | 2 | 0 | Cofee | 1 | 1 |
| Rubber | 2 | 1 | Rubber | 3 | 3 |
| Timber | 2 | 1 | Timber | 2 | 2 |
| Salmon | 2 | 1 | Salmon | 2 | 2 |

The numbers in **bold** and *italic* indicates lags adjusted for autocorrelation.

### 4.2.4 Stability

In order for the VAR model to provide robust results it is, as mentioned in section 4.1.4 Vector Autoregressive Model (VAR), important that the model is stable. All of our tests proved that the eigenvalues are strictly less than one, hence that our model is stable. However, in order to preserve space we have not included the figures confirming the stability.

### 4.2.5 Residual Normality

It is recommended to analyze the residuals when running a regression on a data set, as it is common to believe that linear regressions only are valid for normally distributed outcomes. The reason for this is clear given that there are several different mathematical criteria identifying the t-test and the OLS regression as optimal analysis if the outcomes of a test are normally distributed (Lumley et al. 2002). In this thesis, we have made use of the Jarque-Bera test to test if the residuals are normally distributed. Except for when looking at the Shanghai index vs. Cocoa, Aluminum and Rubber the null hypothesis of normally distributed residuals were rejected. According to Gauss-Markov theorem, the normality condition has to be fulfilled in order to utilize the OLS standard errors, t-statistics and F-statistics. In this section, we will try to investigate why the null hypothesis of normality had to be rejected in all of the cases and to what degree it is essential for the residuals to be normally distributed.

There are some different reasons that may have caused this to happen. In chapter 2.3 Natural resources, one can see how the volatility in the returns of the different commodities and indices not are constant, that some periods have higher volatility than others do. Further, "economic" returns are known to have a distribution that is more peaked and has fatter tails than then that of a normal distribution. However, for longer time-periods the CLT[57] is often invoked in defense of the normal distribution (Aas, 2004). The Central Limit Theorem states that the sum of N independent, identically distributed random variables with finite variance converges to a normal distribution around the mean when N is large. Given that the CLT is extremely sensitive to extreme distributions in small samples, the fact that most of these time series are relative small samples with volatility that varies over time, may indicate that the assumptions for the CLT[58] does not hold.

The residuals are defined as the difference between the original data and the predicted values from the regression equation. In the regression context, a graphic analysis of the residuals is a simple technique to see if there are any obvious patterns left within the unexplained portion of the variation of the dependent variable (Wheeler, 2013). The importance of the residuals is to help you identify patterns that might suggest a relationship between the independent and dependent variable that does not show from the regression analysis, not that they are normally distributed. Wheeler (2013) further states that when organizing the residuals in a histogram we are ignoring the whole point in the analysis of the residuals, which is the discovery of patterns that fit in with the context of the data and organizing the residuals according to their own magnitudes. This organization may result in a bell-shaped histogram, but this will not be indicative of anything regarding our data. Nevertheless, when displaying the residuals in a histogram for all the tests, one can see that they are taking the shape of something that is starting to look like a normally distribution only with fatter tails, which is expected from these kinds of returns. For illustrative purposes we have included the histogram of the residuals from the VAR analysis of Brent and S&P500, see Figure 29.

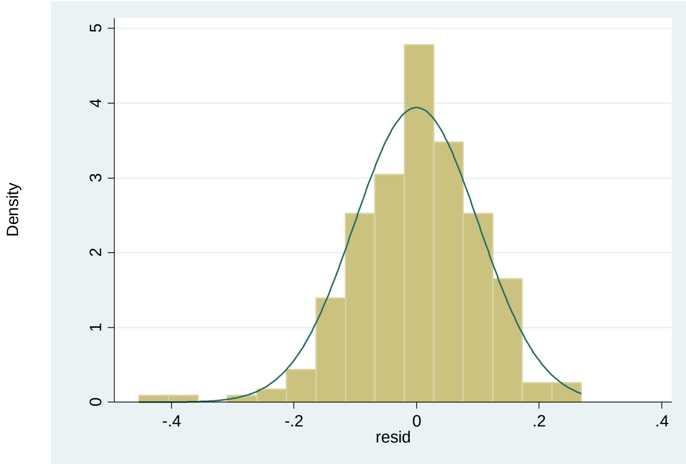
Further, Lumley et al. (2002) concludes that the t-test and least squares linear regression do not require any assumption of normal distribution in sufficiently large samples, and refers to previous simulations studies showing that "sufficiently large" is often under 100[59]. Given that we have about 240 observations in each of our time-series, we state, based on Lumley et al. (2002) that our sample is sufficiently large and does not require any assumption on normal distribution. In addition, based on the research conducted by Aas (2004) and Wheeler (2013) we choose to proceed our research even though, according to the Jarque-Bera test, the residuals are not perfectly normally distributed. However, the reader should keep this in mind when interpreting our results and conclusion.

[57] Central Limit Theorem.

[58] For further reading on CLT see Stock & Watson (2007).

[59] Read more about this in: Lumley et al. (2002).

Figure 29: Residual from the Brent vs. S&P500 VAR analysis.

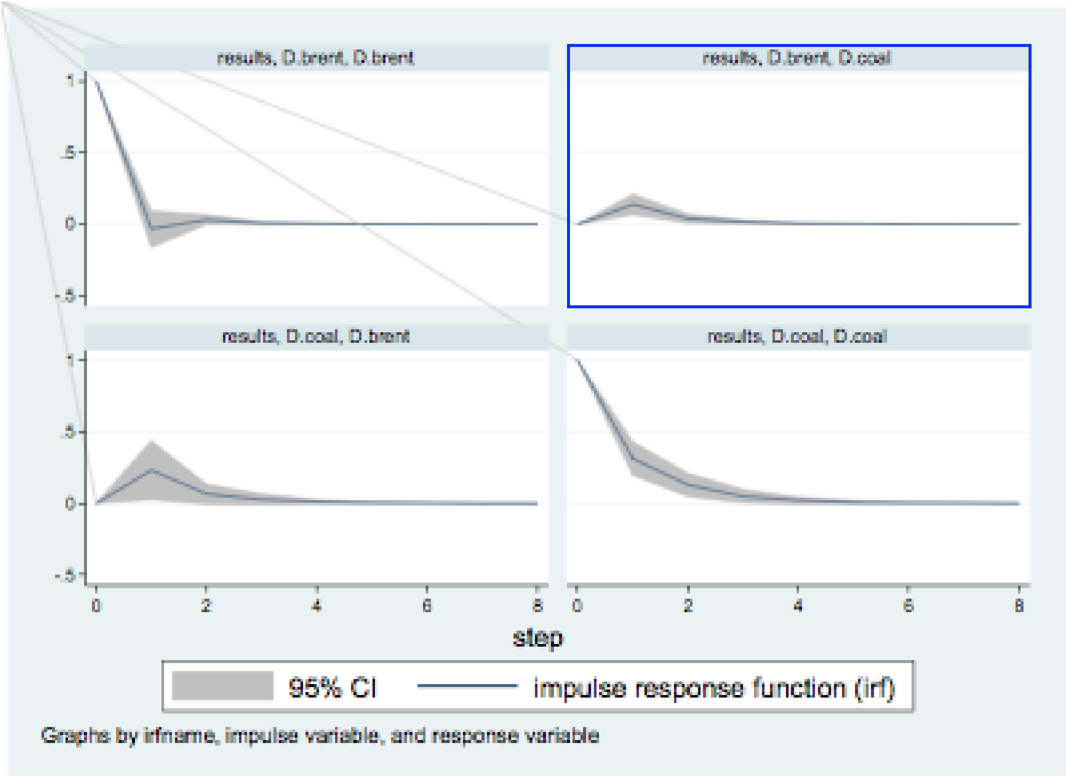



### 4.2.6 Granger Causality & Impulse Response Functions

By using the Granger causality test and the IRF, we can better investigate how the different variables will affect each other. First, we conducted the Granger causality test to see if there is a significant relationship between the variables, where we rejected the null hypothesis of one variable not granger causing the other at 5% significance level. The results from this analysis can be found in section 5.1. In order to illustrate how two variables affect each other we will to use the IRF that shows how an impulse in one variable affects the other and for how long these effects requires to take place.

The IRF serves as a supplement to the Granger causality as it provides much of the same results. Given that this thesis emphasizes on whether the oil price affects the prices of other commodities or not, the IRF will provide a perfect illustration of how a shock in i.e. the oil price might affect the price of another commodity. In order for a reader without any previous knowledge on how to interpret IRF graphs, we have included an illustration and a short explanation below.

Figure 30: Impulse response function for Brent vs. Coal.




In the figure above, there are four different combinations, where the top left and bottom right illustrates the response of the asset to a shock in the same asset. While the remaining two illustrates the response in the asset due to an impulse in the other. The blue line shows the response in time while the gray surrounding area represents the 95% confidence interval of the IRF, indicating where the impulse response is significantly different from zero. The number along the bottom axis indicates the time-period for each sample. For example, the top right IRF (blue square) illustrates the response of the coal prices due to an impulse in the price of Brent. For a period of time the impulse response is significantly different from zero, indicating that a shock in the oil price will have an effect on the price of coal. The same goes for the bottom left, where the effects of a shock in the price of coal also have a significant effect on the price of Brent.

### 4.2.7 Fisher transformation

In our case we use this transformation to test whether the correlation between crude oil and the commodities for the whole period and for the period up until June 2008 is significant different or not. Since the periods are overlapping with a different amount of observations, it is interesting to see if the number of observations affects the correlation and if this difference is statistically significant. First we specify the hypothesis, where the null hypothesis is that the correlation is equal: $H_0: \rho_{oil} = \rho_{comm}$, and the alternative hypothesis is that they are unequal: $H_A: \rho_{oil} \neq \rho_{comm}$. Except for Aluminum and S&P500 against Brent all null hypothesis were rejected telling us that there is no statistically significant relationship between the correlations of the two time periods.

## 4.3 Model

Since we are examining the relationship between crude oil price and different commodities and stock indices, we have chosen to make use of a VAR model with two different variables. Below a general model is described created for a commodity and a stock index against oil with *(i)* number of lags. The models are listed below respectively.

$$y_{oil,t} = \beta_0 + \beta_1 comm_{t-1} + \beta_2 oil_{t-1} + \beta_3 comm_{t-2} + \beta_4 oil_{t-2} + \cdots + \beta_n comm_{t-i} + \beta_n oil_{t-i} + u_{oil,t}, n = 1,2, \ldots, n \; and \; i = 1,2, \ldots, i$$

$$y_{comm,t} = \gamma_0 + \gamma_1 comm_{t-1} + \gamma_2 oil_{t-1} + \gamma_3 comm_{t-2} + \gamma_4 oil_{t-2} + \cdots + \gamma_n comm_{t-i} + \gamma_n oil_{t-i} + u_{comm,t}, n = 1,2, \ldots, n \; and \; i = 1,2, \ldots, i$$

And

$$y_{oil,t} = \beta_0 + \beta_1 index_{t-1} + \beta_2 oil_{t-1} + \beta_3 index_{t-2} + \beta_4 oil_{t-2} + \cdots + \beta_n index_{t-i} + \beta_n oil_{t-i} + u_{oil,t}, n = 1,2, \ldots, n \; and \; i = 1,2, \ldots, i$$

$$y_{index,t} = \gamma_0 + \gamma_1 index_{t-1} + \gamma_2 oil_{t-1} + \gamma_3 index_{t-2} + \gamma_4 oil_{t-2} + \cdots + \gamma_n index_{t-i} + \gamma_n oil_{t-i} + u_{index,t}, n = 1,2, \ldots, n \; and \; i = 1,2, \ldots, i$$

# 5.0 Results and Discussion

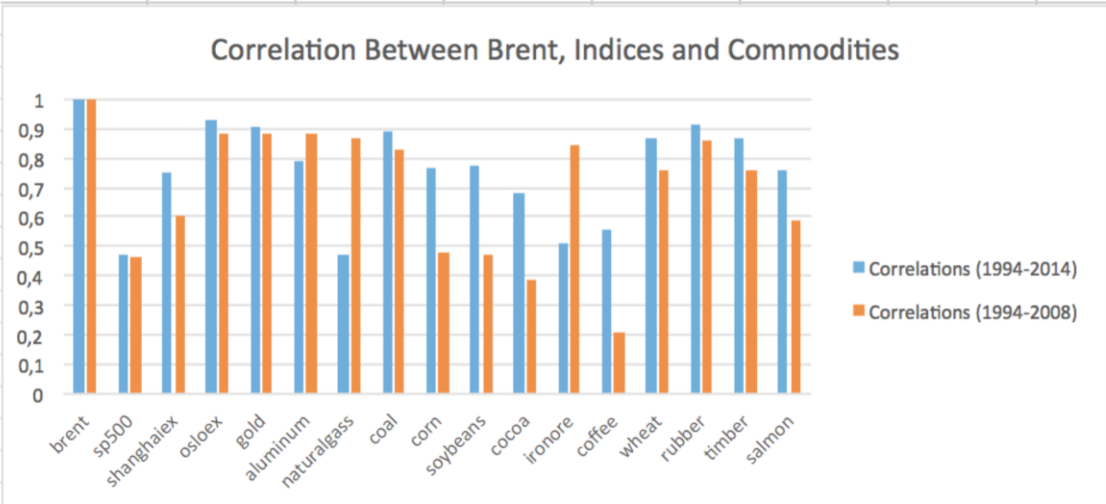
## 5.1 Results

In this chapter, we will first present the results obtained from the VAR analysis, with emphasis on the Brent/commodities causation relationship. We use two overlapping datasets: (1) a dataset including prices until the financial crisis in 2008 (1994 -2008) and (2) a dataset including the financial crisis (1994-2014). We chose two overlapping datasets to ensure an adequate number of observations in both datasets. First, we examine the results in our pre-financial crisis dataset before we compare these results with the findings in our complete dataset. This will allow us to evaluate any changes in the relationship due to the financial crisis and changes in the economy since the crisis. Finally, we will discuss the results obtained from the various analyses, as statistical analysis not necessarily corresponds to financial theory.

It is most common and arguably correct to think that it is economic growth that affects the commodity prices through demand and supply. However, as crude oil is such an important substance in most productions and for all sorts of transportation, as well as having a significant impact on both national and the global economy, one would have a reason to believe that there is a relationship between the price of crude oil and the price of other commodities. However, because economic growth is highly relevant in determining commodity prices we have included some indices to reflect the relationship between them and the commodity prices.

The reason why we have compared two overlapping time series (1994-2008 and 1994-2014) is to see how and if the relationship changes due to the financial crisis and its aftermath. The different correlations in these two overlapping time series changes to a varying degree, where some increases and others decreases, as illustrated in Figure 31 and the correlation graphs Figure 40 and Figure 41 in the Appendix. As mentioned earlier in this thesis, the EIA (2012) found the correlation between crude oil and commodities to increase in periods with financial stress. From Figure 31 we can see how the various correlations change through the financial crisis. The correlations between two variables can give a hint to whether there is a causation relationship between them, but it does not imply that there is a causation relationship.

Figure 31: Changes in the correlations between Brent, indices and commodities




Given that even though the results indicate that Brent or the indices "Granger causes" the commodities, there are still some possibilities that these results are only by chance. In order to make some more robust conclusions regarding the causality relationship between the price of crude oil and the commodities we have chosen to assess the different commodities in separate groups. The metal sector, including aluminum and iron ore; the energy sector, including coal and natural gas; agriculture, soybeans, corn, wheat, timber and rubber; beverages, including cocoa and coffee. We have also included gold in order to investigate the relationship with a popular precious metal, and salmon as it is interesting to see if there is a relationship and since both crude oil and salmon are of high importance to the Norwegian industry.

## 1994-2008

From Table 6, one can see how S&P 500 as an indicator for global economic growth, the Shanghai Exchange index (SHCOMP) as an indicator for economic growth in China, and Brent affects the various commodities in (1). Through this sample period (1994-2008), Brent does not seem to have any effect on either of the commodities. While both S&P 500 and SHCOMP have a significant effect on the price of coal and delayed but significant effect on cocoa.

Table 6: Granger Causality, Brent and Indices vs. Commodities (1994-2008)

| | Brent and Indices vs Commodities | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | S&P 500 | | | Shanghaiex | | | Brent | | |
| | Chi^2 | df | Prob>Chi^2 | Chi^2 | df | Prob>Chi^2 | Chi^2 | df | Prob>Chi^2 |
| Aluminum | 1.589 | 1 | 0.207 | 1.0765 | 2 | 0.584 | 0.00192 | 1 | 0.965 |
| Ironore | 0.242 | 1 | 0.623 | 3.408 | 3 | 0.333 | 0.01927 | 1 | 0.89 |
| Coal | 12.896 | 3 | 0.005*** | 10.066 | 3 | 0.018**(***) | 2.472 | 1 | 0.116 |
| Naturalgas | 2.139 | 1 | 0.144 | 0.5338 | 2 | 0.766 | 2.6892 | 3 | 0.442 |
| Soybeans | 0.187 | 1 | 0.666 | 4.6666 | 2 | 0.097* | 0.49815 | 1 | 0.48 |
| Corn | 0.894 | 1 | 0.345 | 0.08591 | 2 | 0.958 | 1.1427 | 1 | 0.285 |
| Wheat | 3.763 | 1 | 0.052* | 2.6754 | 2 | 0.262 | 0.01748 | 1 | 0.895 |
| Timber | 0.374 | 1 | 0.541 | 0.30302 | 1 | 0.582 | 0.6062 | 1 | 0.436 |
| Rubber | 0.466 | 1 | 0.495 | 1.0624 | 2 | 0.588 | 0.86775 | 1 | 0.352 |
| Cocoa | 5.776 | 2 | 0.056*(***) | 5.3407 | 2 | 0.069*(**) | 2.2016 | 1 | 0.138 |
| Coffee | 0.817 | 1 | 0.366(*) | 0.17996 | 2 | 0.914 | 1.2661 | 1 | 0.261 |
| Gold | 0.527 | 4 | 0.971 | 0.65578 | 2 | 0.72 | 0.71489 | 1 | 0.398 |
| Salmon | 0.641 | 1 | 0.423 | 1.6644 | 2 | 0.435 | 1.2514 | 1 | 0.263 |

Testing the null hypothesis $H_0$: that lagged S&P 500, Shanghaiex or Brent does not "Granger Cause" the commodities. Stars (*) in the parentheses indicates that we obtain significant values by increasing the lag used in the VAR model.

*** Significant at 1% ** Significant at 5% * Significant at 10%

What is quite interesting is that all the agricultural commodities except for timber and rubber seems to have a delayed but significant effect on the price of Brent and the same goes for gold (see Table 7).

Table 7: Granger Causality, Commodities vs. Brent and Indices (1994-2008)

| | Commodities vs Brent and Indices | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | S&P 500 | | | Shanghaiex | | | Brent | | |
| | Chi^2 | df | Prob>Chi^2 | Chi^2 | df | Prob>Chi^2 | Chi^2 | df | Prob>Chi^2 |
| Aluminum | 0.582 | 1 | 0.446 | 3.2815 | 2 | 0.194 | 0.11688 | 1 | 0.732 |
| Ironore | 3.546 | 1 | 0.060* | 3.8687 | 3 | 0.276 | 0.17867 | 1 | 0.673 |
| Coal | 4.499 | 3 | 0.212 | 5.1086 | 3 | 0.164(*) | 3.4505 | 1 | 0.063*(**) |
| Naturalgas | 0.836 | 1 | 0.360(***) | 0.32313 | 2 | 0.851 | 1.7951 | 3 | 0.616 |
| Soybeans | 0.163 | 1 | 0.686 | 1.1009 | 2 | 0.577 | 0.51351 | 1 | 0.474(**) |
| Corn | 0.275 | 1 | 0.600 | 1.3365 | 2 | 0.513 | 0.85534 | 1 | 0.355(**) |
| Wheat | 0.004 | 1 | 0.950 | 1.1618 | 2 | 0.559 | 2.5006 | 1 | 0.114(*) |
| Timber | 1.003 | 1 | 0.316 | 0.58406 | 1 | 0.445 | 0.59993 | 1 | 0.439 |
| Rubber | 2.096 | 1 | 0.148 | 6.0894 | 2 | 0.048** | 0.64864 | 1 | 0.421 |
| Cocoa | 6.614 | 2 | 0.037** | 0.28088 | 2 | 0.869 | 0.73934 | 1 | 0.39(*) |
| Coffee | 0.014 | 1 | 0.906 | 0.93009 | 2 | 0.628 | 0.02001 | 1 | 0.887 |
| Gold | 17.170 | 4 | 0.002*** | 2.5638 | 2 | 0.278 | 0.06877 | 1 | 0.793(**) |
| Salmon | 0.299 | 1 | 0.585 | 4.1503 | 2 | 0.126 | 2.5285 | 1 | 0.112 |

Testing the null hypothesis $H_0$: that lagged commodities does not "Granger Cause" S&P, Shanghaiex or Brent.
Stars (*) in the parentheses indicates that we obtain significant values by increasing the lag used in the VAR model.

*** Significant at 1% ** Significant at 5% * Significant at 10%

### 1994-2014

From Table 8, one can see how the indices and Brent affect the price of the various commodities in (2). In this sample period (1994-2014), the metal sector seems to be affected by both the indices as well as by Brent. Whereas aluminum seems to be more affected by global economic growth and iron ore more affected by the economic growth in China. Brent however, does not seem to have any effect on iron ore, but when assessing the IRF graph in Figure 32 we can see that a positive shock to the iron ore prices yield a significant positive effect to the price of Brent in (2). This is also evident in Table 9, which displays the commodities effect on Brent and the indices.

Table 8: Granger Causality, Brent and Indices vs. Commodities (1994-2014)

| | Brent and Indices vs Commodities | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | S&P 500 | | | Shanghaiex | | | Brent | | |
| | Chi^2 | df | Prob>Chi^2 | Chi^2 | df | Prob>Chi^2 | Chi^2 | df | Prob>Chi^2 |
| Aluminum | 9.479 | 1 | 0.002*** | 3.139 | 2 | 0.208 | 5.1008 | 1 | 0.024** |
| Ironore | 0.825 | 3 | 0.843 | 8.0493 | 2 | 0.018** | 4.6786 | 3 | 0.197 |
| Coal | 16.886 | 3 | 0.001*** | 24.543 | 8 | 0.002*** | 13.807 | 1 | 0.000*** |
| Naturalgas | 0.975 | 1 | 0.323(*) | 1.5217 | 2 | 0.467 | 4.0259 | 2 | 0.134(**) |
| Soybeans | 0.400 | 1 | 0.527 | 12.235 | 4 | 0.016** | 1.0639 | 2 | 0.587 |
| Corn | 0.299 | 1 | 0.584 | 0.31378 | 2 | 0.855 | 1.3799 | 1 | 0.240 |
| Wheat | 0.061 | 1 | 0.804 | 15.925 | 7 | 0.026** | 0.00601 | 1 | 0.938 |
| Timber | 0.001 | 1 | 0.974 | 1.1885 | 2 | 0.552 | 0.17674 | 1 | 0.674 |
| Rubber | 2.980 | 1 | 0.084* | 8.2824 | 2 | 0.016** | 7.3527 | 2 | 0.025** |
| Cocoa | 0.059 | 1 | 0.808 | 4.0371 | 2 | 0.133(**) | 2.2761 | 1 | 0.099* |
| Coffee | 1.434 | 1 | 0.231 | 1.5886 | 2 | 0.452 | 0.53368 | 1 | 0.465 |
| Gold | 0.429 | 1 | 0.513 | 1.0863 | 2 | 0.581 | 0.98272 | 1 | 0.322 |
| Salmon | 1.990 | 1 | 0.158 | 1.2881 | 3 | 0.732 | 2.4997 | 1 | 0.114(**) |

Testing the null hypothesis $H_0$: that lagged S&P 500, Shanghaiex or Brent does not "Granger Cause" the commodities.
Stars in the parentheses (*) indicates that we obtain significant values by increasing the lag used in the VAR model.

*** Significant at 1% ** Significant at 5% * Significant at 10%

Within the energy sector, we can clearly see that coal is highly affected by both indices as well as Brent. This is, however, expected as China is responsible for more than 50% of the total world coal consumption[60], as well as coal being a close substitute to crude oil. From Table 9, we can also see that there is a reverse causality were it actually seems like S&P 500 is more affected by coal than the other way around. For natural gas on the other hand, there does not seem to be much of a relationship. However, by increasing the number of lags we get that Brent has a significant effect on natural gas. This is illustrated in the IRF graph in Figure 32, where one can see that a positive shock to Brent yield a significant positive shock to natural gas after about 7 months.

For the agriculture sector, it seems like the prices are more influenced by economic growth in China rather than by Brent. The only commodities that seem to have a relationship with Brent are rubber and soybeans. This is also somewhat expected, as natural rubber is a direct substitute to synthetic rubber and soybeans being used in the biofuel production.

The beverage sector does not seem to be much affected by either indices or by Brent. The only exception is cocoa where the null hypothesis can be rejected at the 10 percentile for Brent and at the 5 percentile for SHCOMP by increasing the number of lags, which indicates that economic growth in China yield a delayed effect on the cocoa price. The same goes for Brent`s effect on the price of salmon, which yield

[60] BP (2013)

significant numbers after increasing the number of lags. The price of gold on the other hand does not seem to be affected by the indices or by Brent.

Table 9: Granger Causality, Commodities vs. Brent and Indices (1994-2014)

| | Commodities vs Brent and Indices | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | S&P 500 | | | Shanghaiex | | | Brent | | |
| | Chi^2 | df | Prob>Chi^2 | Chi^2 | df | Prob>Chi^2 | Chi^2 | df | Prob>Chi^2 |
| Aluminum | 2.381 | 1 | 0.123 | 0.39146 | 2 | 0.822 | 1.1408 | 1 | 0.285 |
| Ironore | 20.843 | 3 | 0.000*** | 8.544 | 2 | 0.014** | 8.684 | 3 | 0.034** |
| Coal | 8.544 | 3 | 0.036** | 25.937 | 8 | 0.001*** | 4.9358 | 1 | 0.026** |
| Naturalgas | 0.318 | 1 | 0.573 | 0.02512 | 2 | 0.988 | 0.90585 | 2 | 0.636 |
| Soybeans | 1.966 | 1 | 0.161 | 10.951 | 4 | 0.027** | 8.2565 | 2 | 0.016** |
| Corn | 0.079 | 1 | 0.779 | 0.75783 | 2 | 0.658 | 0.66911 | 1 | 0.413 |
| Wheat | 1.879 | 1 | 0.170 | 10.651 | 7 | 0.155 | 0.05579 | 1 | 0.815 |
| Timber | 0.655 | 1 | 0.418 | 1.3333 | 2 | 0.513 | 0.19298 | 1 | 0.660 |
| Rubber | 0.000 | 1 | 0.998 | 6.5133 | 2 | 0.039** | 8.5147 | 2 | 0.014** |
| Cocoa | 1.225 | 1 | 0.268 | 1.0914 | 2 | 0.579 | 0.00079 | 1 | 0.978 |
| Coffee | 0.387 | 1 | 0.534 | 1.8469 | 2 | 0.397 | 0.25677 | 1 | 0.612 |
| Gold | 0.038 | 1 | 0.845 | 0.69578 | 2 | 0.706 | 0.27694 | 1 | 0.599 |
| Salmon | 0.886 | 1 | 0.347 | 6.4094 | 3 | 0.093* | 3.8804 | 1 | 0.049** |

Testing the null hypothesis $H_0$: that lagged commodities does not "Granger Cause" S&P, Shanghaiex or Brent.
Stars (*) in the parentheses indicates that we obtain significant values by increasing the lag used in the VAR model.

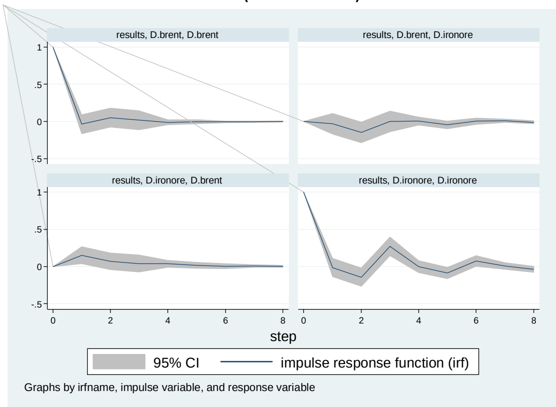
*** Significant at 1% ** Significant at 5% * Significant at 10%

## Impulse response functions (IRFs)

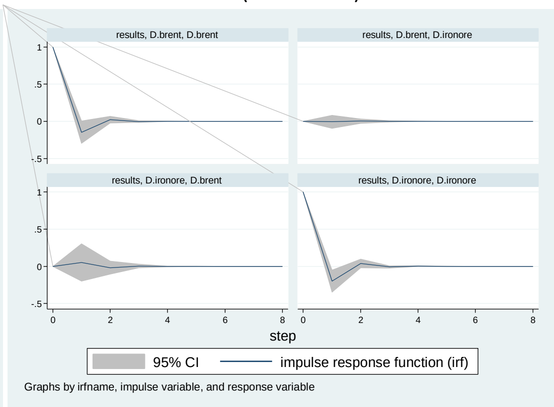
From Figure 32 we can see how a shock to the price of soybeans has a small significant but delayed effect on Brent and the same goes for gold that proves to have a significant effect on S&P 500 as well as Brent. Wheat and cocoa does also proves to have a somewhat significant but delayed impact on the price of Brent in (2). However, these were significant at the 10 percentile, and as we are using a 5-percentile rejection region, the null hypotheses cannot be rejected and consequently we find no significant relationship.

Figure 32: Brent vs. Commodities IRFs

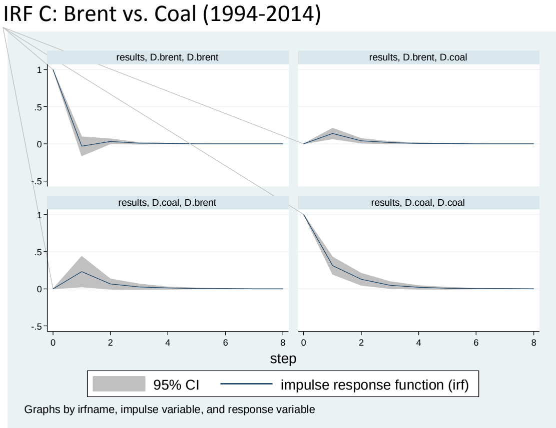
IRF A: Brent vs. Iron Ore (1994-2014)



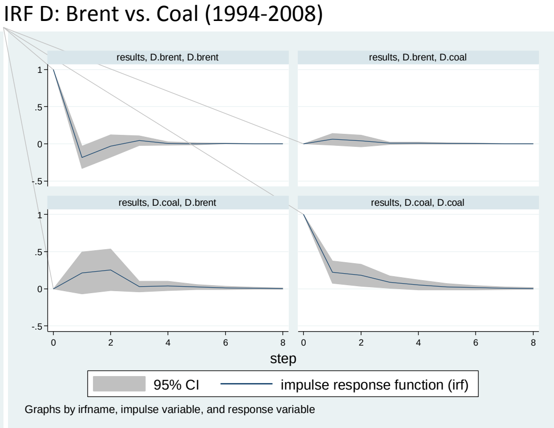

IRF B: Brent vs. Iron Ore (1994-2008)



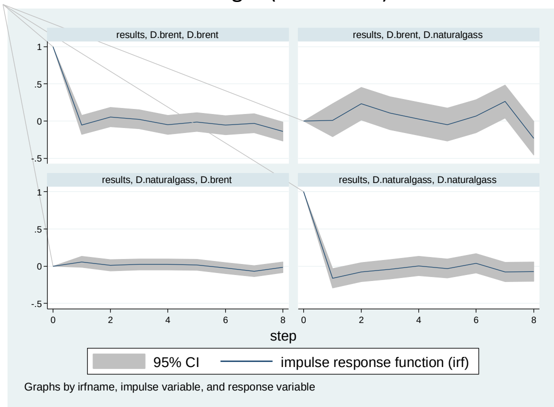

IRF C: Brent vs. Coal (1994-2014)



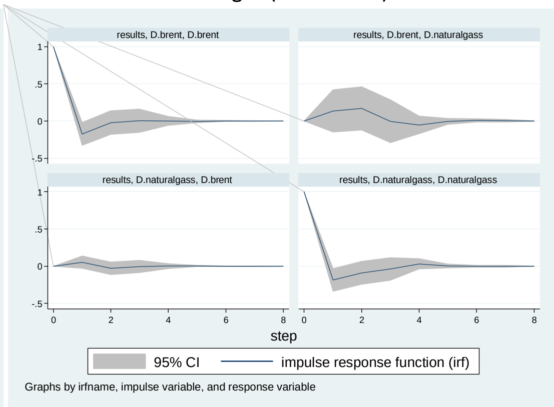

IRF D: Brent vs. Coal (1994-2008)



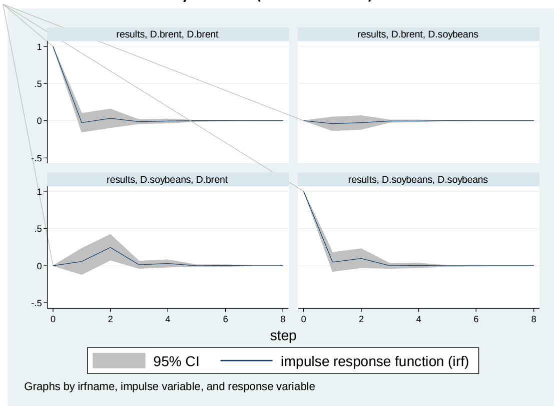
IRF E: Brent vs. Natural gas (1994-2014)



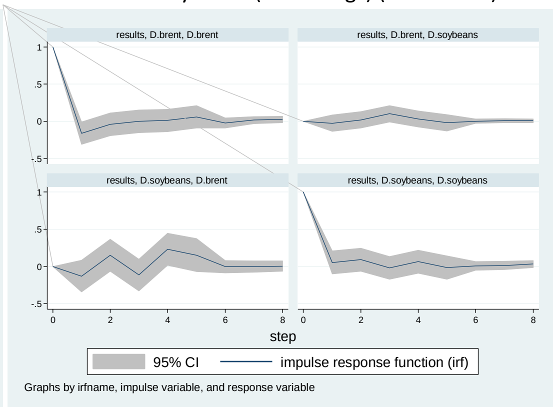

IRF F: Brent vs. Natural gas (1994-2008)



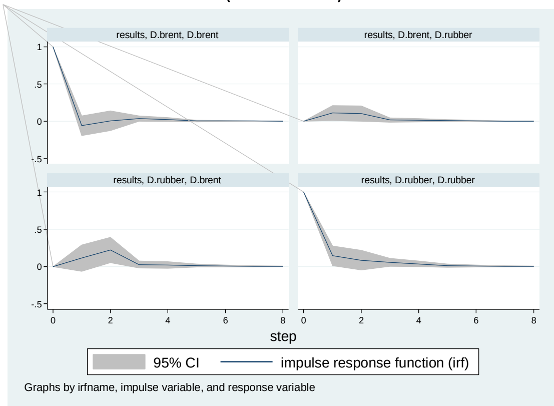

IRF G: Brent vs. Soybeans (1994-2014)



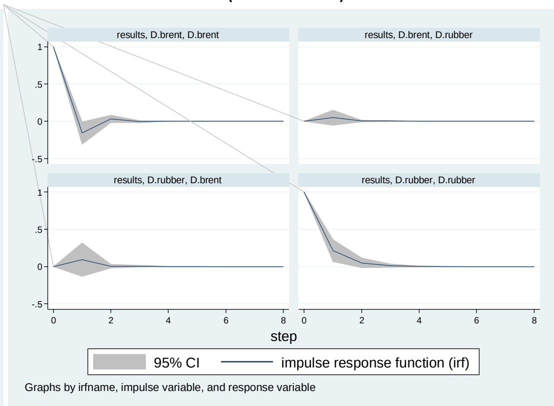

IRF H: Brent vs. Soybeans (with 5 lags) (1994-2008)



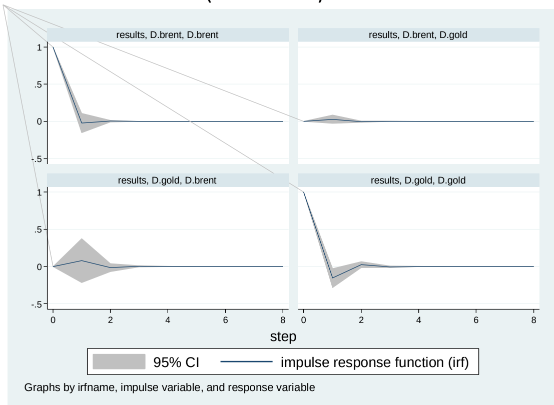

IRF I: Brent vs. Rubber (1994-2014)



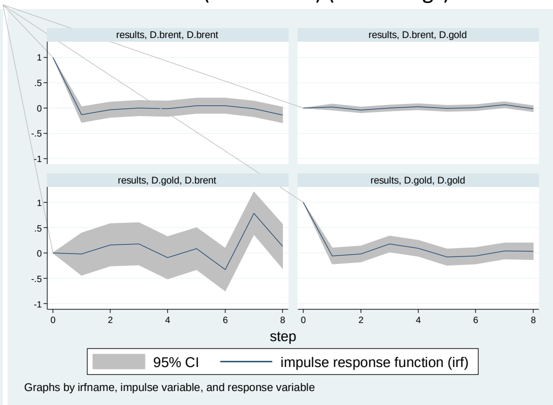

IRF J: Brent vs. Rubber (1994-2008)




IRF K: Brent vs. Gold (1994-2014)




IRF L: Brent vs. Gold (1994-2008) (With 8 lags)



### Brent and indices

To be able to support or reject our findings regarding causation relationships between Brent and the commodities, we ran the test for the various commodities with indices, reflecting global economic growth and economic growth in China. These tests might indicate that economic growth is a better explanatory indicator for changes in commodity prices than Brent is.

First by looking at Table 10 and Table 11, we can see how Brent affects and is affected by the various economies. From the correlation graphs Figure 40 and Figure 41 in the Appendix, Brent`s correlation with S&P 500 is rather low for both the sample periods, while the correlation with SHCOMP is relatively high and increases through the financial crisis. The correlation with OSEBX is very high and increases through the financial crisis as well.

Table 10: Granger Causality, Brent vs. Indices

| | Brent vs Indices(1994-2014) | | | | Brent vs Indices (1994-2008) | | |
|---|---|---|---|---|---|---|---|
| | Brent | | | | Brent | | |
| | Chi^2 | df | Prob>Chi^2 | | Chi^2 | df | Prob>Chi^2 |
| S&P 500 | 0.02789 | 1 | 0.867 | S&P 500 | 2.695 | 1 | 0.101(**) |
| Shanghaiex | 0.32294 | 2 | 0.851(***) | Shanghaiex | 0.15744 | 1 | 0.692(**) |
| Osloex | 0.32793 | 1 | 0.567 | Osloex | 1.2841 | 1 | 0.257 |

Testing the null hypothesis $H_0$: that lagged commodities does not "Granger Cause" S&P, Shanghaiex or Brent.
Stars (*) in the parentheses indicates that we obtain significant values by increasing the lag used in the VAR model.

*** Significant at 1% ** Significant at 5% * Significant at 10%

Table 11: Granger Causality, Indices vs. Brent

| | Indices vs Brent (1994-2014) | | | | Indices vs Brent (1994-2008) | | |
|---|---|---|---|---|---|---|---|
| | Brent | | | | Brent | | |
| | Chi^2 | df | Prob>Chi^2 | | Chi^2 | df | Prob>Chi^2 |
| S&P 500 | 7.6769 | 1 | 0.006*** | S&P 500 | 0.43727 | 1 | 0.508 |
| Shanghaiex | 2.7459 | 2 | 0.253 | Shanghaiex | 1.0221 | 1 | 0.312 |
| Osloex | 16.802 | 1 | 0.000*** | Osloex | 0.88444 | 1 | 0.347(*) |

Testing the null hypothesis $H_0$: that lagged indices does not "Granger Cause" Brent.
Stars (*) in the parentheses indicates that we obtain significant values by increasing the lag used in the VAR model.

*** Significant at 1% ** Significant at 5% * Significant at 10%

From the results, it does not seem like S&P 500 is affected by the price of Brent in (2). However, in (1) we obtain significant results by increasing the number of lags, indicating that the price of Brent will have a significant but delayed effect on the S&P 500 index. On the contrary, S&P 500 does in fact seem to have a highly significant effect on the Brent price in (2), but not in (1). The S&P 500 index reflects all sorts of changes in the worldwide economy, hence it is likely that the index would both tend to affect the price of Brent as well as be affected by price changes.

China has been one of the major drivers of the price of crude oil, and many other commodities, during the last decade and from the results, one can see that Brent in fact has a significant effect on the Chinese economy in both the sample periods, which one would expect. However, one would also expect the Chinese economy to have an effect on the price of Brent, but that does not appear from the results. Because of its major importance to the Norwegian economy and as a check for the robustness of our model, we also chose to include the OSEBX. From Figure 24, one can see how Brent and OSEBX follow each other all the way through the sample period. This is because most of the “heavy weight” companies in OSEBX are all oil or oil related companies. Note however, that the test results are rather strange, as they indicate that OSEBX affects the price of Brent and not the other way around as one expects (and knows).

### Commodities and the world economy

Because the primary goal of this thesis is to investigate the causation relationship between Brent and commodities, we will not dig too deep into the relationship between the indices and commodities. However, because economic growth is such an important factor we cannot leave it completely untouched. From Figure 31 and from Figure 40 and Figure 41 in the appendix one can see that the correlations between SHCOMP and the commodities tends to be larger in all cases compared to the correlations between S&P 500 and the commodities. This could be due to the fact that S&P 500 reflects a greater proportion of the global economy compared to SHCOMP, which mainly reflects the economic growth in China. Typically, economic growth in China has historically been followed by an increased demand for commodities hence increasing the prices for the commodities.

S&P 500 proves, despite low correlations, to have a causation relationship mainly with the metal and energy sector in the two sample periods. However, the S&P 500 and cocoa seems to both have an effect on each other in (1), whereas the correlation actually is negative. For the other sample period (2), the correlation between the two is zero, probably a reason for why there is no causation relationship between them in this sample period. In addition, the price of gold proves, according to the results, to have an effect on S&P 500 in (1).

SHCOMP on the other hand, is a bit more correlated with the commodities compared to S&P 500. In (2) we get that the Chinese economy affects the price of iron ore, coal, soybeans, wheat, rubber and cocoa, whereas the price of iron ore, coal, soybeans and rubber also have an effect on the Chinese economy. In (1), the results indicate that SHCOMP only had an effect on coal and cocoa, while it was affected by the price of rubber. This indicates that most of the causation relationships present in (2), in fact started during or after the 2008 financial crisis.

## 5.2 Discussion

The results obtained from the VAR analysis does not, for all of the cases, correspond with financial theory. We will through this chapter discuss the results obtained from the analysis and see if they are plausible from an economic point of view.
When the results obtained from the Granger causality analysis[61] rejects the null hypothesis, of no causality, at the 5% significance level, there is still a 1/20 probability that the results are by chance. In order to interpret the results we will make use of previous research as well as financial theory.

Some of the results obtained are not, from a financial point of view, possible or at least highly unlikely. For instance, that OSEBX affects the price of Brent and not the other way around is rather impossible due to the relative sizes of these markets. However, as we utilize relatively short time series we are aware that there might be some deceptive results. The information included in the model is rather limited and hence it does not see the big picture. Therefore, it is highly important to utilize financial theory when interpreting these answers as well as look at relevant former research and news that might help explaining the results. We interpret results like the aforementioned (OSEBX vs. Brent) as if there is a causation relationship between them, rather than thinking of it as a one-way relationship. If there is a two-way causation relationship, we interpret this, as it is more likely that the results are not by chance.

### Brent and the commodity sectors

*Metal sector*

For the commodities included in the metal sector, only aluminum proved to be affected by Brent. Aluminum require large amounts of energy to be processed from bauxite, and given that many of these processing plants utilizes crude oil or coal in these processes, one would expect the price of aluminum to be somewhat affected by changes in the oil price. The price of aluminum has, since the post-recession highs of 2011, been in a downward decline. The reason for this is a decline in the demand from China combined with a global over-production. This reduction in the price of aluminum could be an important reason for the decline in the correlation between the price of aluminum and Brent between (1) and (2). What is interesting is that despite a reduction in the correlation between aluminum and Brent, it seems like a causation relationship between them started after the financial crisis.

From the results, Brent did not seem to have any effect on the price of iron ore. Moreover, from Figure 31, one can see that the correlation between Brent and iron ore have decreased during and/or after the 2008 financial crisis. The reason why the

[61] For further explanation, see section: 4.1.4 Vector Autoregressive Model (VAR).

correlation has dropped is arguably due to the lately disappointing economic growth from China alongside with the tightening credit scenario in China, causing the price of iron ore to drop down to historical low prices. What is quite surprising from the results is that iron ore seems to affect the price of Brent in (2). We find this rather hard to explain. Even though the iron ore market is relatively big, it lacks the necessary size to be able to influence the crude oil market. However, this might indicate that there is a relationship between the two commodities, and that this occurred after the 2008 financial crisis.

(1) did not yield any results indicating that there is a relationship between Brent and the metal sector. In Baffes (2007), it is suggested that the extraction companies and the respective governments might have been negotiating the prices, which effectively weakens the link between prices paid by the companies and the world energy prices. Further, they stated that the energy sector of metal producing countries may be subject to policy distortions with a number of metal companies state-owned, implying that energy prices may not reflect marginal cost pricing. In addition, coal is to a larger extent than oil used as a source of energy in the metal processing (ETSAP, 2010).

The automobile and aerospace production is a major consumer of steel[62] and especially aluminum. In events of high oil prices and recessions, the demand for automobiles, airplanes etc. tends to decrease, which again reduces the demand for important input metals such as steel and aluminum. On the other hand, an increase in the demand for metals, such as steel and aluminum, could serve as an early indicator for increased demand for crude oil. Given economic growth, an increase in the production in the i.e. transport sector causes increases in sales, which again increases the demand for refined crude oil products causing an upside pressure on the crude oil price.

*Energy Sector*
Being the second largest source of energy and a direct substitute to crude oil, coal is expected to both influence and be influenced by the price of crude oil, which is quite evident in (2). This is not the case for (1), where the results indicate that coal affects Brent, but not the other way around. This could be due to the price of coal has remained more stable relative to the price of crude oil up until the 2008 financial crisis. The high volatilities in the price of coal leading up to and after the financial crisis has also caused the correlation between coal and crude oil to increase somewhat, which might be why the causation relationship is not a two-way relationship in (1).

[62] 98% of the iron ore is used for the production of steel. See section 2.3.2.

Another energy substitute to crude oil is natural gas, which from the results seems to have a significant but delayed affect from changes in the price of Brent. However, from (1), the results indicated that Brent does not have any effect on the price of natural gas or the other way around, which might indicate that this "relationship" has occurred during the 2008 financial crisis or its aftermath. EIA (2012) finds that prior to 2006 the Henry Hub natural gas showed a consistently strong correlation with the WTI price, but after the second quarter of 2009 it did not show any significant correlation with WTI or any other commodities. This is quite similar to our findings with the Henry hub natural gas prices and Brent, where the correlation between the two is significantly smaller in (2) compared to (1). Further, Brent is being subject to worldwide changes such as crude oil supply disruptions in the Middle East etc., while the Henry Hub natural gas price movements has over the last years been subject to supply side developments with large tight- and shale gas findings, pushing the price of natural gas downwards. The findings from the EIA (2012) states that the correlation between WTI and the Henry Hub natural gas price has decreased, but that does not necessarily indicate that one not can have any effect on the other. Natural gas and crude oil are both close substitutes to each other, hence it is not unreasonable that changes in the price of Brent will have a significant effect on the price of natural gas. Moreover, regarding the futuristic markets, the correlation between natural gas and crude oil are expected to increase as focus on clean fuels as well as new technology may cause an increase in the use of more environmentally friendly fuels. In addition, in order to avoid large price deviations it is likely that more gas producers will price gas related products by indexing them against the crude oil price.

*Agriculture sector*

From the correlation graph (Figure 31), one can see how the correlation between Brent and the agriculture commodities have increased during or in the aftermath of the financial crisis. However, the results from the VAR analysis gave a mixed picture. From (2), only soybeans and rubber provided significant results. Where Brent and rubber both had a significant effect on each other, while soybeans only had a significant effect on Brent and not the other way around.

As we are assessing the price of natural rubber, which is a direct substitute to synthetic rubber where crude oil is a main substance, the price of crude oil would be expected to have an effect on the demand side of rubber. However, due to the relative market sizes it is not likely that the price of rubber would have any effect on the price of crude oil.

Soybeans and corn are both used in the biofuel production, which is a direct substitute for refined crude oil products. In fact, in some countries a portion of ethanol is used in the gasoline mix, where the portion of ethanol tends to follow the oil price to a certain degree. The use of biofuel as a substitute for refined crude oil products is becoming more and more common these days as the world constantly is trying to reduce the overall $CO_2$ emissions. Today, much of the crops grown by farmers can be used in the biofuel production, in animal feed (for cattle, fish farms, etc.) as well as for human food. In addition, the farmers tend to grow more of the crop that yield the most profit. Through the last years, soybeans have yielded more profit relative to that of corn, encouraging farmers to grow the former. In addition, from the test results only soybeans proved to have a significant effect on Brent in the two sample periods while corn only proved to have an effect on Brent in (1).

From the results corn proved to have a causation relationship with crude oil in (1), but this relationship is absent in (2). This is quite in line with the research of Tyner (2009) who also found the crude/corn correlation to be higher before the financial crises compared to after. In the period from 2006 and up until the financial crisis the crude oil prices increased at a high pace, making it more profitable to make use of ethanol as a source of energy. The ethanol industry requires large amounts of corn in order to produce ethanol. This caused an increase in the demand increasing the price of corn hence making it more profitable for farmers to grow a larger portion of corn relative to other crops and sell it to the ethanol industry. However, with the crude oil prices plummeting and the demand for gasoline decreasing in the aftermath of the financial crisis the ethanol business faced difficulties. The price of corn was high and the price of crude oil and gasoline was low, causing many of the ethanol refineries to go out of business. In addition, today there is something called a "blend wall" meaning that no more than a certain amount of ethanol is allowed in the gasoline mix. This blending wall reduces the amount ethanol demanded by the market, and with an already over-supplied market, forcing some plants down to shut-down levels because of the high competition in capturing blending wall determined market (Tyner, 2009). With the high oil prices that we are experiencing today the demand for ethanol fuel should normally increase, but the blending wall breaks this causation relationship between crude oil and ethanol hence with corn. Further, we found that the corn/crude causation relationship only is significant when increasing the number of lags, which is quite similar to the findings of Mallory, Irwin, and Hayes (2012).

It is not just through the price of biofuel that the price of crude oil will affect agricultural products. In fact, a study conducted by the University of Illinois (2008) found that between 1972 through 2007, each USD 1 increase in crude oil price increases corn production costs by USD 1.51 per acre and the soybean production costs by USD 0.90 per acre. Because of higher production costs farmers needs higher crop prices in order to be profitable, which is why many farmers have tended to utilize a larger part of their land to soybeans rather than corn. In addition, Chang and Su (2010) found that there is a positively significant impact from crude oil futures to soybean and corn futures during high oil price periods. Which may explain why we attained significant numbers for both in (1) and not in (2). The former sample period stops at the record high crude oil price in the summer of 2008, and does not include the enormous price drop caused by the financial crisis.

Even though timber seems to be highly correlated with Brent, and the correlation in fact increased from the first sample period to the other, timber did not show any sign of a causation relationship with Brent. These findings are rather different from the findings in Baffes (2007), who in fact found that the pass-through elasticity from crude oil to timber to be -0.13. This was pretty much the same as for wheat that, despite for high correlations, did not prove to have any significant causation relationship with Brent in either sample period. Timber is also to some extent used in the ethanol production, indicating that the price of timber should be affected by changes in the biofuel prices due to changes in crude oil prices. In addition, timber is highly dependent on transportation, which is another channel where the price of crude oil could affect the price of timber. However, as our model does not indicate any causation relationship between timber and crude oil, it might be that the "timber industry" is subject to the same as the metal sector; the lumber companies and the respective governments negotiate the price of timber, making the price of timber not reflecting changes in the energy prices.

*Beverages*

Neither coffee nor cocoa seems to have any significant causation relationship with Brent for either of the sample periods, despite relative high correlations. They are both tree crops and thus substitutability on the input side is very limited. Cocoa is used as an essential substance in confectionary, chocolate etc. while coffee is consumed as a beverage. They are both highly demanded, as the opportunity to substitute on the output side is very limited, in fact, coffee is the second most traded commodity in the world. The harvesting of both cocoa and coffee are very labor-intensive as most of the harvesting and processing is done by hand, at least for cocoa. Leaving the very essential freight rates being the only factor where the price of crude oil could spill on the price of these commodities. However, according to our results it does not seem to have any significant effect on their prices.

*Gold*

Being a precious metal, the demand for gold tends to increase as disposable income increases. For oil exporting countries, an increase to the price of crude oil tends to increase the disposable income hence increase the demand for some commodities such as gold. High crude oil prices are also characterized by inflationary pressure and gold is often used as a secure way of investing in order to store wealth, as the price of gold is not affected by inflation the same way as the value of money. Further, gold is the commodity that has the highest correlation with Brent in this thesis, indicating that the probability for a causation relationship is present. In other words, that an increase to the crude oil price should, in most cases, increase the demand for gold in an oil exporting country and hence the gold price. However, as the world consists of some oil importing countries and some oil exporting countries, which would be the ones most affected by changes to the price. An increase to the price of oil would increase the disposable income in one country while decreasing it in another, which might indicate that there is some sort of a balance in the demand for gold. However, the result indicating that gold has a significant effect on Brent is rather unlikely.

*Salmon*

In Norway, we are very dependent on the exports of crude oil and the income that it provides. However, farmed fish and especially farmed salmon is also a big industry in Norway and a relative big portion of the Norwegian export industry. Because of the importance of these two commodities to Norway, we were interested in see if there is a causation relationship between them. As mentioned in the section 5.1 Results, salmon and Brent seems to have a reversed causation relationship for (2), but no affect either way in (1).

That the price of salmon will have an effect on the price of Brent is rather unlikely, however the findings are interesting. Brent has a significant effect on the price of salmon when increasing the number of lags, indicating that the change in the price of crude oil will have a delayed but significant effect on the price of salmon, which is reasonable. Asche (2011) states that in the long run it is the production costs that will decide the price of salmon and in the short run the price will vary because of imbalance between supply and demand. The proportion of crude oil or refined crude oil products in the production is a rather small proportion of the production costs of salmon. Moreover, the feed that are fed to the salmon today contains large amounts of soybean meal (18.5%) and as the feeding constitute by far the largest proportion of the production costs for farmed salmon (60%) the price of soybeans will have a significant effect on the production costs[63]. As mentioned earlier in this thesis, soybeans and crude oil seems to affect each other, suggesting that an increase in crude oil would cause the feeding costs of farmed salmon to increase hence the price of salmon. The only way crude oil directly could affect the price of salmon is through the transportation. As salmon mainly is "produced" in Norway, Chile and Scotland, the salmon is highly dependent on being transported to various markets around the world where it is to be sold.

Why the causation relationship between Brent and salmon is absent in (1) is rather difficult to say. However, the correlation between salmon and Brent has increased through the financial crisis and as correlation is necessary for causation this could explain the lack of a causation relationship before the financial crisis. Just before the

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[63] ilaks (2013)

financial crisis Chile was contaminated with a salmon virus killing millions of salmons, crippling Chile`s salmon export. As the world's second largest exporter of salmon, this caused for a major increase in the salmon price. In addition, the price of fishmeal has increased significantly from 2005 up until now. This has largely been due to a major decline in the number of anchovies fished, which is the main substance in the fishmeal. To be able to avoid these high fishmeal prices, the industry turned to other sources of protein such as soybeans. The increased use of soybeans in the salmon diet during this period could also be a reason why a causation relationship between Brent and salmon is evident in (2) and not (1).

## 6.0 Conclusion

We have in this thesis studied how changes in the price of crude oil affect the prices of other commodities. Because there still is a possibility that the results obtained from the VAR analysis are only by chance, we chose to divide and assess the commodities in more aggregated groups, since this will provide more robust answers than only comparing individual commodities. In order to obtain necessary results required to answer our research question we have utilized a VAR model based on monthly data from 1994 to 2014. We have studied the causation relationship between the price of crude oil and various commodities, both for a period from 1994 and up to the 2008 financial crisis as well as for a period from 1994 and up until today. We have also studied the causation relationship between Brent and some indices (S&P 500, SHCOMP and OSEBX) to see how they affect each other, as well as the causation relationship of both S&P 500 and SHCOMP and the commodities. We have built further on previous work conducted by the EIA (2012) and Baffes (2007) by using a more advanced model as well as using more frequent time series.

We found that both metal and the energy sector share a causation relationship with the oil price. Where these relationships seemed to have started during or after the financial crisis, as only coal provides significant results in period up until the financial crisis. The agricultural sector gave a quite different picture. Leading up to the financial crisis soybeans and corn seemed to be affected by the Brent price, while for (2) it was soybeans and rubber. The beverage sector showed no sign for any causation relationship with Brent at all, while gold provided significant numbers only for the period up until the financial crisis. Salmon proved to have a causation relationship with the Brent price in (2) while not in (1). We found this in particular to be quite interesting as in the period after the financial crisis, soybeans has become a large part of the salmons feed.

Moreover, the SHCOMP index does also prove to have a causation relationship with most of the commodities. Especially in (2), where we obtained significant numbers for iron ore and coal, most of the agricultural commodities and cocoa while in (1), only coal provided significant numbers. Compared to the S&P 500, SHCOMP seems to have more effect on most commodities, suggesting that economic growth in China, to a larger extent than the “general” global economy (S&P 500), will have an effect on the price of the various commodities. These findings are quite similar to the findings in Aastveit, Bjørnland, and Thorsrud (2012)

Based upon the research conducted in this thesis we conclude that the price of crude oil to a varying degree will have a significant impact on some commodity sectors. However, based on previous research finding that the correlation between commodities tends to increase in periods of financial stress, and the fact that our sample periods both includes extreme increases in commodity prices of 2008, this could indicate that these causation relationships arises in a period of extreme prices. The increase in correlations and causation relationship between the commodities might be because most commodities today are traded as derivatives and in index/hedge funds. What would be interesting to see is if there is a significant change in the correlation and causation relationship between the price of crude oil and commodities before and after the start of the frequent trading of commodities as derivatives. However, as this frequent trading mainly took place from the millennium we lack the proper amount of data in order to conduct a proper research thus we leave this for further research.

## 7.0 Weaknesses

When utilizing and creating a model such as a VAR, which is fairly simple in many dimensions, it is important to be cautious when interpreting the results. Because of the low order required in order for it not to be too complicated, all the omitted variables will be in the residuals. This affects the interpretation process of the IRF`s and may cause the results to be inaccurate (Bjørnland & Thorsrud, 2014) and (Stock & Watson, 2007).

General economic growth is a major factor in supply vs. demand, we have accounted for this by including various indices, however these indices does not fully reflect the economic growth and we could have included other variables such as change in GDP to obtain a more accurate picture of economic growth.

The commodities within the agricultural section are as mentioned highly seasonal dependent, and thus will cause the price to fluctuate throughout the year. When conducting our research this may have affected our findings.

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# Appendix

Figure 33: Non-OPEC productions effect on the price of WTI oil

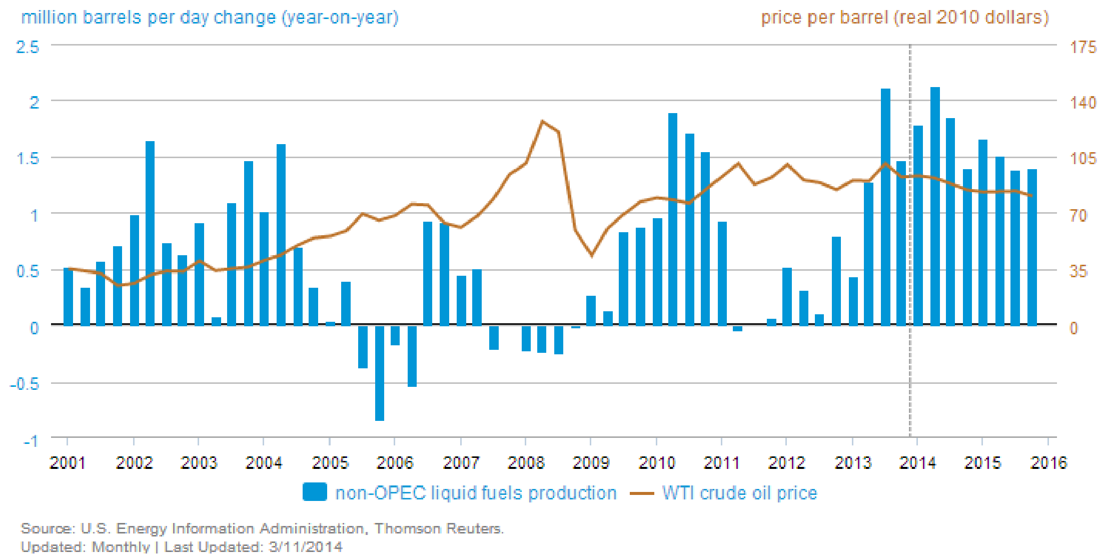


Figure 34: Non-OECD liquid fuels consumption and GDP.

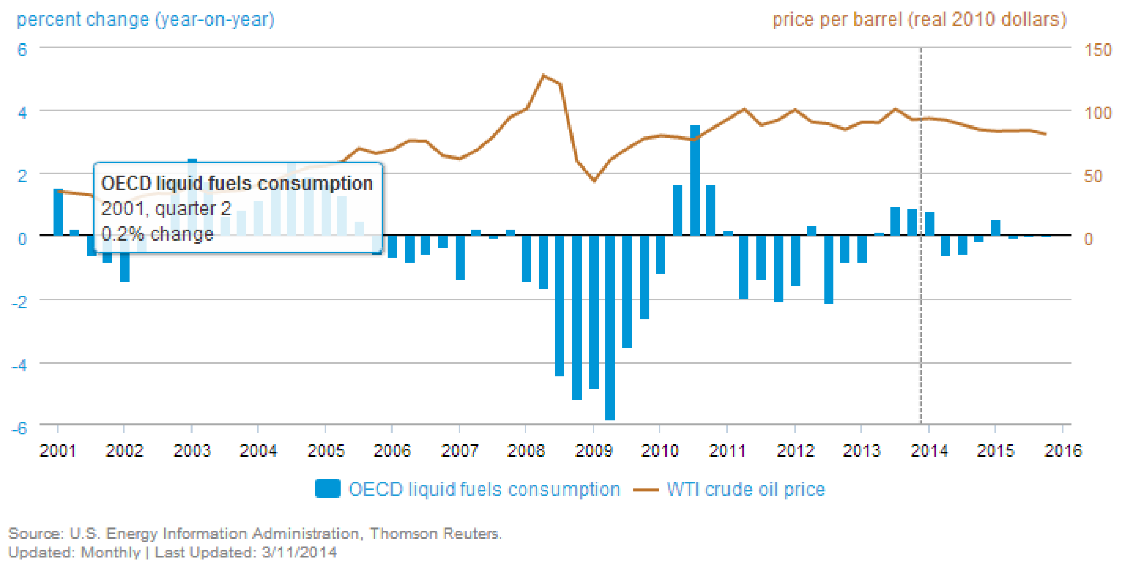

Figure 35: OECD liquid fuels consumption and WTI crude oil prices

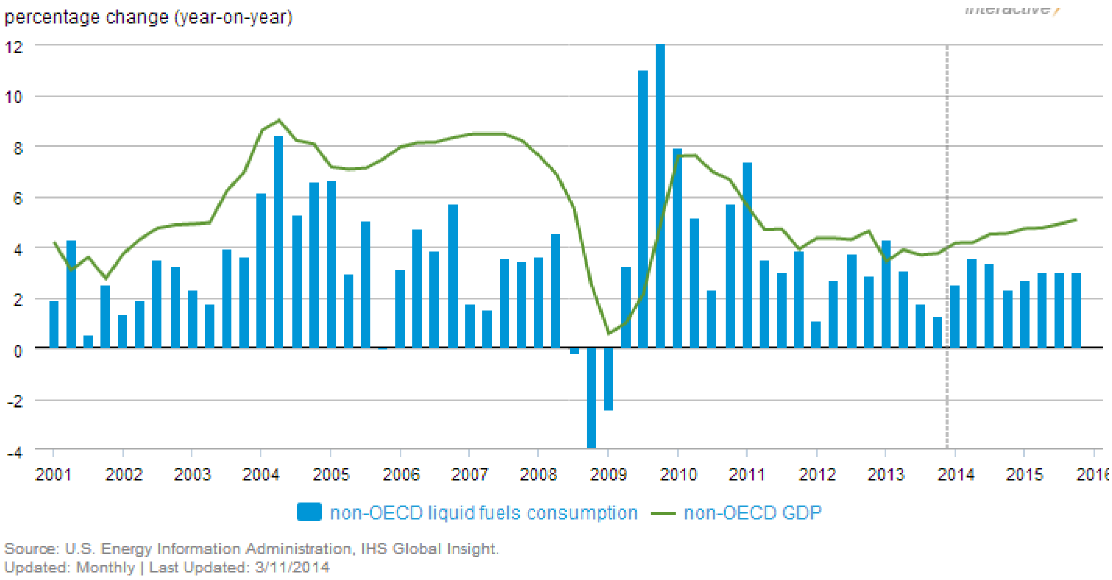


Figure 36: Changes in OPEC production targets and WTI crude oil prices

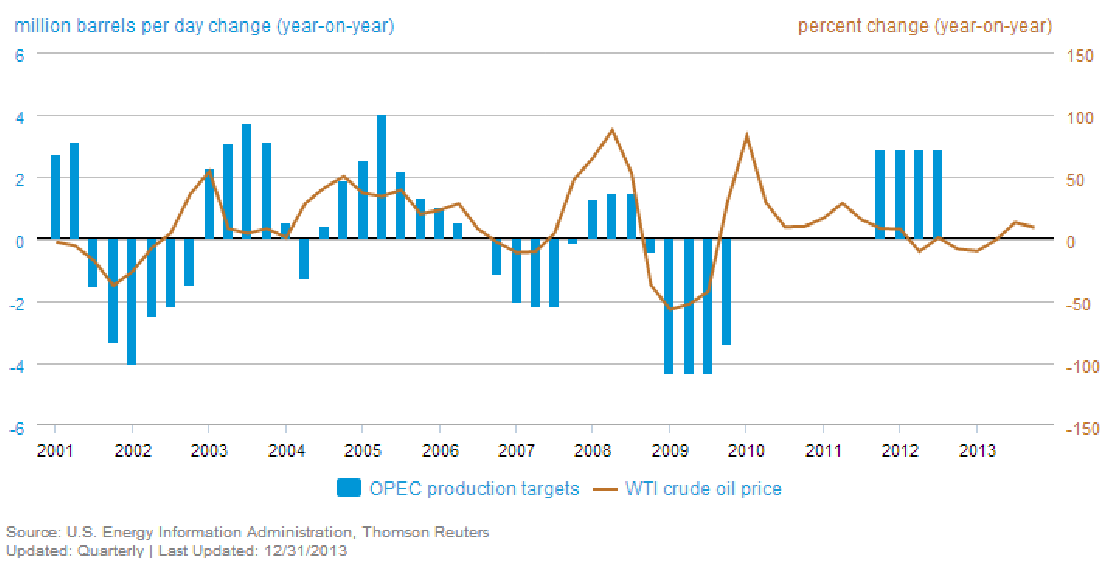

Figure 37: OPECs spare capacity and oil prices.

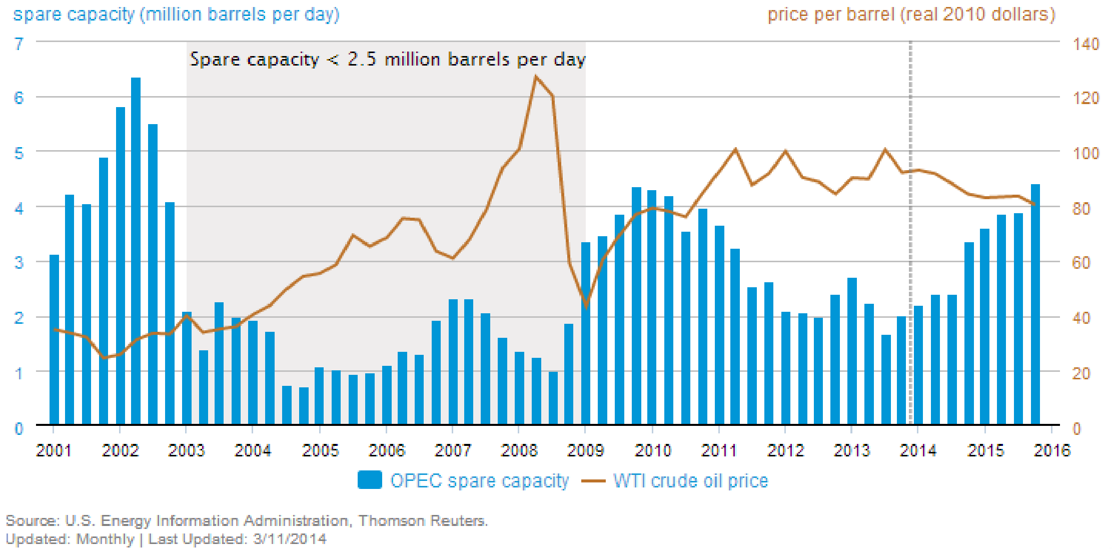


Figure 38: The reaction of crude oil prices due to geopolitical and economic events.

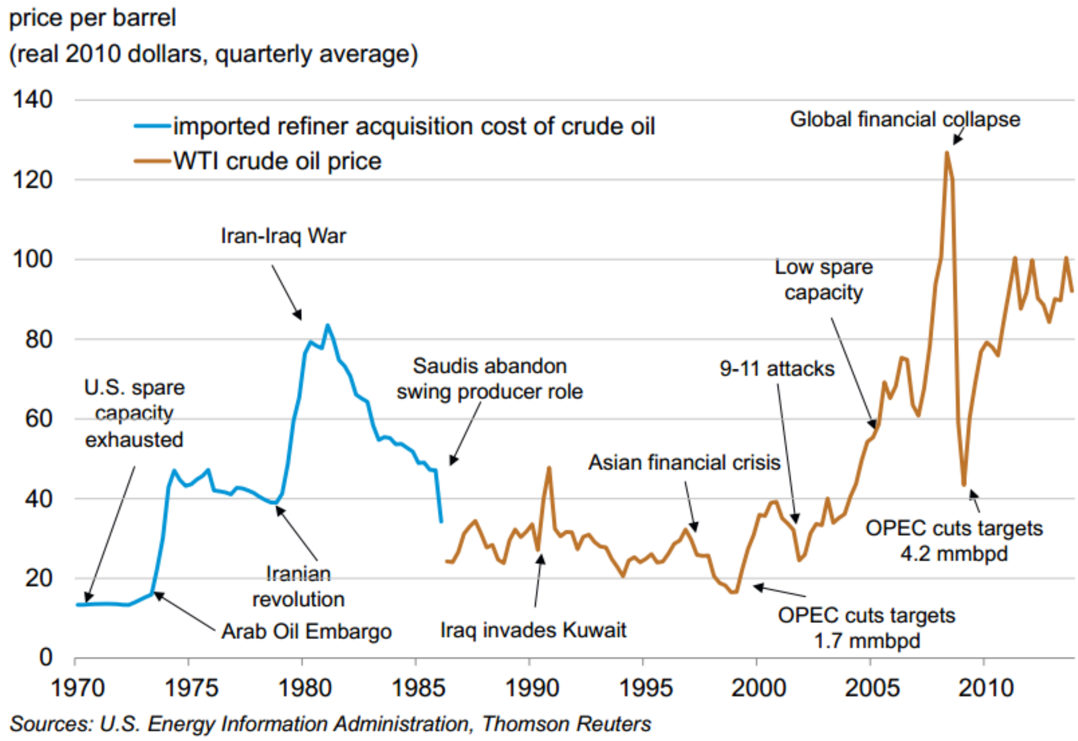

Figure 39: OECD liquid fuels inventories and WTI futures spread.

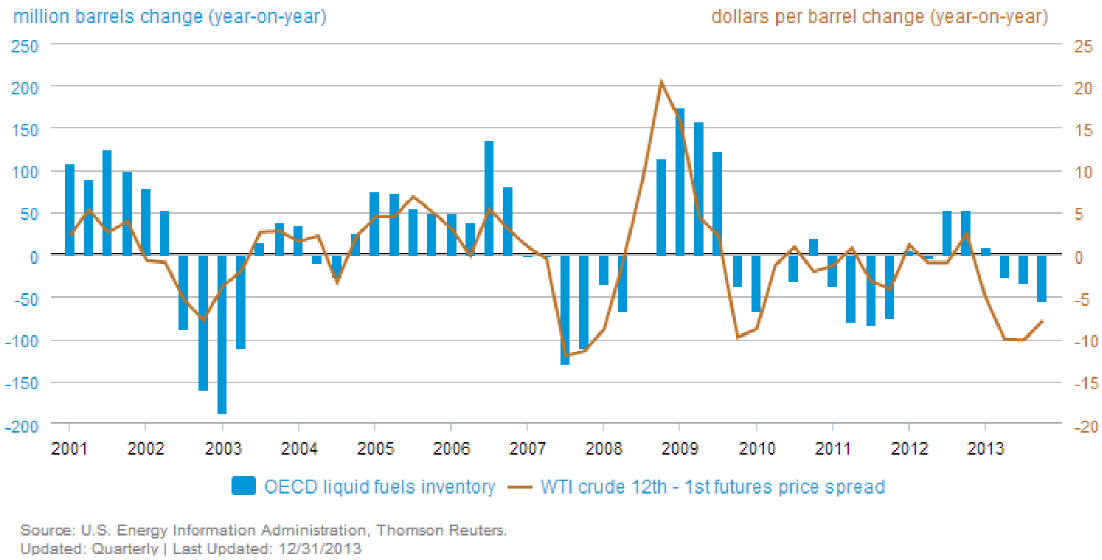


Figure 40: Correlation between S&P 500, Indices and Commodities

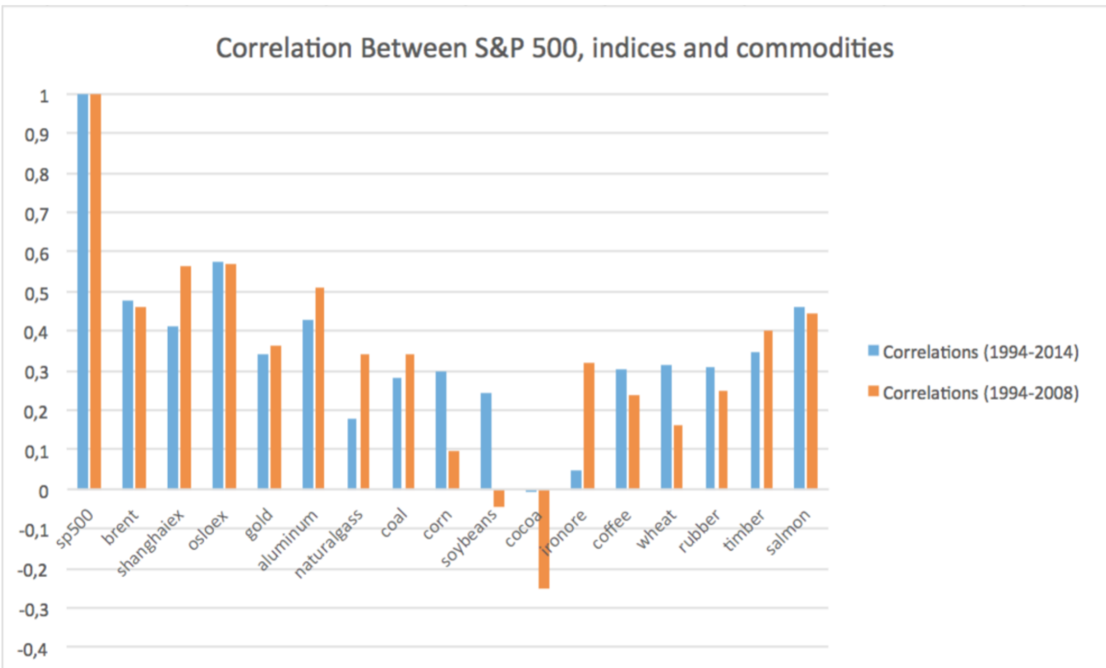

Figure 41: Correlations between SHCOMP, Indices and Commodities

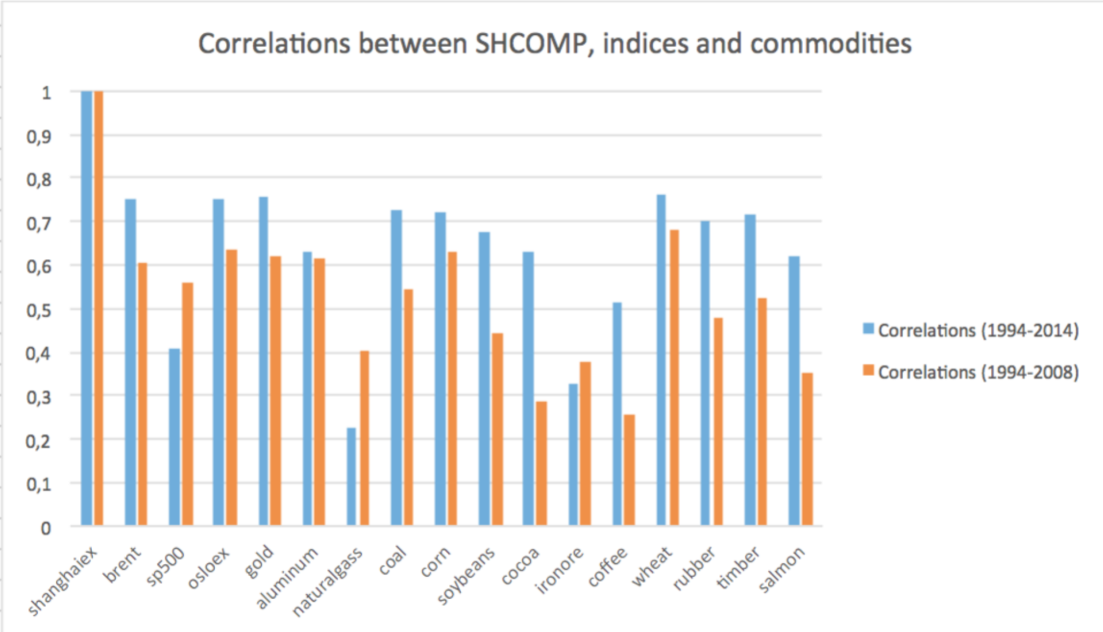

Table 12: ADF results for S&P 500 vs. Commodities

| Delperioden | | | | | |
|---|---|---|---|---|---|
| **ADF Unit Root Test** | | | | | |
| | Log Level | | | First log difference | |
| | #Lags | Test Statistics | | #Lags | Test Statistics |
| **S&P 500** | 1 | -2.508 | | 1 | -10.287*** |
| Aluminum | 2 | -0.347 | | 1 | -8.717*** |
| Gold | 1 | 1.858 | | 4 | -4.967*** |
| Wheat | 2 | -0.407 | | 1 | -8.507*** |
| Natural gas | 2 | -1.236 | | 1 | -10.605*** |
| coal | 4 | 0.126 | | 3 | -4.429*** |
| corn | 2 | -1.020 | | 1 | -7.607*** |
| soybeans | 1 | -0.371 | | 0 | -11.993*** |
| cocoa | 3 | -0.462 | | 2 | -7.701*** |
| iron ore | 2 | -1.064 | | 1 | -10.852*** |
| cofee | 2 | -1.374 | | 1 | -8.006*** |
| Rubber | 2 | -0.031 | | 1 | -8.172*** |
| Timber | 2 | -1.419 | | 1 | -7.558*** |
| Salmon | 2 | -2.325 | | 1 | -8.762*** |

Optimal lag number varies when comparing S&P 500 with the different commodities, but as theese changes does not alter the ultimate conclution we will only present the results from S&P500 with one lag.
Numbers in **bold** and *kursive* indicates lag adjustment to avoid autocorrelation

*** Significant at 1%  ** Significant at 5%  * Significant at 10%

| Hele perioden | | | | | |
|---|---|---|---|---|---|
| **ADF Unit Root Test** | | | | | |
| | Log Level | | | First log difference | |
| | #Lags | Test Statistics | | #Lags | Test Statistics |
| **S&P 500** | 1 | -2.204 | | 1 | -11.539*** |
| Aluminum | 2 | -2.429 | | 1 | -8.614*** |
| Gold | 1 | 0.421 | | 4 | -17.725*** |
| Wheat | 2 | -1.348 | | 1 | -10.293*** |
| Natural gas | 2 | -2.586* | | 1 | -17.848*** |
| coal | 4 | -1.463 | | 3 | -6.143*** |
| corn | 2 | -1.602 | | 1 | -14.547*** |
| soybeans | 1 | -1.058 | | 0 | -14.688*** |
| cocoa | 3 | -1.367 | | 2 | -16.574 *** |
| iron ore | 2 | -1.123 | | 1 | -9.939*** |
| cofee | 2 | -1.519 | | 1 | -9.290*** |
| Rubber | 2 | -1.308 | | 1 | -8.706*** |
| Timber | 2 | -1.418 | | 1 | -9.164*** |
| Salmon | 2 | -2.113 | | 1 | -9.550*** |

Optimal lag number varies when comparing S&P 500 with the different commodities, but as theese changes does not alter the ultimate conclution we will only present the results from S&P500 with one lag.
Numbers in **bold** and *kursive* indicates lag adjustment to avoid autocorrelation

*** Significant at 1%  ** Significant at 5%  * Significant at 10%

Table 13: ADF results for Shanghaiex vs. Commodities

| Delperioden | | | | |
|---|---|---|---|---|
| **ADF Unit Root Test** | | | | |
| | Log Level | | First log difference | |
| | #Lags | Test Statistics | #Lags | Test Statistics |
| **Shanghaiex** | 1 | -1.115 | 1 | -6.121*** |
| Aluminum | 1 | -0.490 | ***2*** | -6.947*** |
| Gold | 3 | 1.724 | ***2*** | -13.584*** |
| Wheat | 1 | -0.572 | ***2*** | -6.448*** |
| Natural gas | 2 | -1.236 | 2 | -10.605*** |
| coal | 4 | 0.126 | ***2*** | -4.429*** |
| corn | 1 | -0.739 | 1 | -11.011*** |
| soybeans | 1 | -0.371 | ***2*** | -11.993*** |
| cocoa | 1 | -0.749 | ***2*** | -13.686*** |
| iron ore | 4 | -0.978 | ***2*** | -6.204*** |
| cofee | 2 | -1.374 | 2 | -8.082*** |
| Rubber | 2 | -0.031 | 2 | -6.684*** |
| Timber | 2 | -1.419 | 2 | -7.558*** |
| Salmon | 3 | -2.027 | 3 | -8.030*** |

Optimal lag number varies when comparing SHCOMP with the different commodities, but as theese changes does not alter the ultimate conclution we will only present the results from SHCOMP with one lag.
Numbers in **bold** and *kursive* indicates lag adjustment to avoid autocorrelation

*** Significant at 1% ** Significant at 5% * Significant at 10%

| Hele perioden | | | | |
|---|---|---|---|---|
| **ADF Unit Root Test** | | | | |
| | Log Level | | First log difference | |
| | #Lags | Test Statistics | #Lags | Test Statistics |
| **Shanghaiex** | 1 | -1.685 | 1 | -8.374*** |
| Aluminum | 2 | -2.429 | 1 | -8.614*** |
| Gold | 1 | 0.421 | 0 | -17.725*** |
| Wheat | 5 | -1.983 | 7 | -5.865*** |
| Natural gas | 2 | -2.374 | 2 | -10.090*** |
| coal | 5 | -1.51 | 8 | -5.242*** |
| corn | 1 | -1.602 | ***2*** | -7.847*** |
| soybeans | 1 | -1.058 | 4 | -6.743*** |
| cocoa | 1 | -1.367 | ***2*** | -9.321*** |
| iron ore | 3 | -1.282 | 2 | -12.733*** |
| cofee | 3 | -1.870 | 2 | -9.176*** |
| Rubber | 3 | -1.25 | 2 | -7.608*** |
| Timber | 3 | -1.443 | ***2*** | -7.639*** |
| Salmon | 8 | -0.980 | 3 | -8.011*** |

Optimal lag number varies when comparing SHCOMP with the different commodities, but as theese changes does not alter the ultimate conclution we will only present the results from SHCOMP with one lag.
Numbers in **bold** and *kursive* indicates lag adjustment to avoid autocorrelation

*** Significant at 1% ** Significant at 5% * Significant at 10%

Table 14: ADF results for Brent vs. Indices

| Delperioden | | | | |
|---|---|---|---|---|
| **ADF Unit Root Test** | | | | |
| | Log Level | | First log difference | |
| | #Lags | Test Statistics | #Lags | Test Statistics |
| **Brent** | 1 | 0.592 | 1 | -10.263*** |
| S&P 500 | 2 | -2.638* | 1 | -10.287*** |
| Osloex | 2 | 0.308 | 1 | -7.883*** |
| Shanghaiex | 1 | -1.115 | 0 | -9.781*** |

Optimal lag number varies when comparing Brent with the different indices, but as theese changes does not alter the ultimate conclution we will only present the results from Brent with one lag.
Numbers in **bold** and *kursive* indicates lag adjustment to avoid autocorrelation

*** Significant at 1% ** Significant at 5% * Significant at 10%

| Hele perioden | | | | |
|---|---|---|---|---|
| **ADF Unit Root Test** | | | | |
| | Log Level | | First log difference | |
| | #Lags | Test Statistics | #Lags | Test Statistics |
| **Brent** | 1 | -0.985 | 1 | -10.296 *** |
| S&P 500 | 1 | -2.151 | 1 | -11.539*** |
| Osloex | 2 | -1.163 | 1 | -8.364*** |
| Shanghaiex | 1 | -1.330 | ***2*** | -7.326*** |

Optimal lag number varies when comparing Brent with the different indices, but as theese changes does not alter the ultimate conclution we will only present the results from Brent with one lag.
Numbers in **bold** and *kursive* indicates lag adjustment to avoid autocorrelation

*** Significant at 1% ** Significant at 5% * Significant at 10%